Scientific Research Publishing

Journal of Computer and Communications, 2023, 11, 102-108
https://www.scirp.org/journal/jcc
ISSN Online: 2327-5227
ISSN Print: 2327-5219

A Miniaturized Broadband Wilkinson Power Divider Using Micro-Strip Branch Lines

Taifu Zhou

Southwest China Institute of Electronic Technology, Chengdu, China
Email: taifuzhou@163.com

How to cite this paper: Zhou, T.F. (2023) A Miniaturized Broadband Wilkinson Power Divider Using Micro-Strip Branch Lines. *Journal of Computer and Communications*, **11**, 102-108.
https://doi.org/10.4236/jcc.2023.1112007

Received: December 6, 2023
Accepted: December 26, 2023
Published: December 29, 2023

Abstract

A miniaturized broadband Wilkinson power divider is proposed. Micro-strip branch lines are introduced to replace multiple resistors used in multi-stage Wilkinson power dividers to increase the bandwidth of single-stage Wilkinson power dividers. To demonstrate its performance, an improved single-stage Wilkinson power divider with four micro-strip branch lines was designed. Simulated results show that the insert loss is better than 3.2 dB, the input return loss, output return loss, and isolation are better than 15 dB respectively, across a 76% bandwidth from 18 to 40 GHz.

Keywords

Broadband, Micro-Strip Branch Lines, Power Divider

1. Introduction

Wilkinson power divider is one of the most widely used passive components, which allows microwave signals to split equally or unevenly. The simplest Wilkinson power divider is shown in **Figure 1(a)**. It is a single-stage component with 50 Ω input and output ports, two 70.7 Ω quarter wavelength transformers, and a 100 Ω resistor bridged between the two output ports to provide isolation and matching. Its disadvantage is the limited bandwidth. Due to the rapid growth of wireless communications, there is a great demand for broadband components, including broadband Wilkinson power dividers. Therefore, the study of broadband Wilkinson power dividers is of great significance at this time. For this purpose, manly wideband power dividers [1]-[6] have been developed so far. But few of them introduce the millimeter-wave wideband Wilkinson power divider. Typically, multi-stage Wilkinson power dividers have improved operating bandwidth compared to standard single-stage Wilkinson power dividers. According to the characteristics of millimeter wave Wilkinson power dividers, as the operating frequency increases, the influence of parasitic parameters on chip resistors will become significant. If the number of chip resistors increases, the performance of the millimeter wave Wilkinson power divider will deteriorate. In order to overcome the influence of multiple resistors and effectively improve the bandwidth of a single-stage Wilkinson power divider, this paper proposes a millimeter wave broadband Wilkinson power divider using micro-strip branch lines.

2. Power Divider Design

The general circuit of a multi-stage Wilkinson power divider is shown in **Figure 1(b)**. It contains N pairs of equally transmission lines and N bridge resistors, distributed from the input port to the two output ports. It is easiest to analyze through even mode and odd mode excitation methods [7].

As is well known, with the increase of transmission line segments and resistors, the bandwidth of the Wilkinson power divider has been effectively improved. In order to achieve broadband isolation, the resistors of the multi-stage Wilkinson power divider provide multiple transmission paths for electromagnetic waves, such as path 1, path 2, path N, etc., as shown in **Figure 1(b)**.

The transmission line modeling (TLM) of the 2 way equal split Wilkinson power divider (WPD) is shown in **Figure 2**. This power divider contains one input port, two quarterwave transmission line, two output ports and one isolation resistor across the output ports.

