T.C.
DOKUZ EYLÜL UNIVERSITY
ENGINEERING FACULTY
ELECTRICAL & ELECTRONICS ENGINEERING

EED4103 Microwave Theory And Applications

Wilkinson Power Divider Report

by

Efe Kiraz 2016502071

20 January 2021

Abstract

Due to the better isolation characteristics, Wilkinson divider precedes lossless T-junction[1]. In this paper simulation of wilkinson power divider will be implemented by using ANSYS™Electronics Desktop Circuit. The comparision of the results obtained in ADS™[2] and ANSYS™will be made.

1 Introduction

Power divider is a passive microwave component which is utilized generally in antenna applications to feed the antenna or generalized load. Wilkinson power divider is preferred in today's applications due to its matched and port isolation characteristics.

2 Notion of Losslessness, Matched, Reciprocity

It is impossible to design a multiport network which satisfies losslessness, matched and reciprocity at each port[1]. In the design process, there must trade off one of these properties. Wilkinson power divider is lossless when the output ports are matched. This three port device can divide the incoming power as -3dB through the other two ports. Moreover, the device can make the reverse of this division due isolation property. This means Wilkinson Divider can also be used as a power combiner.

3 Analysis Of Wilkinson Divider

Distributed models have a corresponding lumped element models. First lumped element wilkinson divider topology can be seen in Fig. 2.

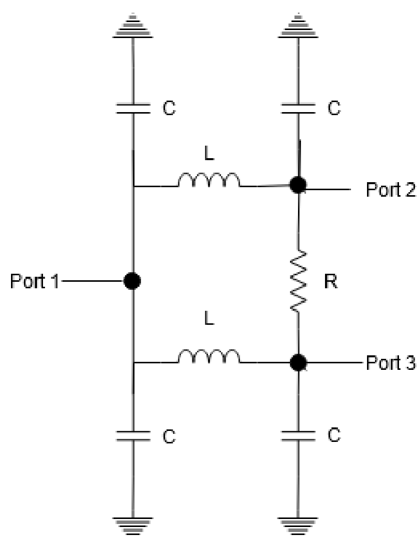


Figure 2: Lumped Model Of Wilkinson Power Divider

In order to gain insight about the behavior of the Wilkinson divider, even and odd mode analysis are required. In Fig. 3, the topology is drawn to show the midline -symmetry axis- between upper and lower half.

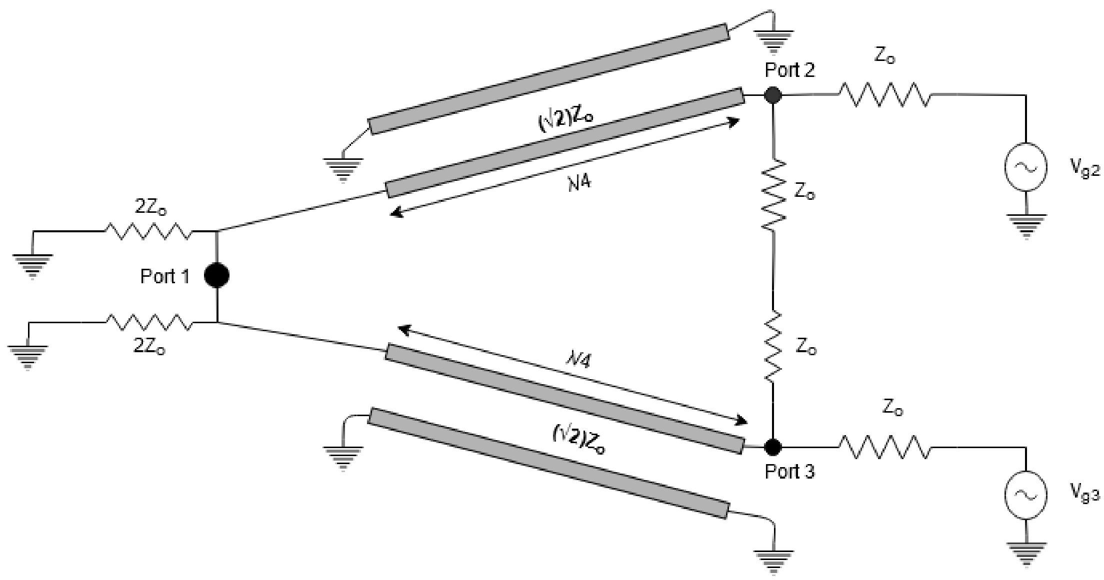


Figure 3: Distributed Model Of Wilkinson Power Divider

If the output ports are not matched, then the reflected power will be dissipated on resistive part. As it was mentioned in previous section, the divider compensates the reflected power with the help of the resistive component -equivalent value is $2Z_o$- between *Port 2* and *Port 3*.

