A novel miniaturized Wilkinson power divider using comb-like defected ground structure

Lizhong Song\textsuperscript{1,2a} and Yuming Nie\textsuperscript{2}

\textsuperscript{1} State Key Laboratory of Millimeter Waves, School of Information Science and Engineering, Southeast University, Nanjing 210096, P. R. China

\textsuperscript{2} Department of Electronics and Information Engineering, Harbin Institute of Technology, Harbin 150001, P. R. China

\textsuperscript{a)} songlizhonghit@gmail.com

Abstract: A compact two-way planar Wilkinson power divider with dimensions of over 40 mm × 28 mm × 0.8 mm operating at L-band is presented. By using two comb-like symmetric defected ground structures (DGS), the divider is reduced by about 50% in size. The measured results demonstrate that the insertion loss is less than 3.2 dB, the input return loss is smaller than \(-15\) dB from 1.3 to 1.7 GHz while the isolation is larger than 20 dB.

Keywords: Wilkinson power divider, defected ground structure, microstrip line

Classification: Microwave and millimeter wave devices, circuits, and systems

References

1 Introduction

Power dividers are often used in microwave systems to divide or combine the power of RF signals, such as power amplifiers, antennas feeds, phase shifters, the feeding networks for antennas, vector modulators, and mixers [1, 2]. The conventional Wilkinson divider provides fixed bandwidth and pass power at frequencies outside of the usable bandwidth. A Wilkinson divider is one of the most commonly used passive components owing to its simple design and topology [3]. Compact size and broadband is desired for advantages such as a high level of integration and low-cost systems [4]. However, the quarter-wave transmission line structure of the Wilkinson divider has impeded its applications in monolithic microwave integrated circuits (MMICs), especially for frequencies below 10 GHz [5].

The band rejection property and the slow-wave effect of the defected ground structure (DGS) can provide longer electric length of transmission line than that of a conventional line, which can reduce the microwave and millimeter device size [6, 7].

This letter presents a simple and compact power-divider. By using a comb-like DGS, the power-divider dimension is reduced significantly. Besides, stubs and broadband resistance are employed to enhance the divider’s characteristics.

2 Structure and design of a power divider using DGS

A typical two-way equal-split Wilkinson power divider (as shown in Fig. 1) is designed at 1.5 GHz. An opened ring and a broadband resistance are introduced to enhance the divider’s performance.

The impedance bandwidth of the designed divider above is 400 MHz, isolation is larger than 20 dB, insertion loss is less than 3.2 dB. The size of the divider is 60 mm × 40 mm × 0.8 mm. Limited to the large size, it is not suitable for special applications, such as phased-array radar systems.

To reduce the size of the power divider above, a comb-like DGS (the red part as shown in Fig. 2) is employed. Four stubs are introduced to compensate for the transmission characteristics made by DGS.
3 Simulated and measured results

Based on the design procedure discussed above, a three-port power divider for operation in the L-band is designed. The divider is simulated and optimised by using the commercial software – High Frequency Structure Simulator (HFSS) based on the finite element method algorithm and a simple resonant equation.

The proposed power divider scheme is designed at 1.5 GHz and realised on FR.4 substrate with thickness $h = 0.8$ mm, dielectric constant $\varepsilon_r = 4.8$, and loss tangent $\tan \delta = 0.016$ by standard PCB process. The final dimensions of the power divider are: $W_1 = 2.2$ mm, $W_2 = 1.2$ mm, $L_1 = 8.8$ mm, $L_2 = 15.7$ mm, $L_d = 40$ mm, $W_d = 28$ mm, $L_{d1} = 6.8$ mm, $L_{d2} = 2.4$ mm, $L_{d3} = 1.5$ mm, $L_{d4} = 0.9$ mm, $W_{d1} = 0.4$ mm, $W_{d2} = 0.6$ mm, $L_s = 2.8$ mm, $W_s = 0.8$ mm, $M_1 = 2.2$ mm, $M_2 = 11.2$ mm, $M_3 = 5.3$ mm, $M_4 = 6.8$ mm.

Photographs of the fabricated divider are shown in Fig. 3. The coaxial probe inner conductor diameter is 1.3 mm, and the outer conductor diameter is 4.2 mm.
Compared with the typical Wilkinson divider, the proposed divider is reduced by about 50% in size.

The S parameters are carried out with Agilent E8362B vector analyzer. The simulated and measured results are generally in good agreement, although slight deviations are seen. These deviations are mainly due to the influence of the SMA connectors at input and output ports.

Fig. 4(a) shows the simulated and measured input and output matching of the power divider for the one-way signal path mode. Input and output matching performance better than $-15\,\text{dB}$ is accomplished. The insertion loss and isolation are depicted in Fig. 4(b). From the measured $S_{21}$ and $S_{31}$, it is clear that the input
power is equally divided into two output ports at the designed frequency with an insertion loss of 3.2 dB. The port isolation between two output ports is larger than 20 dB from 1.3 to 1.7 GHz. The measured phased responses for $S_{21}$ and $S_{31}$ are described in Fig. 4(c). Good agreement between measured $S_{21}$ and $S_{31}$ is achieved.

4 Conclusion

A novel power divider operating at L-band is designed, built and measured. By using comb-like DGS, the divider dimensions are reduced significantly. Good agreement between simulated and measured results is obtained. The proposed divider is simple, compact, low cost and ideal for integrated circuit applications.

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