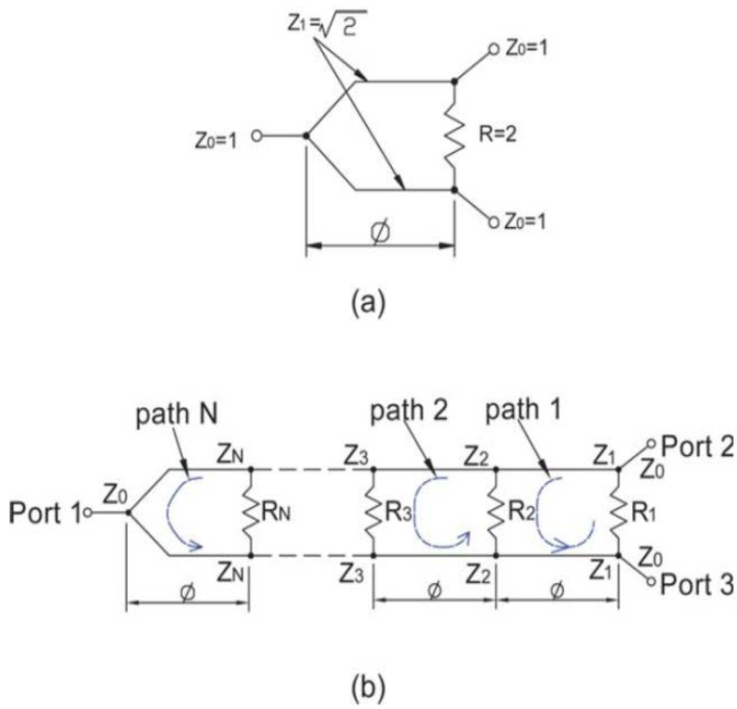


Figure 1. General circuits of Wilkinson power divider: (a) Simplest Wilkinson power divider and (b) Multistage Wilkinson power divider.

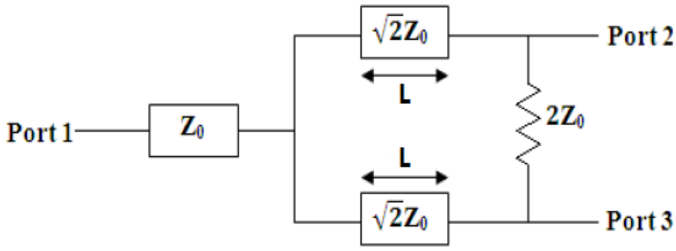


Figure 2. Transmission line modelling of WPD.

The expressions of input return loss (S_{11}) and transmission coefficient (S_{21}) of WPD from the above TLM circuit are

$$S_{11}(f) = \frac{-1}{(3 + j2\sqrt{2}\tan(\beta l))}$$

$$S_{21}(f) = \sqrt{\frac{(1 - S_{11}{}^{2}(f))}{2}}$$

The even and odd mode analysis computes the output responses (S_{22} and S_{23}) of WPD very easily and a voltage excitation of Vs is applied at port 2 for the analysis of even and odd mode. The voltage excitation at port 2 and 3 for even and odd mode are Vs/2, Vs/2 and Vs/2, −Vs/2 respectively. The even and odd mode diagrams of WPD are shown in **Figure 3**. From these even and odd mode analysis the derived expressions of output response (S_{22} and S_{23}) are

$$S_{22}(f) = \frac{1}{(8\tan^{2}(\beta l) - j8\sqrt{2}\tan(\beta l) - 3)}$$

$$S_{23}(f) = \frac{-2 - j2\sqrt{2}\tan(\beta l)}{(-8\tan^{2}(\beta l) + j8\sqrt{2}\tan(\beta l) + 3)}$$

In order to increase the bandwidth of the input and output responses of the power divider, we used micro-strip branch lines in our research.

In [8], an improved Wilkinson power divider for suppressing nth harmonic output is proposed by adding a short cut transmission line between the resistor and each output port. We can imagine that multiple resistors in **Figure 1(b)** can be replaced with branch lines to increase the bandwidth of a single-stage Wilkinson power divider. Then, a new broadband Wilkinson power divider was proposed. To demonstrate its improved performance, a broadband Wilkinson power divider with four branches was designed using only one resistor in **Figure 2**. It was modeled using Ansoft HFSS and designed on an Al_2O_3 ceramic substrate with a relative dielectric constant of 9.8 and a thickness of 0.254 mm. We use thin film resistor in our design. The original size of the power distributor is determined using the same method used in the design of multi-stage Wilkinson power distributors. In addition, multiple resistors are replaced by branch lines with the same characteristic impedance. In order to minimize the complexity of the simulation model, the width of its two main output lines is the same, 0.25 mm, and the length of all branch lines is the same. After optimization by HFSS, its simulation model is shown in **Figure 4**.

