

# Design and Implementation of 4:1 Wilkinson Power Divider

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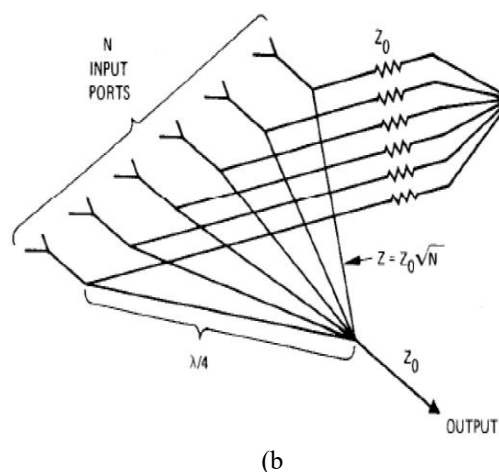
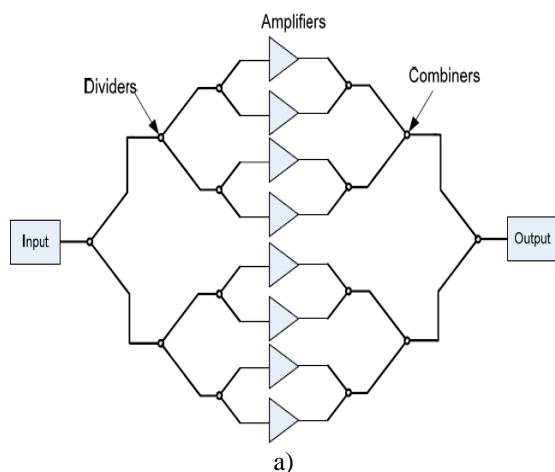
## ABSTRACT:

In this paper, 4:1 Wilkinson and Gysel combiner are designed and simulated for high-power applications. Since Wilkinson power combiner provides broad bandwidth characteristics and low insertion loss, it can be an appropriate candidate for realizing the required power combiner. The fabricated combiner provides a maximum insertion loss of about 0.5dB and Max  $S_{11}$  and  $S_{22}$  of about -10 dB in the frequency band of 8-9.2 GHz. It was designed in such a way that it can easily be tuned to compensate phase mismatch between four different inputs with a precision of about 15 degrees.

**KEYWORDS:** Wilkinson, Gysel, Power Combiner, Insertion Loss, Isolation.

## 1. INTRODUCTION

In high-power amplifiers, the output power of several parallel amplifiers is usually combined to increase the output power. The frequency response (bandwidth), insertion loss, isolation between the ports, and the dimensions of the combiner/divider are essential parameters in the design process of the divider/combiner[1]. There are various structures for implementing power combiner/divider. A combining structure can be realized in one step or several steps, as shown in Fig.1.



**Fig.1.** Multi-stage power combination a) One-stage power combination.

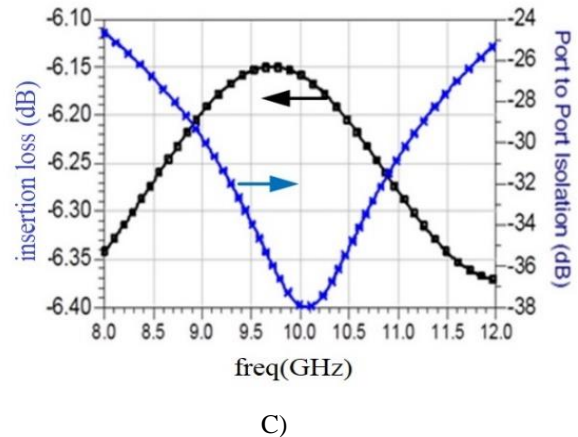
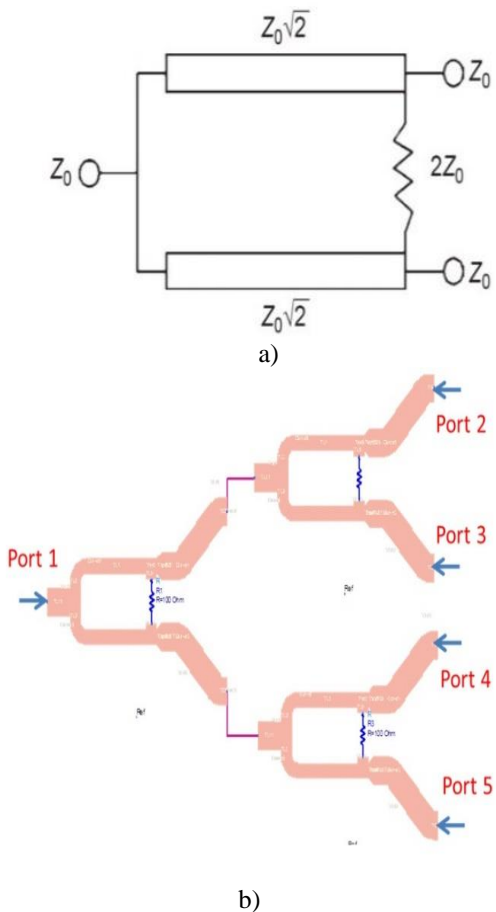
Suppose the number of amplifiers that are combined is less than six. In that case, a multi-stage power combination will be the best way because it provides an appropriate bandwidth, low insertion loss, and simple implementation. As the number of amplifiers increases, single-stage N-power combiners will have lower losses than multi-stage combiners [2].