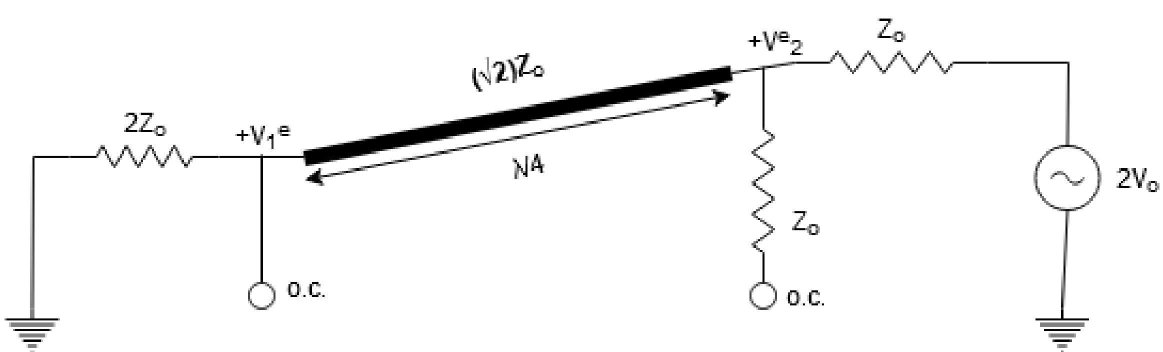


Figure 4: Upper half of the distributed model in even mode analysis

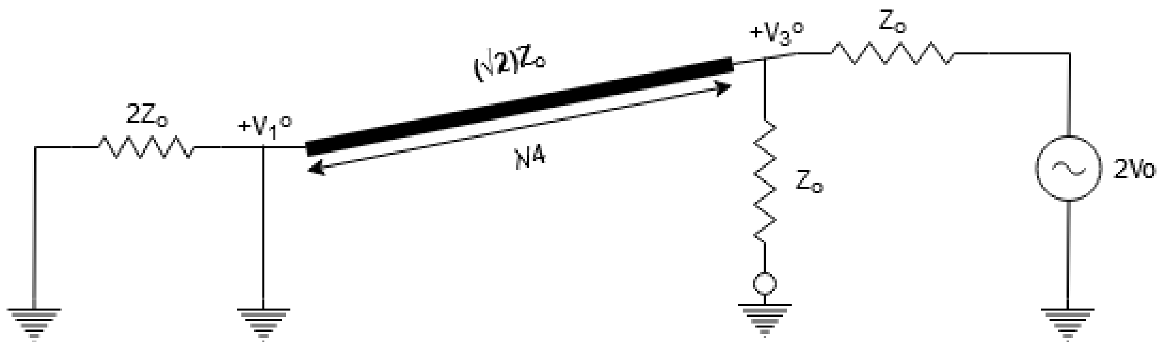


Figure 5: Upper half of the distributed model in odd mode analysis

Even and odd mode analysis results can be combined by using superposition principle. This technique provides the information about the behavior of the divider.

4 ANSYS Design Process

Design process of RF circuits is mainly conducted in computer aided simulations. Ansoft™Electronics Desktop contains different types of simulation approaches. For instance, it can solve circuit schematics as a *Linear Network Analysis* solution setup. This simulation provides S-matrix, ABCD-matrix and linear system solution. Also, noise can be added to simulation as a analysis parameter.

Another solution type solves 2D Maxwell equations as a simulation which is relatively slow with respect to linear system simulation of circuit schematic. The accuracy is greater is in this type of simulation.

The last solution type solves 3D Maxwell equations in a most accurate approach. This type of solution covers HFSS design process. Meshing the 3D geometry and analysis of circuit schematic is implemented.

4.1 The Simulation Of The Wilkinson Power Divider

As it was mentioned above, power dividers are used in antenna applications, such as array-feeding networks [4]. In addition of the ANSYS™based applications, there are other simulations which are implemeted on Advanced Design Systems (ADS) [2] [3].

Due to its comprehensive approach, the paper[2] will be implemented on ANSYS in this research.

In the design process characteristic impedance will be used as 50Ω. The distributed model in Fig.3 shows a transmission line with a characteristic impedance of $\sqrt{2}Z_o$ which is approximately equal to 70.71Ω.