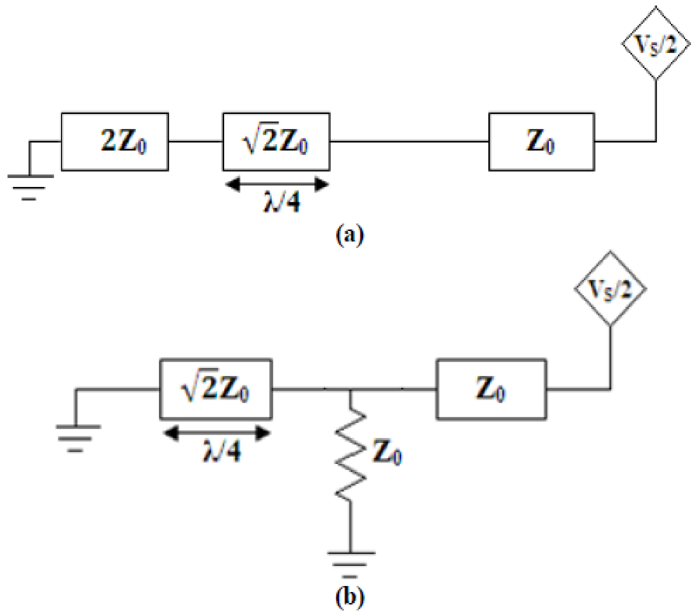


Figure 3. TLM circuit of WPD for (a) even mode (b) odd mode analysis.

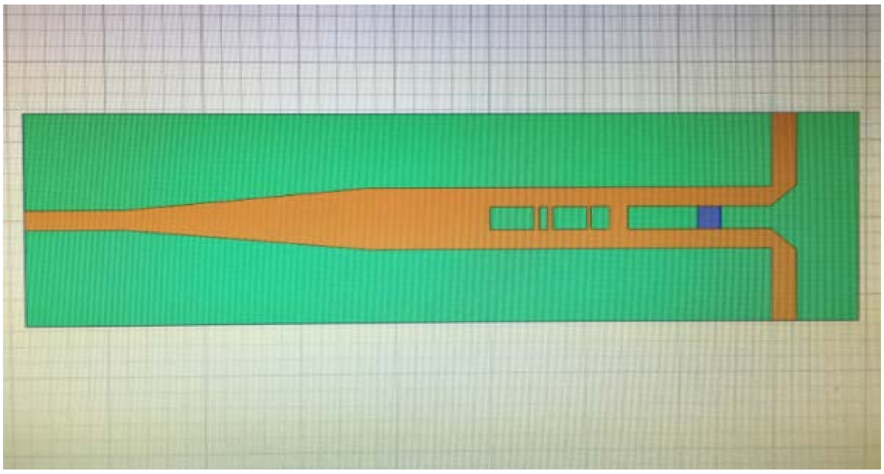


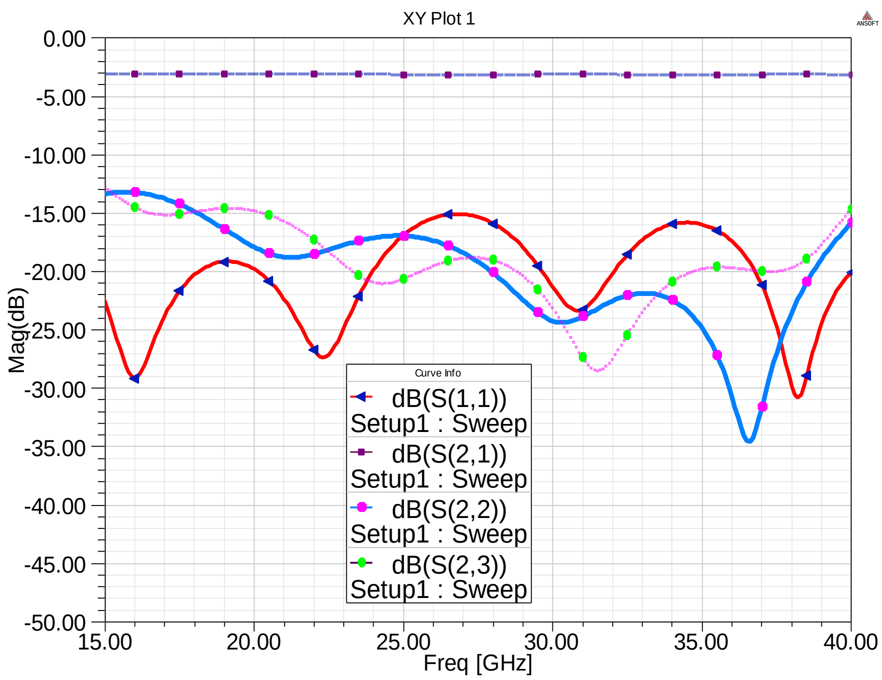
Figure 4. Proposed miniaturized Wilkinson power divider model in HFSS.

