HA # 5

Problem-1

Assignment Scope

Design a coupled-line coupler with the following specifications:

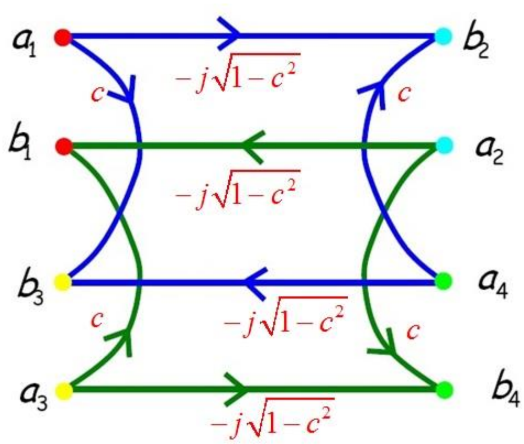
Number of sections: 5
Center Frequency: 3 GHz
Coupling: 12 dB
Port Impedance: 50Ω
Frequency Response: Maximally Flat

Assignment 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 dB from 0 to 6GHz, using a vertical scale from -50dB to 0dB.

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 value 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 $|S_{11}|^2$, $|S_{21}|^2$, and $|S_{31}|^2$, 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 $|S_{11}|^2$, $|S_{21}|^2$, and $|S_{31}|^2$ (in dB) from 0 to 6GHz, 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 ($\Gamma_{L2} = -1$) to **port-2** of the coupler **signal flow graph** (with ports 3 and 4 terminated in matched loads). Reduce this graph and determine **in decibels** the numeric values of $|S_{11}|^2$, $|S_{31}|^2$, and $|S_{41}|^2$, 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 $|S_{11}|^2$, $|S_{31}|^2$, and $|S_{41}|^2$ (in dB) from 0 to 6GHz, 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?

Q5: Verify the results in EM simulation and comment on the anomaly (if any!) between the results obtained in schematic, and EM simulation.

Assignment Report (Hard Copy – No email)

1. You basically should view the project report as a **lab report**. **Show how** and why the design parameters were determined. "Construct" the circuits in ADS, and then "measure" the

circuits in ADS. Provide the results of these "measurements" in report. **Discuss** your results, and include the answers to the questions posed earlier (put particular emphasis on the answers to questions with the word "**why"**!).

2. Assume your audience is a **knowledgeable microwave engineer** (i.e., **me**!) Thus, you do not need to provide a long (or even short) discussion about what coupled-line couplers are, or why they are so great, or what their general characteristics are, or a multiple reflection analysis of them, etc. I assume you know the material that has been presented in class. What I don't know is if you can take that material and: 1) **design** a coupled-line coupler that works and; 2) explain the behavior of that design when analyzed on ADS.
3. Thus, I am looking for **quality** over quantity. I do not want this to be a massive report requiring tons of writing. Make the points that you want to make in a clear and complete manner, and then **stop** writing! However, do not confuse the word "**why**" with the word **"what**". I have frequently asked you to explain **why** an observation is true, or **why** something happened, or **why** an observation makes sense. Students often instead just tell me **what** is observed, or **what** happened when something was changed—do **not** do this!
4. You must describe the synthesis process you used to design the coupled-line coupler. I require that your **computations** be presented in your report. I must be able to see **where** the error was made if your results or design are erroneous. I want to see all the **general equations** used, and then the **values** used for the **variables** in the equations, and **then** the numeric results of the equation.
5. Moreover, the report should flow from one section to another as one continuous document. Often I receive a set of independent pieces, stacked together and called a report—do not do this! To this end, figures, tables, and appendices should be labeled, number, and titled and referred to in the report.

Problem-2

Design a single-band (2GHz) Wilkinson Power Divider (port-1 is input, 60% power exits port-2, and 40% power exits port-3). Obtain the EM results and develop a layout that can be fabricated on FR4 board.

Problem-3

Using ADS, design a branchline hybrid coupler using 100Ω microstrip on 32-mil RO4003C for a center frequency of 2.5GHz. Include the effects of copper and substrate losses.