4.2 Design Properties

The simulation is carried out by using *Roger Droid 5880* substrate in Ansys Electronics Desktop 2020 R2 Circuit. Thickness of the dielectric is 0.787mm and thichness of the copper 35μm. The substrate relative permittivity is 2.2 and the dissipation factor is 0.0009 . The simulation is carried out in the frequency range of 1-4GHz by linear equally spaced 400 steps.

According to the given simulation parameters transmission line width for different characteristics impedances can be calculated with the formula,

$$Z_o = \begin{cases} \dfrac{60}{\sqrt{\epsilon_e}} ln\left(\dfrac{8d}{W} + \dfrac{W}{4d}\right) & \text{if } \dfrac{W}{d} \leq 1 \\ \dfrac{120\pi}{\sqrt{\epsilon_e}[W/d + 1.393 + 0.667\ln(W/d) + 1.444]} & \text{if } \dfrac{W}{d} \geq 1 \end{cases} \quad (1)$$

The results will be found as

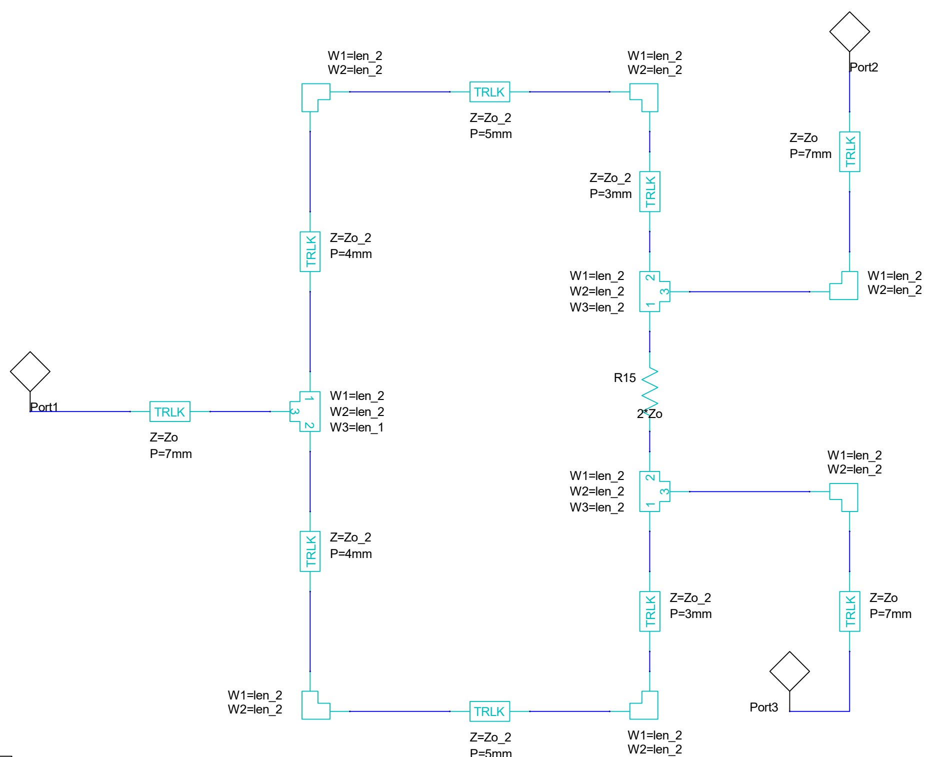
Parameters	Impedance Values	Physical Dimension of The Microstrip Line (W)
Z_o	50Ω	2.40337mm
$\sqrt{2}Z_o$	70.7107Ω	1.36428
$2Z_o$	100Ω	-

Table 1: Ideal Parameters of 2-Way Wilkinson Power Divider[2]

4.3 Design Schematic

In the next page, the circuit schematic of the design can be seen. The names of components and simulator labels, which was used in the design, are

- Transmission Line with Physical Length, (TRLK_NX)
- Bend (MS_BEND)
- Tee, Reference Planes at Center (MS_TEEC)
- Resistor
- Port (with reference node ground)



Design Properties
len_1 = 2.4033mm
len_2 = 1.3642mm
Zo = 50ohm
Zo_2 = 70.7107ohm

4.4 The Evaluation Of The Results

Linear Solution Setup is set from the *Analyze* title. After the simulation, S-parameters were obtained by using *Rectangular Plot*. S-parameter results can be seen below,

