

# Design of a Wilkinson Power Divider with Harmonic Suppression for Mobile Application

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**Abstract**—This paper presents a Wilkinson Power Divider (WPD) operating at 6 GHz capable of suppressing unwanted harmonics up to the 3rd harmonic. The design formulas are analysed and presented in detail. Power dividers are widely used in microwave circuit structures. Indeed, this paper outlines the design and simulation of a 1:1 power divider for mobile applications using CST Studio Suite.

**Keywords:** *Wilkinson power divider, microwave, equal power division, and harmonic suppression.*

## 1. INTRODUCTION

The Wilkinson Power Divider, designed primarily for mobile applications, is a critical component in radio frequency (RF) systems, distributing RF power to various output ports with equal amplitude. In the world of mobile applications, the design of a Wilkinson Power Divider requires advanced considerations, balancing power division accuracy, bandwidth needs, and, most importantly, harmonic suppression. The Wilkinson Power Divider for mobile applications is designed not only to efficiently split the incoming RF signal but also to minimise harmonic production, which can affect signal quality and regulatory compliance. Harmonic suppression in the Wilkinson Power Divider requires optimising important parameters, such as resistor values and transmission line lengths, frequently using simulation tools like CST Studio Suite to eliminate undesirable harmonics.

They are commonly used as essential components in various microwave applications for power distribution and synthesis. The Wilkinson Power Divider is particularly favoured for its high return loss, excellent isolation, and low insertion loss, all achieved through a simple design. In the following sections, we will examine the design process of the proposed equal Wilkinson Power Divider in detail.

## 2. DESIGN OF WILKINSON POWER DIVIDER AND ITS PARAMETERS

This paper proposes designing a 1:1 Power Divider using CST Studio Suite software. Thus, a conception of a Wilkinson Power Divider with a ratio of 1:1 is presented at a central frequency of about  $f_0 = 6$  GHz.

### 2.1 Design of a Wilkinson Power Divider

In this section, Figure 1 shows the proposed design of the Wilkinson Power Divider after it has been optimised by simulating CST Studio Suite software.

From this figure, the WPD is designed based on this dimension at a length of 40 mm and width of 50 mm. The substrate material used is Rogers RO4350B with a dielectric constant of 3.66. The thickness of the substrate is set to be 1.524 mm with a loss tangent of 0.0037. The lower the loss tangent, the better the performance of the Wilkinson Power Divider.

### 2.2 Design of Wilkinson Power Divider with Harmonic Suppression

Fig. 2 shows the method of suppressing the harmonics by cutting some of the copper parts to the ground. It also illustrates the dimensions of the cutting slot at the centre of the ground copper plate, with 8mm X 40mm representing length and width, respectively.

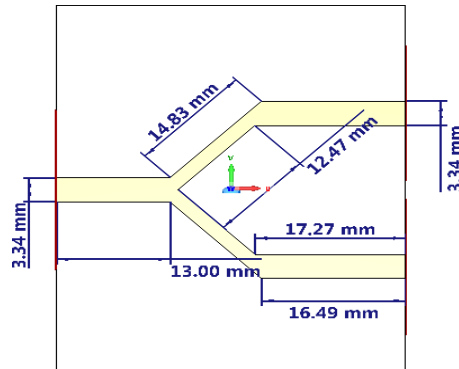


Fig. 1. Design of Wilkinson Power divider

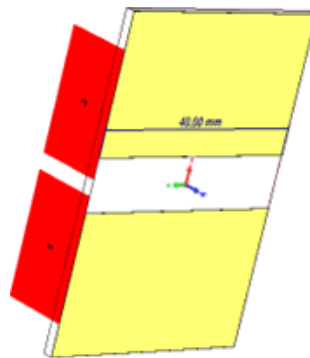


Fig. 2. Harmonic suppression layout

### 3. RESULTS AND DISCUSSION

This section will include all the findings to examine how well the Wilkinson Power Divider with harmonic suppression performs. It will then provide a deeper understanding by analysing theoretical and simulation results based on the behaviour of power dividers.

