A Miniaturized Dual-Frequency Wilkinson Power Divider Using Planar Artificial Transmission Lines

Shangbin Fang, Huiping Guo, Xueguan Liu, IEEE member Lingfeng Mao
IEEE Conference Publishing
Soochow University,Suzhou Jiangsu 215021, P. R. China

Abstract- **In this paper, an arbitrary dual-frequency Wilkinson power divider using planar artificial transmission lines has been designed, fabricated, and measured. The results demonstrate that after such a method has been used the size of dual-frequency Wilkinson power divider can be reduced to be only 50% of the traditional power divider. Both simulations and measurements show that such a dual-frequency Wilkinson power divider has good performance of S-Parameters, which include an equal power split, impedance matching at all ports, and a good isolation between the two output ports at two arbitrary frequencies simultaneously.**

***Index Terms*- power divider, dual frequency, Wilkinson power divider.**

I. INTRODUCTION

The power divider is one of the indispensable components in various microwave circuits. Recently, the development trend of multiband mobile phones leads a worldwide effort to develop dual-band power dividers. A dual band unequal Wilkinson power divider has been reported in Ref.[1]. In addition, a dual-frequency Wilkinson power divider operated at two arbitrary frequencies has been presented in Ref.[2]. Meanwhile, the investigators have developed various techniques to reduce the sizes of passive microwave circuit components [3-6]. A miniaturized power divider using lumped elements has been proposed in Ref.[3]. The photonic band gap (PBG) structure provides alternative way for miniaturization [4-5]. Although the PBG structure can significantly reduce circuit size, the lack of an easily extracted equivalent circuit model makes it in unsystematic and troublesome for designing. In recent years, the slotted ground plane structure has been implemented to microwave circuits for harmonic suppression [6]. However, this structure has a relatively limited ability to miniaturize the circuit size. To design a power divider with an even more compact size, a new miniaturized Wilkinson power divider with the planar artificial transmission line (ATL) proposed in Ref.[7]. The new design method uses four sections composing of the artificial transmission line to replace the conventional transmission lines in a Wilkinson power divider. After such a design has been used, the occupied size can reduce to be 50% of the traditional Wilkinson power divider.

This paper is organized as following. In section II, the design concepts of the artificial transmission line. are briefly introduced and the propagation characteristics of the artificial transmission line is also discussed. In Section III, the proposed miniaturized Wilkinson power divider with the ATL is designed, fabricated, and measured. The results show that the power divider after using ATL can largely miniaturize its size when it keeps good performance. Finally, the conclusions are given in Section IV.

II. ANALYSE THE PLANAR ARTIFICIAL TRANSMISSION LINE

Lossless conventional transmission line can be equivalent to the circuit of fig.1, and its characteristic impedance Z_c and guided wave-number β can be given by

$$Z_c = \sqrt{L/C} \qquad \beta = \omega\sqrt{L \times C}$$

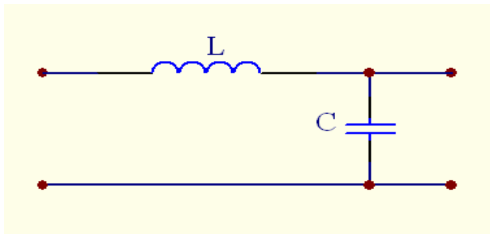

Fig.1 Equivalent lumped circuit of transmission line.

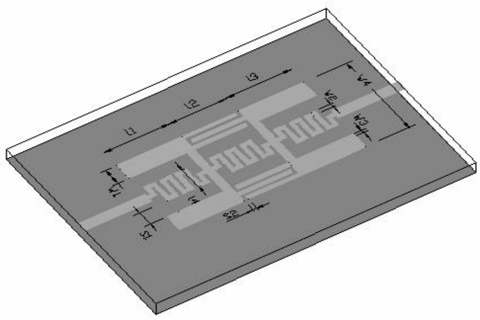

Fig. 2 the artificial transmission line [7].

where, L and C are the equivalent inductor and capacitor for unit length of transmission line, respectively, and ω is working angle frequency. On the other hand, the artificial transmission line proposed in [7] shown in Fig. 2 also can be equivalent to the Fig.1, and it is composed of three cascade stages of quasi-lumped inductors and capacitors, which can miniaturize the circuit size. For example, the lengths of the 90-degree phase delay using conventional microstrip line with $\varepsilon_r = 2.55$ of substrate are 46 mm at 1GHz and 25 mm at 1.8GHz, respectively, whereas the length is only 12 mm by using the artificial transmission line. Obviously, using the artificial transmission line can lead to remarkable reduce in the circuit size. This implies that using the artificial transmission line is a good method in reducing the size of the power divider.