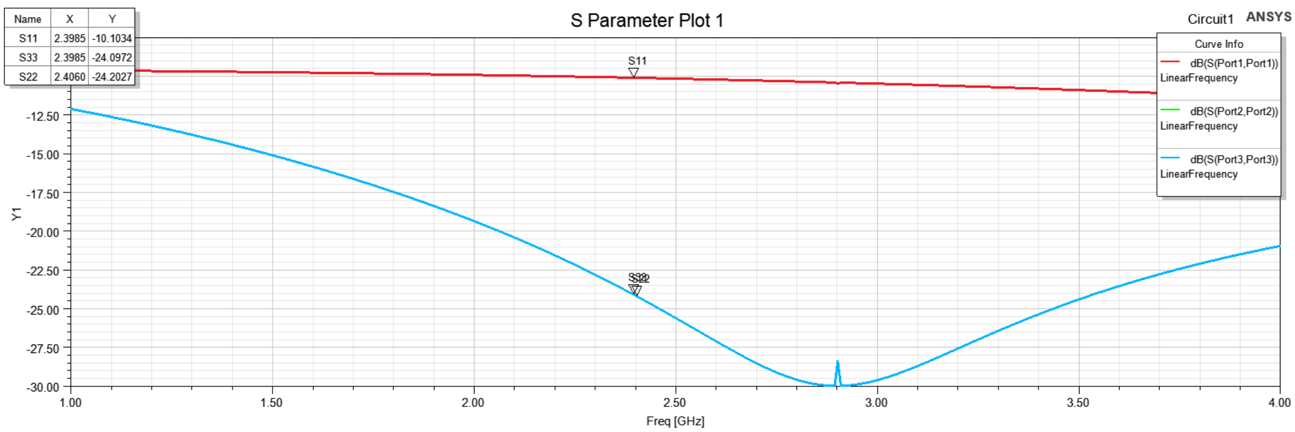


Figure 6: S11, S22, S33 parameters of the network

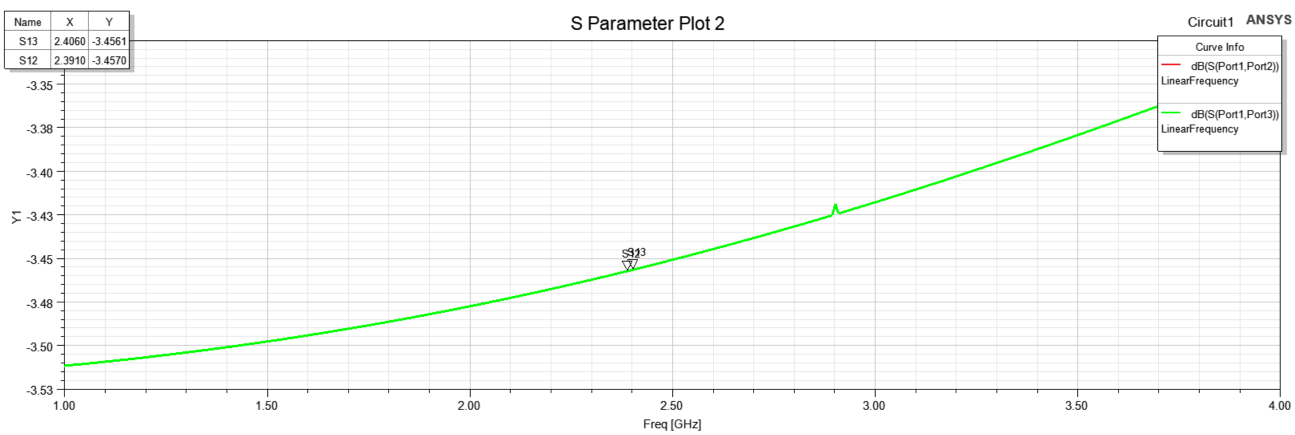


Figure 7: S12, S13 parameters of the network

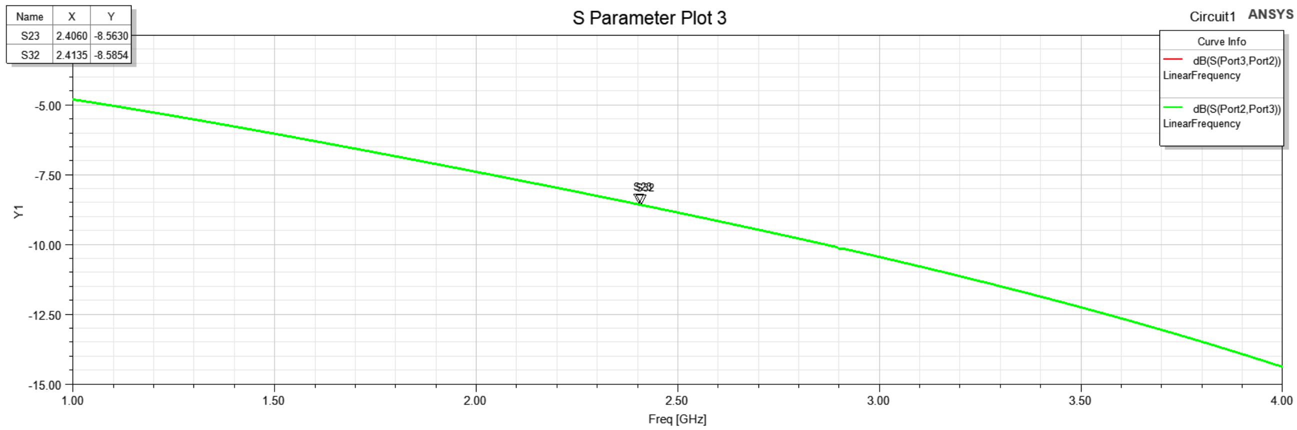


Figure 8: S23, S32 parameters of the network

The estimations about the mismatch of the S11, S23, S32 parameters that I found and the ones which were obtained by using ADS[2],

- The bend component does not provide a smooth curve. The curvature is 90°. This results in discontinuity in microstrip transmission line.
- The required substrate definition is not provided by default at the beginning - The definition errors may occur about the substrate.
- More simulation parameters on the ANSYS™- The circuit simulation in the ANSYS Circuit asks for the distance between the microstrip line and the cover of the box, the *HU* parameter in Fig.9. (In order to calculate effective dielectric constant for the Roger Droid substrate). It is selected randomly.