#### 3.1 Return Loss Before and After Adding a Suppressing Element

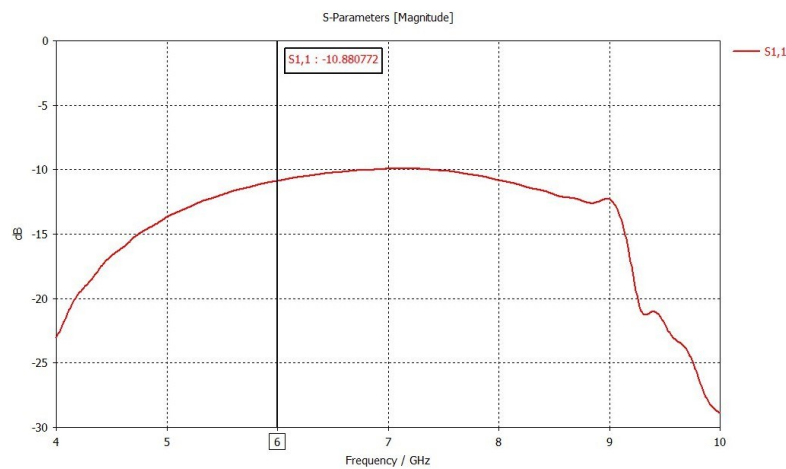


Fig. 3. S11 result without suppressing element

The return loss (S11) of this design without suppressing element is displayed on an S—S-parameter plot throughout the frequency range of 4 GHz to 10 GHz, with an emphasis on 6 GHz, where S11 is around -10.88 dB based on Figure 3.

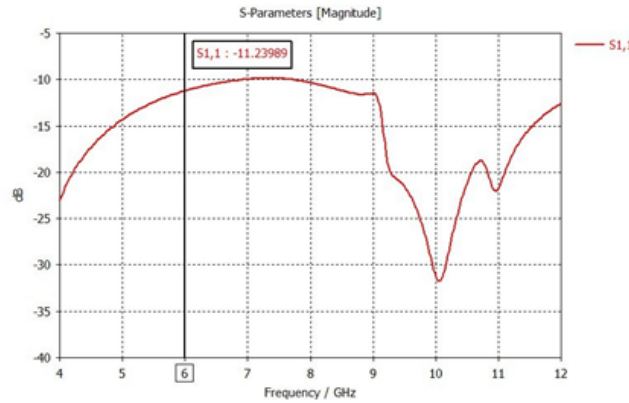


Fig. 4. S11 results in suppressing element

Meanwhile, Figure 4 shows that the return loss at 6 GHz is -11.24 dB which means the component transmits 92% of the incident power and reflects around 8% of it back to the source. In addition, the figure displays different return losses at different frequencies. Near 10 GHz, improved impedance matching is shown, as seen by the lower S11 value. As can be viewed from both figures, the return loss values improved from -10.88 dB to -11.24 dB. This means that the amount of signal being reflected to the input port is reduced.

