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A Novel Three-Way Gysel Power Divider/Combiner on Plane Structure

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Abstract—A modified three-way in-phase equal Gysel power divider/combiner (PDC) and a method for implementing this novel three-way Gysel PDC on plane structure are proposed in this article. To obtain accurate values of the line impedance, the derivation of the exact equations is based on even-odd mode analysis. An experimental prototype is realized. The results show that this three-way Gysel PDC has good matching, isolation and magnitude-phase balances with high power handling capabilities.

1. INTRODUCTION

Power divider/combiner (PDC) is an important component for various microwave circuits and systems, and each type of PDC is suitable for a specific range of power, frequency and application. The Gysel PDC has good electrical characteristics. This type of PDC has attracted more and more attention for its high power-handing capability [1–5].

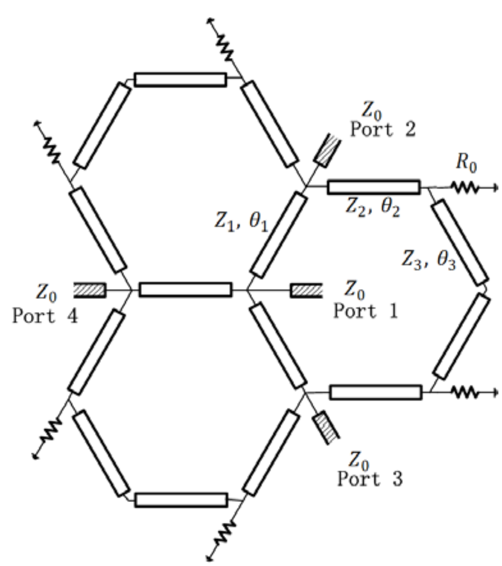

Figure 1. The proposed three-ways in-phase equal Gysel PDC.

Paper [1] shows that the traditional N-ways Gysel PDC has three quarter-wavelength lines in each way. Compared to the Wilkinson PDC with an internal isolation resistor, Gysel PDC's external resistors

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can transfer the heat to the exterior circumstance directly. In many cases, plane PDCs are designed with equal 2^N-ways. However, PDCs with three-ways are also desired to design on plane structure in some special applications. Generally, it is hard to implement conventional multi-way Gysel PDC with plane structure.

Recently, some achievements about Gysel PDC have been published. Several methods were used to get better bandwidth of Gysel PDC [6]. In [7, 8], PDCs are designed for arbitrary impedance terminals or unequal power division. In paper [9], one structure with open- and short-stub was developed for dual-band Gysel PDC. In papers [10, 11], stubs or other ways have been used to suppress harmonic frequencies in PDC. A design procedure is given in [12] for the multi-section Gysel power divider based on the even-odd mode analysis to increase the isolation bandwidth. Papers [1, 13] implement multi-way PDC by using complex 3D structure.

In this paper, main feature of the proposed three-ways in-phase equal Gysel PDC is its plane structure with high power-handling capability, as shown in Fig. 1. This paper is organized as follows. Firstly, the configuration of the novel three-way Gysel PDC and its design theory are introduced. Based on the even-odd mode analysis, explicit formulas are derived. Then, a prototype PDC is simulated, fabricated, and measured. Finally, there is conclusion.

2. ANALYSIS

2.1. Analysis When Community Port as Input

In the proposed PDC, we define electricity lengths of all transmission lines as $\theta_1 = \theta_2 = \theta_3 = 90°$. In microwave systems, the ports and loads are generally equal to $50\,\Omega$. So we define $Z_0 = R_0 = 50\,\Omega$. Also, we define port 1 as input and other ports as output, and output ports are symmetric. So the PDC can be simplified as shown in Fig. 2. When we define Equation (1) as below, we can achieve ideal match at input port.

$$Z_1 = \sqrt{3}Z_0 \approx 86.6\,\Omega \tag{1}$$

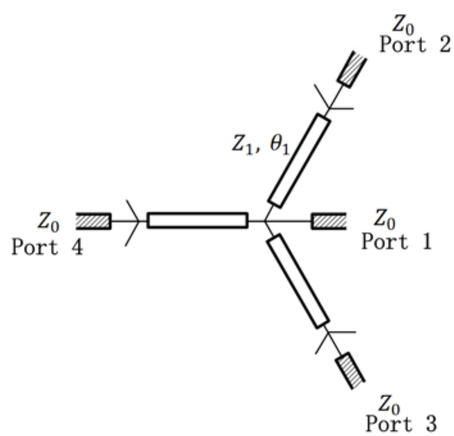

Figure 2. Schematic of the PDC when port 1 as input.

2.2. Even-Odd Mode Analysis on Ports 2 and 3

Since the structure is symmetric, the generalized even-odd mode method can be used. In the even-odd mode analysis, we define port 2 and port 3 as input as shown in Fig. 3. In addition, we can divide the PDC into two symmetrical parts. The impedances of port 1, port 4 and Z_1 are doubled.