Power combiners are implemented in both planar and non-planar forms. Although non-planar combiners usually have a wider bandwidth and lower losses, due to the complexity of their construction, the use of planar combiner is more common [3]. There are various structures and details about implementing a planar

power combiner. In combined power amplifiers, the combiner/divider input signals should have precisely the same amplitude, and all signals should be in phase. It can not easily be achieved in high-frequency bands. This paper will present the simulation results of the Wilkinson and Gysel 4:1 power combiner in the X-band frequency. Finally, the measurement results of the implemented Wilkinson combiner will be discussed.

**2. WILKINSON POWER COMBINER**

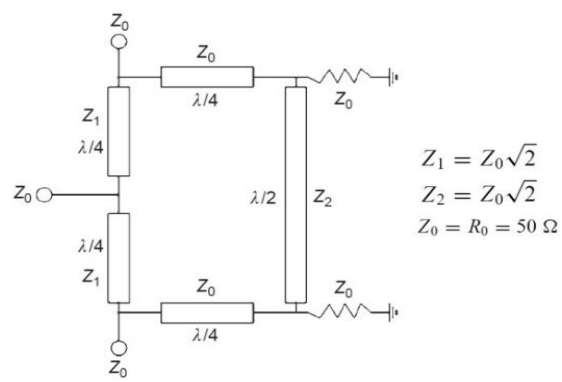
One of the most common structures for the realization of planar power combiner is the Wilkinson power divider/combiner. Figure 2.a shows a simple 1:2 Wilkinson power divider/combiner. Figure 2.b depicts 4:1 Wilkinson power divider/combiner, consisting of three similar 2:1 Wilkinson power divider/combiner. Figure.2c illustrates the simulation results of the designed 4:1 power combiner/divider. As it was shown, it provides appropriate isolation and low insertion loss in the X-band frequency.



**Fig. 2.** a) 1:2 Wilkinson power divider/combiner b) 1:4 Wilkinson power divider/combiner c) the insertion loss and isolation of the designed 1:4 power combiner/divider.

**3. GYSEL POWER COMBINER**

In the Wilkinson power divider/combiner, the resistor's dimensions are too small compared to the wavelength, and thus it can not withstand high power. In power amplifiers, the power tolerance of the resistors in the structure must be high enough. In the Gysel power combiner/divider, as shown in Figure.3, the resistor of the Wilkinson structure was replaced with a combination of  $\lambda/4$  and  $\lambda/2$  transmission lines and two ground-connected resistors [3]. These resistors can have much larger dimensions than the resistor used in the Wilkinson power divider/combiner. Therefore, high-power resistors (with better heat sink) can be easily used for this structure, making the circuit suitable for high-power applications.



**Fig. 3.** Gysel power combiner/divider.

The simulation results of the 4:1 Gysel combiner/divider are shown in Figure 4.a. In the Gysel combiner/divider structure, there are several consecutive  $\lambda/4$  and  $\lambda/2$  lines. As a result, as shown in Figure.4 .b, it has a smaller bandwidth, and higher insertion losses than Wilkinson combine/divider.