III. DESIGN OF MINIATURIZED DUAL-FREQUENCY WILKINSON POWER DIVIDERS

Analytical solutions of the dual-frequency Wilkinson power divider for arbitrary the frequency ratios, which is shown in Fig. 3, have been presented in Ref.[2]. The power divider is

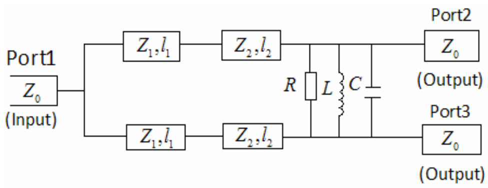

Fig. 3 Dual-frequency Wilkinson power.

symmetric, whose parameters are given by the following equations

$$l_1 = l_2 = \frac{n\pi}{\beta_1 + \beta_2} \tag{1}$$

$$Z_2 = Z_0 \sqrt{\frac{1}{2\alpha} + \sqrt{\frac{1}{4\alpha^2} + 2}} \tag{2}$$

$$Z_1 = \frac{2 Z_0^{\,2}}{Z_2} \tag{3}$$

where

$$\alpha = (\tan(\beta_1 \times l_1))^2 \qquad \beta = 2\pi / \lambda$$

For a power divider working at $f_1 = 1\text{GHz}$ and $f_2 = 1.8\text{GHz}$, The length of the two sections of transmission lines is $l_1=l_2=\lambda_1/5.6$, the characteristic impedance of the two sections of transmission lines is Z_1=80.7Ω, Z_2=62Ω, R=100Ω, C=1.5pF, and L=0.9nH. In order to reduce the circuit size, the 80.7Ωand 62Ωconventional microwave transmission line has been replaced by artificial transmission lines. According to the artificial transmission lines design method, the circuit sizes of 80.7Ω and 62Ω transmission line are 1_1=3.4mm, 1_2=3mm, 1_3=3.4mm, 1_4=2.2mm, w_1=1.2mm, w_2=w_3=0.2mm, w_4=5.4mm, s_1=0.4mm, and s_2=0.2mm,.respectively. Using the above parameters, we can calculate the ATL characteristic impedances and phase delays as a function of the frequency, which is shown in Fig.4. The results indicate that the characteristic impedances are almost the same within 0.5-2.2GHz, while the phase delays are nearly linearly decrease with frequency.

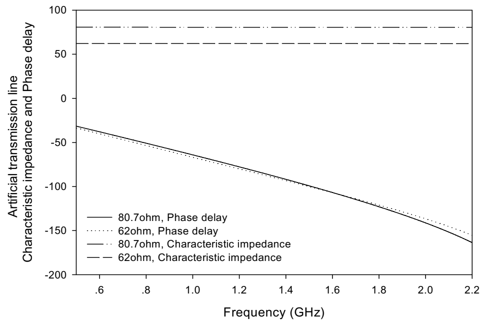

Fig. 4 simulated characteristic impedance and phase delay of 80.7 and 62ohm ATL.

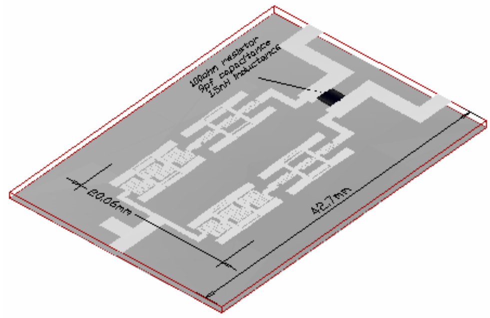

Fig.5 Circuit layout of the miniaturized Wilkinson power divider.

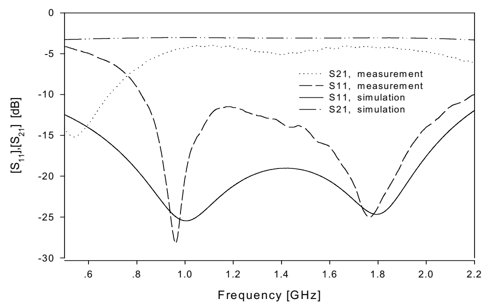

Fig.6 Comparisons of the simulated and measured S_{11} and S_{21} of the miniaturized Wilkinson power.

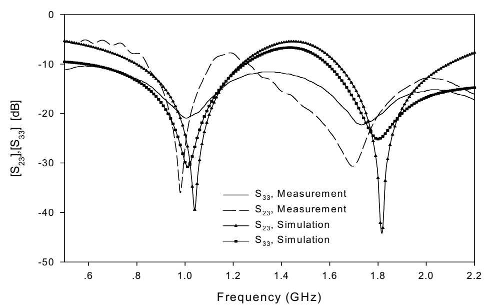

Fig.7 Comparisons of the simulated and measured S_{23} and S_{33} of the miniaturized Wilkinson power.

Then we used the ATL to replace the arms in power divider, The circuit layout is shown in Fig.5. The outputs are shunted with a parallel connection of a resistor R=100 Ω, an inductor L=9nH, and a capacitor C=1.5pF in the dual-frequency Wilkinson power divider, the open stub at input port works as impedance matching. The artificial transmission lines were initially designed with the parameters in Section II, and then fine-tuned to account for the parasitic coupling between the line segments using simulation software. The circuit was also fabricated on 0.8mm Polyflon_NorCLAD substrate and the center frequency is 1 GHz and 1.8 GHz, respectively.

