ECET 3410 Lab 5: DETERMINING AN UNKNOWN IMPEDANCE

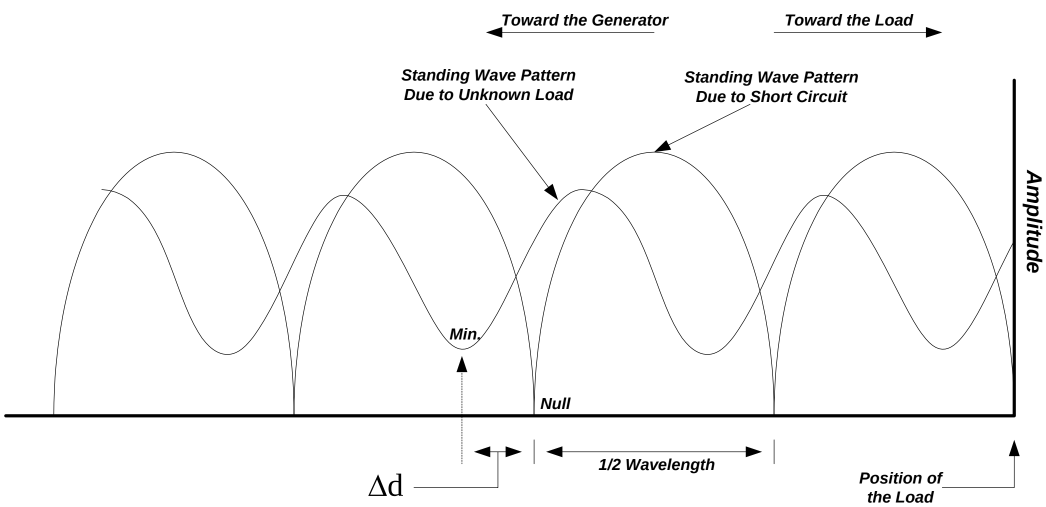
(Simulation-based Version)

INTRODUCTION/THEORY

In this exercise, you will use your knowledge of the nature of standing waves and your slotted line measurement skills developed in Lab 3 to determine the impedance of a line mistermination. A mistermination occurs whenever a line is terminated with a load impedance that is unequal in value to the line's characteristic impedance.

The technique you will use is often referred to as the *short-circuit minima shift method*. In order to establish a phase reference location for the line termination, you will temporarily terminate the slotted line section with a "short-circuit". The "short-circuit" must be attached so that the actual "short-circuit" is located the same distance from the end of the slotted line as the terminating impedance. Locating a voltage minimum for both the "short-circuit" and the mistermination will allow you to determine the phase angle associated with the mistermination reflection coefficient.

The figure below shows the standing wave patterns for both a "short-circuit" and a load. Depending on the load impedance, the load minima may shift towards the generator or towards the load. The magnitude of the mistermination reflection coefficient is determined from the VSWR reading taken when the slotted line is misterminated. Knowing the magnitude and angle of the reflection coefficient, you can determine the normalized load impedance. Multiplying the normalized impedance by the characteristic impedance of the line gives you the impedance of the mistermination.



The load impedance can be determined two ways, either mathematically or through the use of the Smith Chart. For this experiment, you will utilize both of these methods and compare the results.

The theoretical procedures for both the calculation based and the Smith Chart based solutions are presented on the next page. Note that, although you will perform both of these solution methods, the solutions themselves require the same set of slotted-line measurements.

The requirements for the experimental procedure as well as the report guidelines are on the pages following the introduction/theory section.

INTRODUCTION/THEORY (continued)

Mathematical Solution:

1. Place a "short-circuit" on the termination-end of the slotted line and determine the location of two adjacent minima (Nulls).

2. Connect the load to the slotted line and measure the SWR and the position of the minimum in the standing wave pattern that occurs between the two minima of step 1.

3. Compute the unknown impedance using the formula below:

$$Z_L = Z_o \cdot \frac{1 - j \cdot SWR \cdot \tan(X)}{SWR - j \cdot \tan(X)}$$

where: $$X = \frac{(180°) \cdot (\pm \Delta d)}{\frac{1}{2} \cdot \lambda_g}$$

Δd is the displacement distance of the load minimum a short circuit Null in cm.
Δd is ***positive*** when the Null is closer to the load than the Minimum (as above)
Δd is ***negative*** when the Null is further from the load than the Minimum
$\frac{1}{2}\lambda_g$ is one-half of a wavelength (same as the distance between adjacent Nulls)

Smith Chart Solution: [An example of this technique can be found in the textbook (Example 5-1)]

1. Place a "short-circuit" on the termination-end of the slotted line and determine the location of two adjacent voltage minima (nulls).