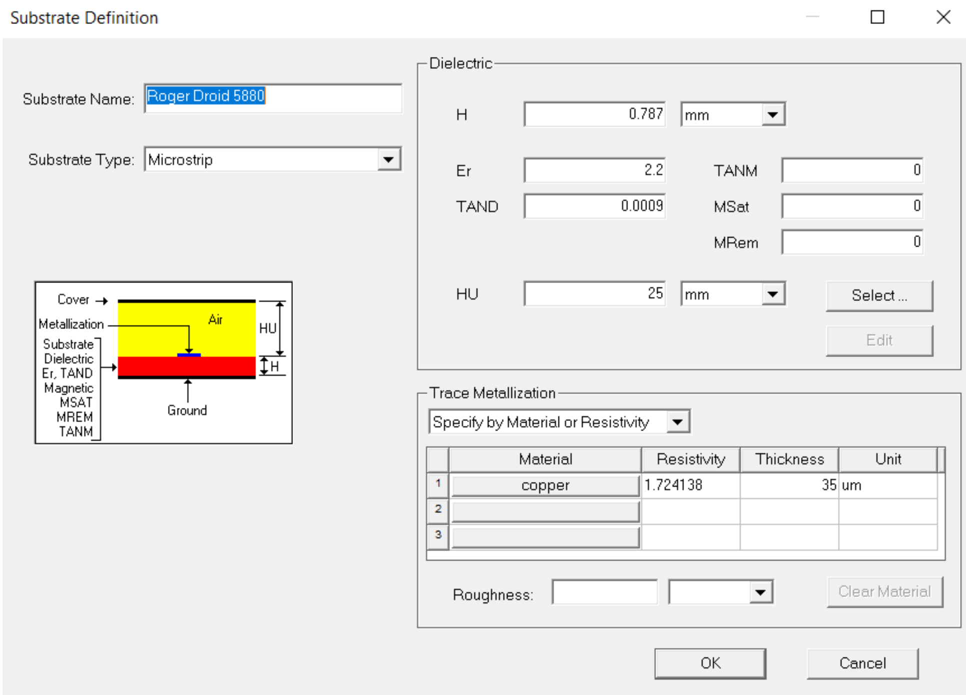


Figure 9: Substrate definition in ANSYS™Circuit

References

[1] Pozar D., Microwave Engineering, , 4^{th} Edition, 2014

[2] Taufiqqurrachman, Kurniadi D.P. , "Design and realization Wilkinson power divider at frequency 2400MHz for radar S-band" , IOSR Journal of Electronics and Communication Engineering, 2012.

[3] Kumari R., Acharya V., "Design and simulation of two way power divider in S band", International Research Journal of Engineering and Technology, Vol 04, 2017.

[4] Harty D.D., " Novel design of a wideband ribcage-dipole array and its feeding network", Master of Science Thesis, Worcester Polytechnic Institute, 2010

[5] Keysight™EEsof EDA, "Microstrip and CPW Power Divider Design"

[6] ANSOFT™Corporation, "Ansoft's State-of-the-art circuit simulator for RF, analog and mixed signal design", 2004.