UNIVERSITY OF TORONTO
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ECE424F Microwaves

Experiment: A 3dB Wilkinson Power Divider in Microstrip

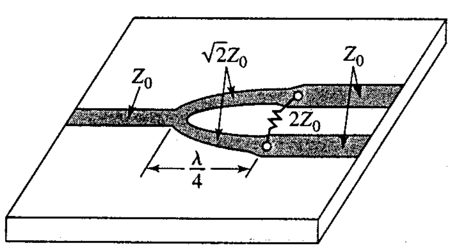
1. Purpose

The purpose of this experiment is to explore the properties of microstrip T-junctions and to design, build and characterize (i.e. test) a 3dB Wilkinson power divider centered at 1GHz. The experiment consists of two parts. In part-I the divider will be designed using Puff. In part II, the designed circuit will be constructed, and characterized using a Scalar Network Analyzer and a Sweep Generator.

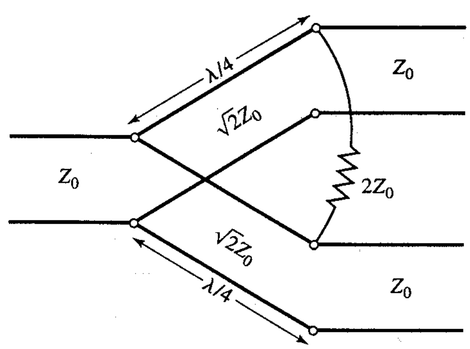
2. Overview

A power divider is a very useful device in microwave engineering. As you may imagine a 3dB power divider is a 3-port network that equally splits the input power between the two output ports. Several 3dB power dividers can be cascaded in a binary tree topology in order to create more complex distribution networks. Obviously, a power divider can also act as a power combiner by merely reversing the role of the input and output ports. In practice, such power dividers/combiners are used in a variety of applications including power amplifiers, broadband mixers and antenna array distribution networks.

Perhaps the most popular power divider in microstrip technology is the Wilkinson power divider. The layout of a 3dB Wilkinson power divider is shown below:



(a)



(b)

Figure 1

As shown in Fig. 1, the divider output fingers need to have a specific length and a given characteristic impedance. The design requirements for a good 3dB power divider are (a) equal power split between the output ports (b) matched ports and (c) good isolation between the output ports. To understand the importance of the good isolation between the output ports, imagine that the input power is to be equally split between two transistor amplifiers. Poor isolation between the output ports would mean that any reflections from one transistor will end up at the input of the other transistor with undesirable consequences.

Looking at the layout of the Wilkinson divider you may wonder about the purpose of the lossy resistor connecting the two output fingers! A hint for understanding the role of the resistor is the fact that a reciprocal and losses 3-port network cannot be matched at all 3 ports simultaneously. An ideal 3dB Wilkinson power divider has the following scattering parameters (input port = port 1) :

$$S_{11} = S_{22} = S_{33} = \mathbf{0}$$
$$S_{21} = S_{31} = \mathbf{3dB}$$
$$S_{23} = \mathbf{0}$$

For a full derivation of the scattering matrix for a Wilkinson power divider in microstrip you may consult your textbook.

Part I

3.1 Wilkinson Power Divider Layout and Design

The layout of the Wilkinson microstrip power divider to be constructed in this experiment is shown below:

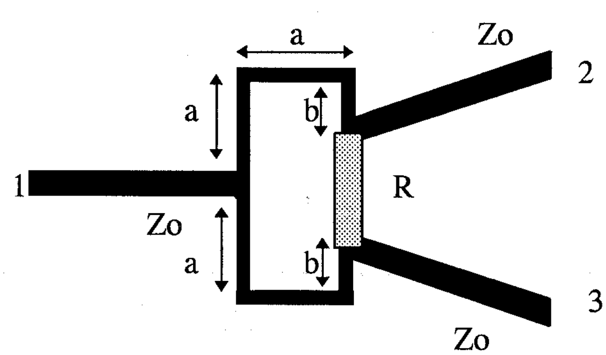


Figure 2

Based on the above layout and the general diagram of Figure 1, design your Wilkinson divider using Puff at 1GHz. The I/O lines are at an impedance level of $Z_o = \mathbf{50\Omega}$. The substrate has a relative permittivity of $\varepsilon_r = \mathbf{4.0}$ and a thickness **h=1.6mm.** You should design the device so that the length **a** in Figure 2 corresponds to a phase shift of 35-degrees.

Determine :

The width for the I/O lines.
The lengths **a,b** and their corresponding width.
The value of the resistor **R**.

3.2 Simulation Experiments With Puff

(a) Verify with Puff the expected values of the S-parameters at the design frequency of 1 GHz.
(b) Repeat your simulations for the S-parameters of the remaining T-junction obtained when the resistor **R** is removed.
(c) Deduce the effect of the resistor R on the scattering parameters of the Wilkinson power divider.
(d) Using hand calculations try to derive the S-parameters of the divider with and without the resistor **R.**

Construct the layout of your design on the provided PC board.

Part-II:

4.1 Characterization of the Wilkinson Power Divider

1. Start by testing the S-parameters of the T-junction (i.e. without the resistor **R)** using the scalar network analyzer. Refering to Figure 1, test S_{11}, S_{22}, S_{33} for matching, the power division S_{21}, S_{31} and the achieved isolation between the output ports S_{23}. Since the scalar network analyzer cannot test more than 2-ports at a time, use the provided **50Ω** BNC loads for terminating the third port.

2. Solder the resistor **R** in place as shown in Figure 2. Repeat the above measurements and record any differences that you may observe between the two sets of measurements.

4.2 Discussion

Compare your measurements with the Puff predictions for the values of the S-parameters of the divider with and without the resistor **R.** Try to explain any discrepancies between the predicted and measured S-parameters.