The measurements were taken by an Agilent performance network analyzer E 5071B. The simulated and measured results are illustrated in Fig. 6-7. The measurements are found to be in good agreement with simulations. It can be seen from Fig. 7 that the measured center frequency of S_{23} is 0.96GHz and 1.7GHz, respectively. Only 5% difference between the experimental values and those obtained the simulated results. The errors result from the lumped capacitance and inductance used in the output port. The measured insertion loss-S_{21} at the center frequencies are 4.26dB and 4.33dB, respectively. It is shown in Fig. 6. This can be the largest number of discontinuities used in the design attributed to and the SMA port loss. The dimension of the divider is 30mm×42.7mm. Accordingly, the occupied size of the proposed design is only 50% of that of the conventional Wilkinson power obtained in Ref. [2].

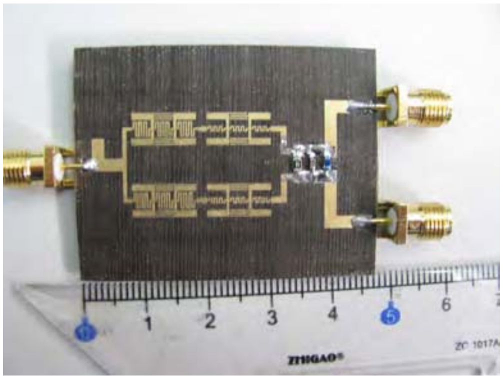

Fig. 8 Photograph of the proposed miniaturized Wilkinson power divider.

IV. CONCLUSIONS

In this paper, a new miniaturized arbitrary dual-frequency Wilkinson power divider has been designed, fabricated, and measured. The new power divider is realized by using artificial transmission lines, which can reduce the size to be 50% of the conventional power divider. The simulated results agree very well with the experiments, and the proposed power divider can be applied in a wide variety of circumstances where circuit miniaturization is demanded.

REFERENCES

[1] Yongle Wu, Yuanan Liu, Yaxing Zhang, Jinchun Gao, and Hui Zhou, " A Dual Band Unequal Wilkinson Power Divider" IEEE Trans Microwave Theory Tech, vol.57, no.1, January. 2009.

[2] Lei Wu, ZengGuang Sun, Hayattin Yilmaz, Manfred Berroth, "A Dual-Frequency Wilkinson Power Divider," IEEE Trans. Microwave Theory Tech, vol.54, no.1,pp278—284, January. 2006.

[3] M.-C. Scardelletti, G.-E. Ponchak, and T.-M. Weller, "Miniaturized Wilkinson power dividers utilizing capacitive loading," IEEE Microw. Wireless Compon. Lett., vol. 12, no. 1, pp. 6-8, Jan. 2002.

[4] F.-R. Yang, K.-P. Ma, Y. Qian and T. I. Itoh, "A uniplanar compact photonic-bandgap (UC -PBG) structure and its applications for microwave circuits," IEEE trans. Microwave Theory Tech., vol. 47, no. 8, Aug. 1999.

[5] Y.-J. Ko, J.-Y. Park, and J.-U. Bu, "Fully integrated unequal Wilkinson power divider with EBG CPW," IEEE Microw. Wireless Compon. Lett., vol. 13, no. 7, pp. 276-278, July. 2003.

[6] J.-S. Lim, S.-W. Lee, C.-S. Kim, D.-A. Nam, and S.-W. Nam, "A 4:1 unequal Wilkinson power divider," IEEE Microwave Wireless Components Lett., vol. 11, no. 3, pp. 124-126, Mar. 2001.

[7] C.-W. Wang, T.-G. Ma and C.-F. Yang, "A new planar artificial transmission line and its applications to miniaturized Butler matrix ," IEEE trans. Microwave Theory Tech,vol.55, no.12, pp.2792 — 2801,december 2007.

[8] W.-R. Eisenstadt and Y. Eo, "S-parameter based IC interconnect transmission line characterization," IEEE trans. Comp., Hybrids, Manufact. Technol., vol. 15, no. 4, pp. 483-490, Aug. 1992.

AUTHOR BIOGRAPHIES

Fang Shangbin is currently working toward the M.S. degree in school of Electronic and Information Engineering, Soochow University, and is concerned with the research of microwave and RF components and wireless communication.

Guo Huiping is an associate professor of Soochow University. Her research interests include electromagnetic field theory, antenna design and EM testing technology.

Liu Xueguan is a professor of Soochow University. His research interests include electromagnetic compatibility, electro-magnetic field theory and wireless communication.

Mao Lingfeng is a professor of Soochow University. His research interests include the integrated circuit devices, integrated optical devices and quantum devices.