### 3.2 Impedance Matching Before and After Adding a Suppressing Element

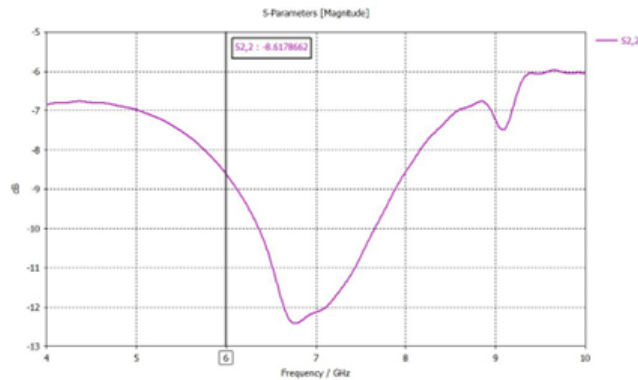


Fig. 5. S22 result without suppressing element

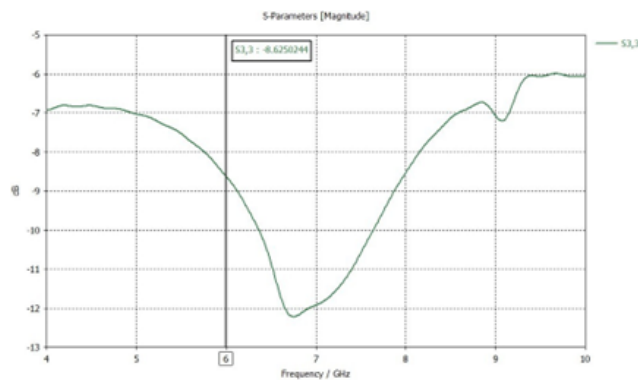


Fig. 6. S33 result without suppressing element

The S22 and S3,3 parameters measure impedance matching, which is crucial for reducing signal reflections at the output ports of a Wilkinson power divider. S22 and S33 are the metrics used to quantify the reflection at Port 2 and Port 3,

respectively. Figures 5 and 6 illustrate that the  $S_{22}$  values without suppressing elements are around -8.6 dB for both figures.

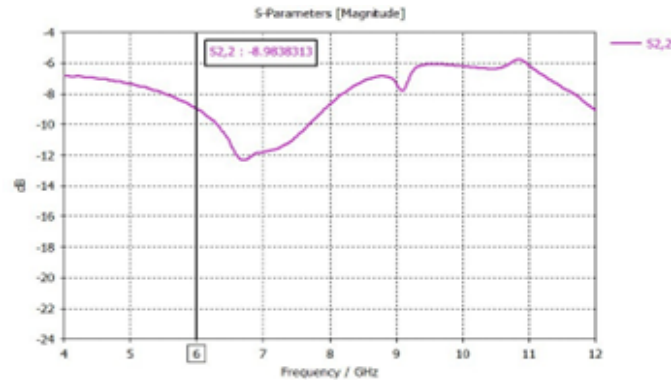


Fig. 7. 7  $S_{2,2}$  result with suppressing element

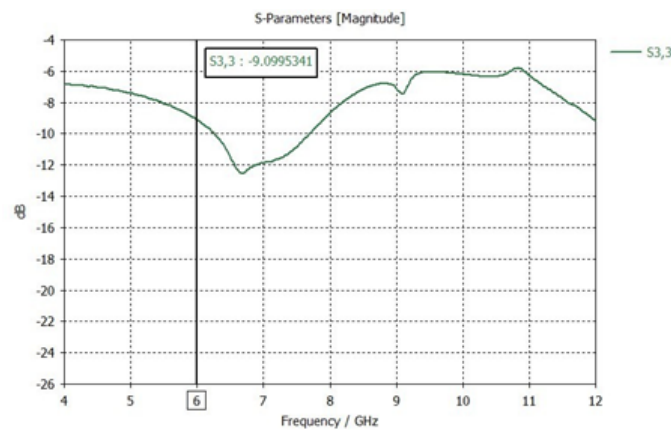


Fig. 8  $S_{3,3}$  result with the suppressing element

However, with the suppressing element, the S-parameters plotted above show suboptimal impedance matching at the output ports, port 2 and port 3. In the  $S_{22}$  and  $S_{33}$  graphs above, they represent an approximate value of -9 dB. The value of -9 dB for  $S_{22}$  and  $S_{33}$  indicates that the system is functioning, but it is far from optimal and should be improved for better performance and efficiency. Nevertheless, it appears that the addition of the suppressing element improves the impedance matching across the entire frequency range, as shown by the lower values for  $S_{22}$  and  $S_{33}$ , which means that most of the signal is passed through the ports with little reflection.