3. Simulation Results

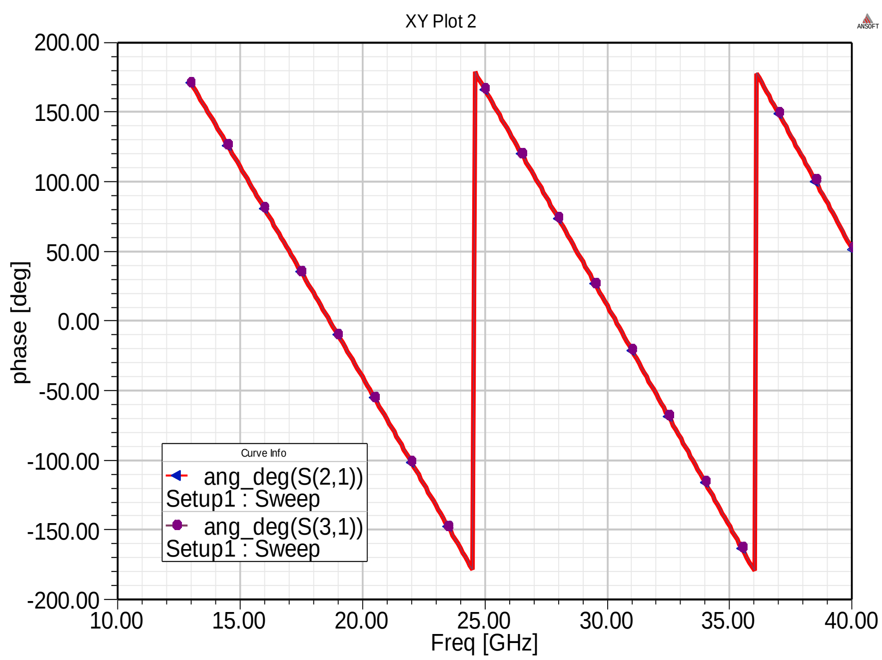
The final simulation results and dimensions of the new broadband power divider are shown in **Figure 5** and **Figure 6**. The results are in good agreement with the ideal values. According to simulation results, the output return loss and isolation are better than 15 dB in the frequency range of 18 to 40 GHz (76%), and the input return loss is better than 15 dB in the 90% bandwidth of 15 to 40 GHz.

From **Figure 5(b)**, it can be seen that the two output ports have good phase consistency between 15 GHz and 40 GHz. And, the increase in branch lines significantly improves the performance of the single-stage Wilkinson power divider.

Its simulated results are compared with the simulated S-parameters of the conventional single-stage Wilkinson divider [9] in **Figure 7**, which is fabricated on the Rogers RT/duroid 5880 dielectric substrate and consists of a 0402 chip resistor. As seen, the operation bandwidth of the modified Wilkinson divider is almost as wide as four times of the bandwidth of the traditional single-stage Wilkinson divider. Thereby, the addition of branch lines significantly improves the performance of a single-stage Wilkinson divider.



(a)



(b)

Figure 5. Simulated S-parameters: (a) Insertion loss S_{21}, return loss S_{11}, return loss S_{22} or S_{33} and isolation S_{23} and (b) Two Channels phase consistency.

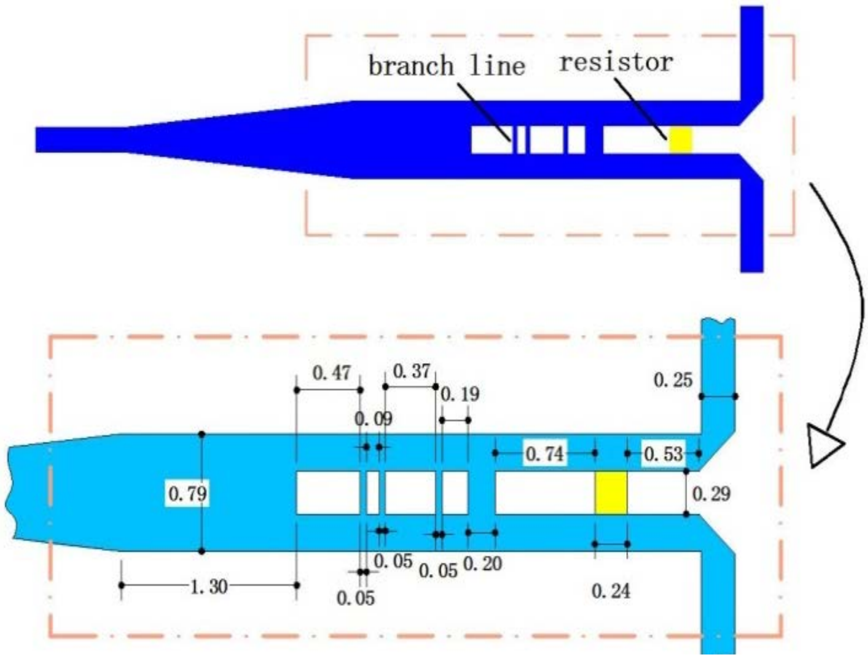


Figure 6. The novel wideband Wilkinson power divider Structure and dimensions (unit in mm).

