Design Project #2: *Coupled Line Couplers*

PROJECT SCOPE

Design a **coupled-line coupler** with the following specifications:

Number of sections	5
Center frequency	3 GHz
Coupling	12 dB
Port impedance	50 Ω
Frequency response	Maximally Flat

PROJECT TASKS:

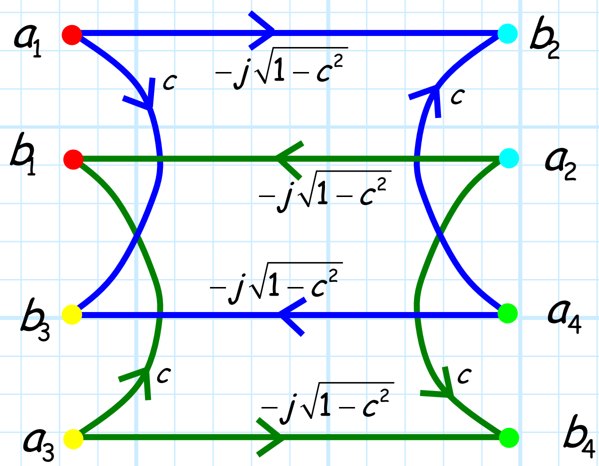
1) Determine the **odd** and **even** mode impedances for each of the **5** sections. Implement this design in ADS.

2) Plot $|S_{11}|^2$, $|S_{21}|^2$, $|S_{31}|^2$ and $|S_{41}|^2$ (in **decibels**) from 0 to 6 GHz, using a vertical scale from -50 dB to 0 dB.

Q1: *Do these results indicate that your design is correct? Explain **why** you think so. Give **specific numerical** examples from each plot.*

3) Use the markers to determine the **bandwidth** of your design, given that the **coupling** must be numerically less than **15 dB** to satisfy specifications(i.e., a 3 dB bandwidth).

4) Draw an **exact** signal flow graph of **this** (4-port) directional coupler. In other words, a signal flow graph of the form below, where *c* is the specific **coupling coefficient** of **this** coupler at the design frequency.



5) Reduce this signal flow graph for the case where ports 2, 3, and 4 are terminated in **matched loads** ($\Gamma_{L2} = \Gamma_{L3} = \Gamma_{L4} = 0$), and determine in **decibels** the numeric values of $|S_{11}|^2$, $|S_{21}|^2$, $|S_{31}|^2$ and $|S_{41}|^2$, at the **design frequency**.

Q2: *Do these values* ***precisely match*** *those provided by the ADS analysis?* ***Why*** *or* ***why not?***

6) Now "attach" a **short** circuit ($\Gamma_{L4} = -1$) to **port 4** of the coupler **signal flow graph** (with ports 2 and 3 again terminated in matched loads). Reduce this graph and determine in **decibels** the numeric values of $|S_{11}|^2$, $|S_{21}|^2$, $|S_{31}|^2$, at the **design frequency**.

7) Likewise place a **short circuit** on port 4 of your ADS design—you now have a 3-port device! Replot $|S_{11}|^2$, $|S_{21}|^2$, $|S_{31}|^2$ (in dB) from 0 to 6 GHz, using the same vertical scale as before. Note you should **not** plot $|S_{41}|^2$!

Q3: *How do these new results* ***compare*** *to the case where port 4 is terminated in a matched load (i.e., tasks 2 and 5)? Use your knowledge of the physical behavior of coupled-line couplers—including any physical insight provided by the signal flow graph of task 6—to explain* ***why*** *you get this result.* ***What physically happens*** *to a wave incident on port 1, once it is inside the coupler?*

8) Now "attach" a **short** circuit ($\Gamma_{L4} = -1$) to **port 2** of the coupler **signal flow graph** (with ports 2 and 4 terminated in matched loads). Reduce this graph and determine in **decibels** the numeric values of $|S_{11}|^2$, $|S_{31}|^2$, $|S_{41}|^2$, at the **design frequency**.

9) Likewise place a **short circuit** on port 2 of your ADS design—you now have a 3-port device! Replot $|S_{11}|^2$, $|S_{31}|^2$, $|S_{41}|^2$ (in dB) from 0 to 6 GHz, using the same vertical scale as before. Note you should **not** plot $|S_{21}|^2$!

Q4: *How do these new results* ***compare*** *to the case where port 2 is terminated in a matched load (i.e., tasks 2 and 5)? Use your knowledge of the physical behavior of coupled-line couplers—including any physical insight provided by the signal flow graph of task 8—to explain* ***why*** *you get this result.* ***What physically happens*** *to a wave incident on port 1, once it is inside the coupler?*

ADS INFORMATION

1. You will need to use **four** ADS "Term" elements (one for each coupler port).

2. You will need **five** "CLIN" elements, which are the ideal coupled transmission lines found in the "TLines-Ideal" element category.

3. The easiest way to attach a **short circuit** to a coupler port is to simply change the characteristic impedance of the "Term" element at that port (but only at that port!) to a value of $Z_0 = 0.1\Omega$ (0.1 ohm is as small as ADS will let you make Z_0). This of course is not exactly a short circuit, but it's pretty **close**!

Of course, you could likewise remove the "Term" element from a coupler port and then connect that port directly to a ground terminal. But, if you remove the "Term" element from a port, then ADS will renumber the remaining ports. For example, if your remove the "Term" element from port 2 and replace it with a short to ground (e.g., task 9), then the terminal at port three will be renamed port 2, and the terminal at port 4 will be renamed as port 3.

This in itself is not particularly bad, but you must make sure you are comparing "apples to apples" when comparing the results of task 2 to the results of task 9. For example, the values of task 9 that are labeled $|S_{21}|$ are actually $|S_{31}|$, if the "Term" element at port 2 is removed.

Project Report

The same as project 1.

Project Grading

The same as project 1.