### 3.3 Insertion Loss Before and After Adding a Suppressing Element

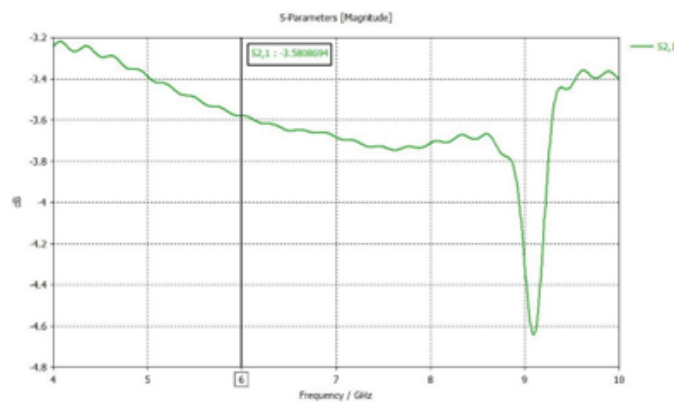


Fig. 9.  $S_{2,1}$  result without suppressing element

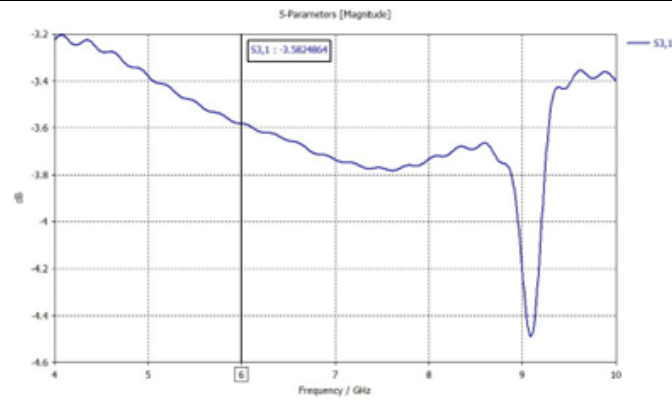


Fig. 10. S31 result without suppressing element

The attenuation or loss of a signal experienced when passing via the Wilkinson Power Divider from Port 1 to Port 2 (S21) or Port 3 (S31) is illustrated in Figures 9 and 10, respectively. For a Wilkinson Power Divider to show uniform power distribution to every output port, its insertion loss should ideally be -3 dB. The insertion loss based on the above figures without harmonic suppression is around -3.58 dB at Ports 2 and 3.