The odd-mode equivalent circuit is shown in Fig. 4(a). In this case, port 1 and port 4 can be simply shorted to ground since the center vertical plane becomes a virtual electric wall. To achieve perfect match and isolation between two output ports at the center frequency, the odd-mode impedance at port

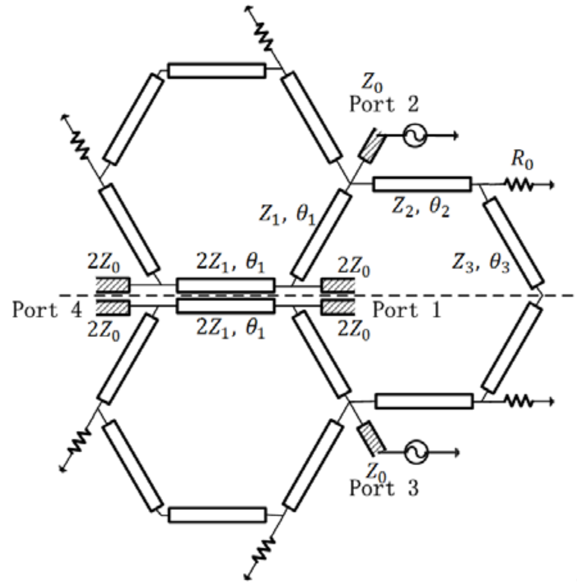

Figure 3. Depart the proposed PDC in even-odd mode analysis.

2 (Z_{odd}) (Z_{odd}) can be expressed by Eq. (2).

$$Z_{odd1} = \frac{Z_2^2}{R_0} \tag{2a}$$

$$Z_{odd2} = \frac{2Z_2^2}{R_0} \tag{2b}$$

$$Z_{odd} = \frac{Z_{odd1}Z_{odd2}}{Z_{odd1}+Z_{odd2}} = \frac{2Z_2^2}{3R_0} = Z_0 \tag{2c}$$

So we can get Z_2 as below

$$Z_2 = \sqrt{\frac{3Z_0R_0}{2}} \approx 61.2\,\Omega \tag{3}$$

Figure 4(b) depicts the even-mode equivalent circuit. The center vertical plane becomes a virtual magnetic wall. We get Z_2 under odd-mode, so the impedances relation can be formulated and validated by Eq. (4). Z_{even2} can be easily deduced by ABCD analysis methods, and we will not deduce here because of the limit of the paper length.

$$Z_{even1} = \infty \tag{4a}$$

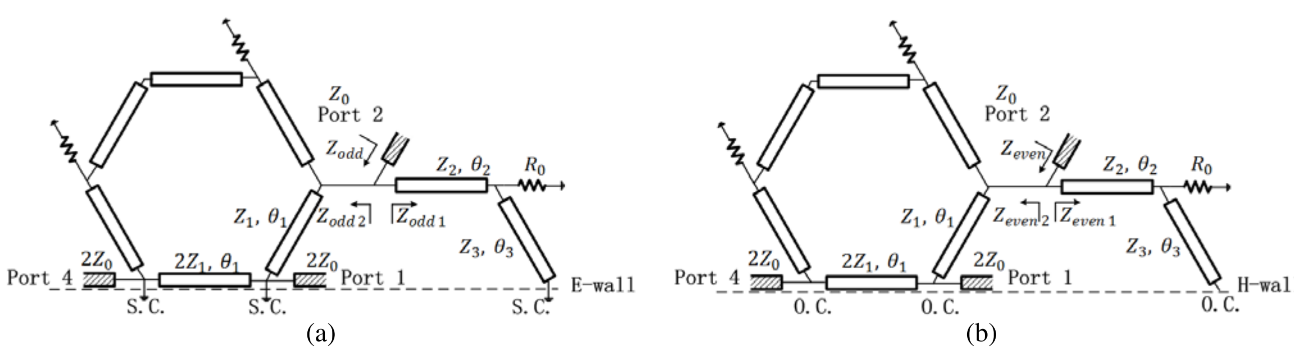

Figure 4. The proposed PDC under (a) odd-mode, (b) even-mode.

$$Z_{even2} = Z_0 \tag{4b}$$

$$Z_{even} = \frac{Z_{evne1}Z_{even2}}{Z_{even1}+Z_{even2}} = Z_0 \tag{4c}$$

From the above equations, we can see that Z_3 has no relationship with the terminal impedance matching and isolation at f_0 in the proposed PDC and only influences the frequency band. Because of the limit of the paper length, we will not discuss the relationship between Z_3 and the frequency band. We just simply define $Z_3 = 35\,\Omega$ in this paper depending on the engineering experience.