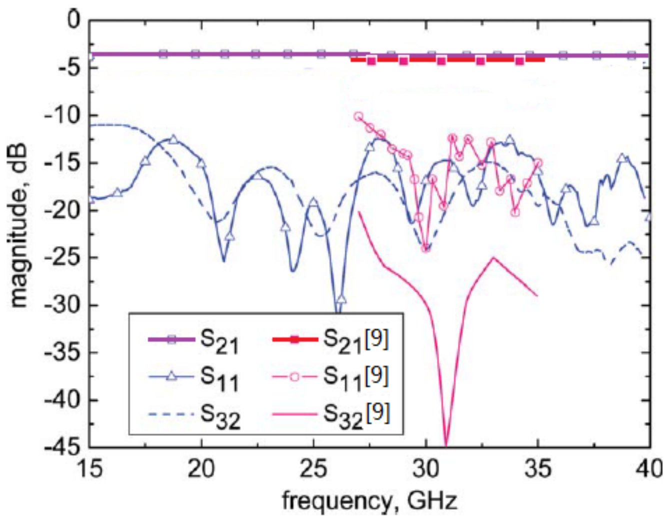


Figure 7. The simulated results comparison between Wilkinson divider in [9] and divider modified in this paper.

4. Conclusion

In order to increase the bandwidth of a single-stage Wilkinson power divider, a Miniaturized Wilkinson power divider using micro-strip branches instead of multiple resistors is proposed. So, it overcomes the influence of multiple resistances. An improved four branch single stage Wilkinson power divider has been designed. Its bandwidth is almost four times that of a traditional single-stage Wilkinson power divider. Therefore, the increased branch lines effectively increase the bandwidth of traditional single-stage Wilkinson power dividers. These clearly indicate that the proposed Wilkinson power divider can be well applied to microwave and millimeter wave systems.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Ehsan, N., Vanhille, K., Rondineau, S., Cullens, E.D. and Popovic, Z.B. (2009) Broadband Micro-Coaxial Wilkinson Dividers. *IEEE Transactions on Microwave Theory and Techniques*, **57**, 2783-2789. https://doi.org/10.1109/TMTT.2009.2032345

[2] Cohn, S.B. (1986) A Class of Broadband Three-Port TEM-Mode Divider. *IEEE Transactions on Microwave Theory and Techniques*, **16**, 110-116. https://doi.org/10.1109/TMTT.1968.1126617

[3] Satio, Y., Fontaine, D., Rollin, J.M. and Filipovic, D.S. (2009) Monolithic Micro-Coaxial Power Dividers. *Electronics Letters*, **45**, 469-470. https://doi.org/10.1049/el.2009.0309

[4] Wentzel, A., Subramanian, V., Sayed, A. and Boeck, G. (2006) Novel Broadband Wilkinson Power Combiner. 2006 *European Microwave Conference*, Manchester, 10-15 September 2006, 212-215. https://doi.org/10.1109/EUMC.2006.281256

[5] Sai, W.W. and Lei, Z. (2008) Ultra-Wideband Power Divider with Good Inband Splitting and Isolation Performances. *IEEE Microwave and Wireless Components Letters*, **18**, 518-520. https://doi.org/10.1109/LMWC.2008.2001009

[6] Zhang, Z.Y. and Wu, K. (2008) Broadband Half-Mode Substrate Integrated Waveguide (HMSIW) Wilkinson Power Divider. 2008 *IEEE MTT-S International Microwave Symposium Digest*, Atlanta, GA, 15-20 June 2008, 879-882.

[7] Reed, J. and Wheeler, G.J. (1956) A Method of Analysis of Symmetrical Four-Port Networks. *IRE Transactions on Microwave Theory and Techniques*, **4**, 246-252. https://doi.org/10.1109/TMTT.1956.1125071

[8] Kim, J.S., Park, M.J. and Kong, K.B. (2009) Modified Design of Wilkinson Power Divider for Harmonic Suppression. *Electronics Letters*, **45**, 1174-1175. https://doi.org/10.1049/el.2009.2126

[9] Xu, H.J., Zhang, Y.H. and Fan, Y. (2007) Ka-Band Wilkinson Power Divider Based on Chip Resistor. 2007 *International Conference on Microwave and Millimeter Wave Technology*, Guilin, 18-21 April 2007, 1-4.