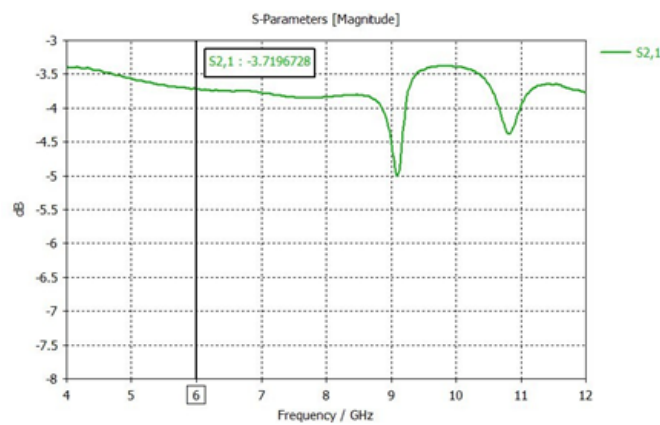


Fig. 11. S21 results with suppressing element

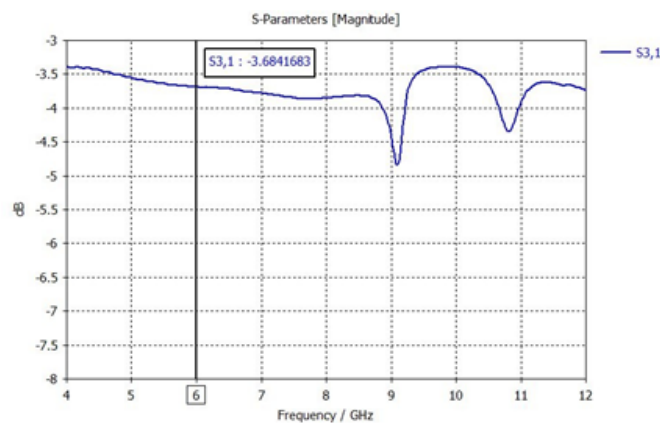


Fig. 12. S31 results with suppressing element

As in Figures 11 and 12, this design with harmonic suppression gained its insertion loss at port 2 and port 3 to approximately -3.7 dB, respectively. The value is still acceptable, as it is near -3 dB. The goal is to minimise insertion loss to guarantee effective signal transmission. Lower insertion loss levels indicate more signal deterioration and improved performance.

### 3.1. Mutual Coupling Before and After Adding a Suppressing Element

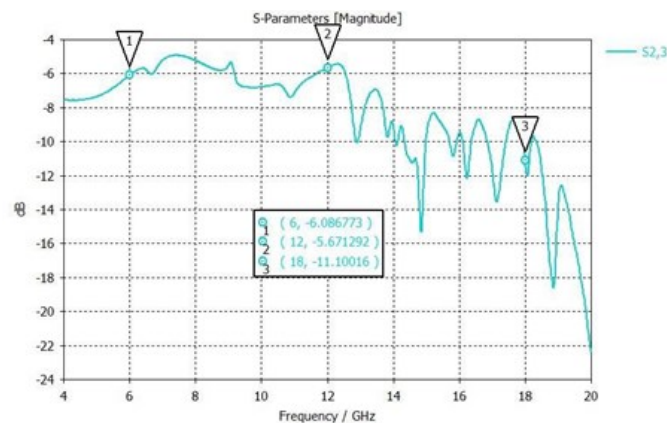


Fig. 13. S23 result without suppressing element

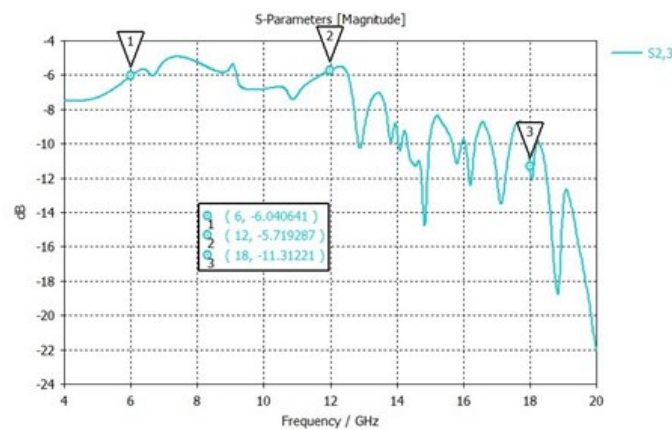


Fig. 14. S23 results with suppressing element

Figure 13 and Figure 14 depict the S23 results, which is the mutual coupling between output port 2 and output port 3. In this segment, three harmonics need to be observed in order to see the value of mutual coupling before and after the suppression element is added. Between Figure 4.5.1 and Figure 4.5.2, at 6 GHz, the harmonics are not sufficiently reduced from -6.08 dB to -6.04 dB. However, in the 2<sup>nd</sup> harmonic at 12 GHz, the value of mutual coupling is efficiently reduced from -5.67 dB to -5.71 dB. Also, in the 3<sup>rd</sup> harmonic at 18 GHz, the mutual coupling is sufficiently reduced from -11.10 dB to -11.31 dB. Hence, it proved that the signals at one port do not interfere with signals at the other port. However, due to flaws in the componentry or layout, there may still be some degree of mutual interaction in actual implementations.

## 4. CONCLUSION

This paper presents a modified WPD with good isolation and harmonic suppression structure. The proposed design requires cutting some part of the copper slot, which is one method used to suppress the harmonics. According to the results obtained, the WPD has a good performance at 6 GHz, which is suitable for mobile applications.

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