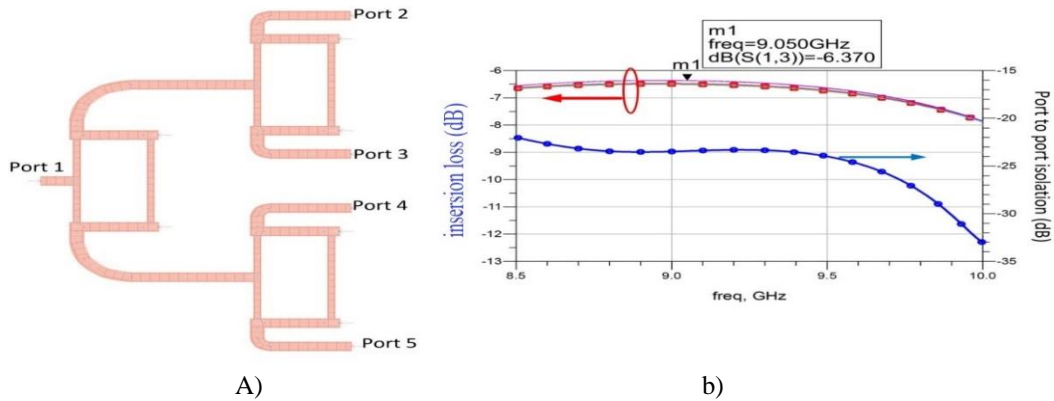


Fig. 4. a) The Gysel power divider/combiner b) The simulation result of the Gysel power divider/combiner.

**4. IMPLEMENTED POWER COMBINER/DIVIDER**

Since the Wilkinson divider/combiner provides low losses and an appropriate bandwidth, it is a good choice for implementing a high-power power combiner. The implemented 4:1 Wilkinson power divider/ combiner and measurement results are shown in Figure 5. It provides an max insertion loss of 0.5 dB, while  $S_{11}$  and  $S_{22}$  are lower than -10dB in the frequency range of 8-9.2 GHz. The employed resistors can tolerate up to 2.5 watts.

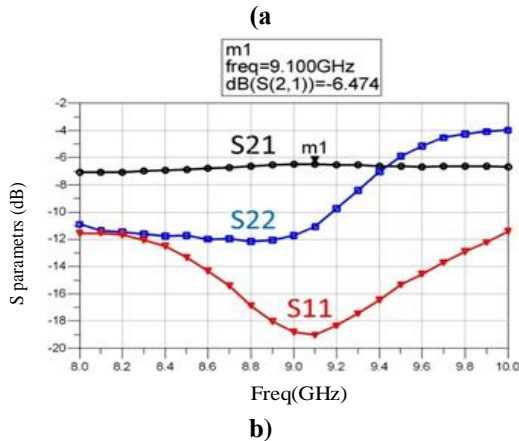
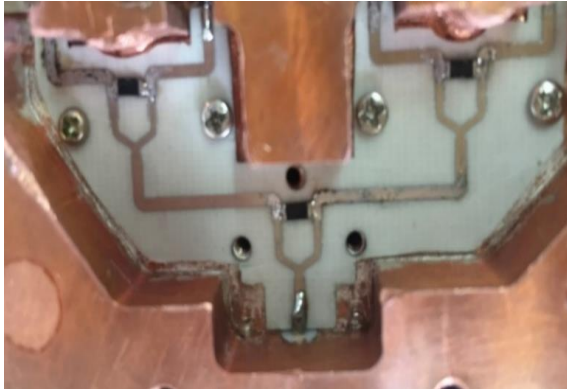


Fig. 5. The implemented power combiner/divider b) measurement results of the proposed combiner.

In the modified version of this 4:1 combiner divider which was shown in Fig.6, some pads are embedded that can be used to compensate the phase mismatch of different input signals of the combiner/divider. This combiner is designed to combine the output power of four different amplifiers. To test this amplifier, we first need to measure the  $S_{21}$  phase of the amplifiers. If the amplifiers are not in phase with each other, we can use silver glue to change the 50-ohm line length at the output of the power divider using 50-ohm pads placed next to the power combiner circuit to equalize the amplifier phase. With this method, the phase of amplifiers can be brought closer to each other with an accuracy of 15 degrees.

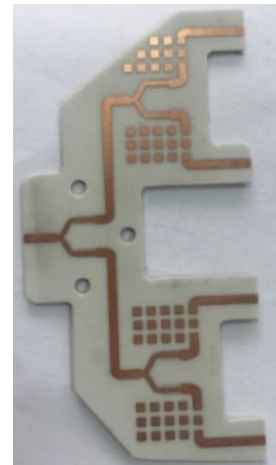


Fig. 6. Phase adjustment using a proposed power combiner/divider.

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