3. SIMULATION & MEASUREMENT

In this section, we present the simulation, fabrication, and measurement of the proposed PDC on the plane structure. As shown in Fig. 5, this proposed PDC is fabricated on a two-layer plane. Port 1, which is located at the center, is connected from the back side of the plane by the SMA connecter. The substrate has a relative dielectric constant of 4.6 and thickness of 1.6 mm, and the center frequency of PDC is 1 GHz as an example. Ports 2, 3, 4 are connected to the center joint by microstrip Z_1. Fig. 6 shows a picture of the novel three-way Gysel PDC, and the size of the PDC is about 9 cm × 9 cm. The external loads R_0, which are different from the surface mounted resistors and are no longer the power-limiting factor of the PDC, are connected to SMA terminals. Therefore, the PDC's power-handling capability depends on the breakdown voltage of transmission lines.

The simulation and measurement are accomplished by EM simulation software and network analyzer, respectively. Excellent agreement between the simulation and measurement results is achieved

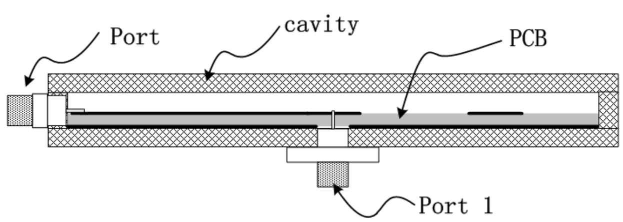

Figure 5. Structure diagram seen from the side.

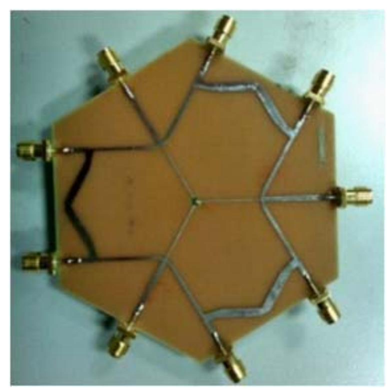

Figure 6. Picture of the proposed PDC.

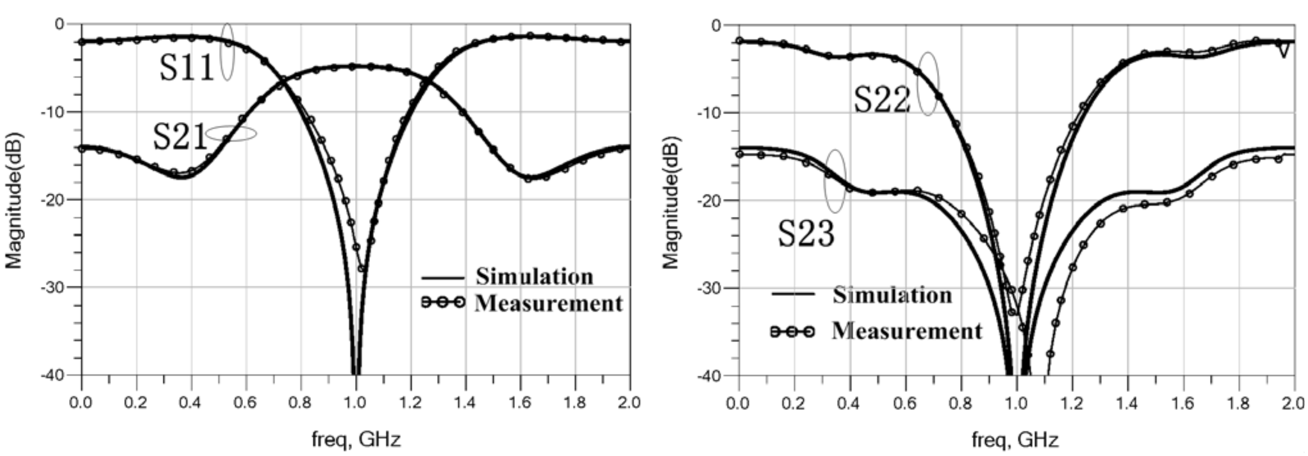

Figure 7. The Simulation and measurement results of proposed Gysel PDC.

for both magnitude and phase responses. The results including transmission, reflection and isolation parameters are shown in Fig. 7. The bandwidth of PDC is about 20% based on the criterion of the ports reflection and isolation blow −15 dB. The insertion loss of the proposed PDC is less than 0.5 dB inside the fundamental band. Therefore, there is generally an acceptable agreement between the simulated and measured results. Because of the instability of the fabrication tolerances and SMA connectors, there is a slight frequency shift between simulation and measurement.

4. CONCLUSION

In this paper, both theory and experiments of a novel plane symmetrical three-ways Gysel PDC have been provided. The even-odd mode method has been used to analyze this PDC. This method simplifies the implementation of the three-way Gysel PDC from a complex 3D structure to a simple two-layer microstrip structure. Since this Gysel PDC has good performances on plane structure, this proposed PDC leads to wider practical engineering applications in high-power microwave circuits. Recently, because of using the via with SMA connecter in the PDC, this proposed PDC is difficult to be applied in high frequency circuits. The works how to design this PDC in high frequency circuits will be our future research.

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