2. Connect the load to the slotted line and measure the SWR and the position of the minimum in the standing wave pattern that occurs between the two voltage nulls of step 1.

3. Plot the constant $|\Gamma|$ or constant SWR circle on the Smith chart.

4. Mark the intersection of the constant SWR circle with the left side of the purely "real" impedance axis on the Smith Chart. This is the location of $\overline{Z}_{L\,\min}$ (note that $\overline{Z}_{L\,\min}$ is the impedance $Z_{L\,\min}$ normalized to Z_O), which has a phase reference ($\phi_\Gamma = 180°$) since the voltage is at a minimum and thus the reflection coefficient is at its negative maximum.

5. Move a distance of $\boldsymbol{\Delta\lambda}$ from $\overline{Z}_{L\,\min}$ along the constant VSWR circle to an adjacent "short-circuit" null. Remember that the "short-circuit" nulls identify the location of the electrical end of the line and establish the phase of Γ_L. Although you may use either null location as long as you travel in the appropriate direction (toward load or toward generator), choose the null closest to the load. The distance you rotate should be the difference between the location of the Null that was measured in step 1 and the minimum location measured in step 2. This distance must be normalized to the guide wavelength for use on the Smith Chart as follows:

   Distance = (Null step 1 – minimum step 2) / (λ_g) = $\boldsymbol{\Delta\lambda}$ on Smith Chart towards load

6. Determine $\overline{Z}_L$ from the Smith Chart and multiply by Z_o to find Z_L.

EXPERIMENTAL PROCEDURE

INSTRUMENTATION

This experiment will be performed by utilizing the Slotted-Line Simulator Software (S-Line) that is available for download on the "Course Information" webpage. This software is designed to function in the same manner as the slotted-line equipment used during experiment three.

You will be assigned an "unknown load" number by your instructor for use during this lab.

MEASUREMENTS (Simulation-based)

Using the S-Line simulation software, perform an slotted-line analysis in order to determine the impedance value of your "unknown load", both at 600MHz and at 800MHz, using the techniques defined in the Information/Theory section on the previous page.

1. Execute the S-Line software.

2. **Set** the **frequency** to **600MHz**.

3. **Choose** the ***WN3*** (short-circuit) terminator.

4. Determine the **location** of **two adjacent** voltage **minima** (Nulls) with the WN3 terminator in place. Note that you performed similar measurements during experiment three.

5. Replace the WN3 with your specified **unknown load**.

6. With your load in place, determine the **location** of the **voltage minimum** that exists <u>between the two minima located during step 4</u>.

7. **Measure** the **VSWR** on the line when it is terminated with your "unknown load".

   To measure the VSWR on the line:
   - **Move the probe to** the location of a **voltage maxima** and **click** the "***Store Reference***" button to normalize the scale on the VSWR meter to that voltage magnitude. After clicking "Store Reference", the simulator should show an SWR value of 1.
   - M**ove the probe** to the location of an **adjacent minima** and **record the SWR value**.

8. **Set** the **frequency** to **800MHz** and **repeat steps 3-7**.

CALCULATIONS

1. Calculate the wavelength (λ_g) of the wave on the line based upon your measured "null" locations that occurred when the line was terminated with the WN-3 load.

2. Calculate the impedance value of your "unknown load", Z_L, as described in the theory section of this procedure. You must perform this calculation for ***both*** of the specified frequencies.

SMITH CHART OPERATIONS

1. Calculate the impedance value of your "unknown load", Z_L, using the Smith Chart operations described in the theory section of this procedure. You must perform this calculation for ***both*** of the specified frequencies.

REPORT GUIDELINES

You may submit this report as a traditional paper-based report since it requires the use of Smith Charts. However, all pages that are not actual Smith Charts must be electronically created in a format similar to that required of the electronically-submitted reports.

Your report must contain (*in the exact order* *specified below*):

1. A **cover page** showing your name, lab number and title, your lab section, and the date of submission. Note that you may present this required information at the top of the first page of the written report as shown in the same memo-style report that is available online.

2. A brief **introductory statement** describing performed experiment as well as the contents of the laboratory report.

3. A **single data table** showing ***all*** of the measured values that you obtained while utilizing the S-Line software at both frequencies.

4. A "***Calculation Section***" showing the **complete** calculation-based solution method that you utilized to obtain the value of your load impedance at 600MHz. *The results of your 800MHz calculation may be summarized and* ***presented in a single table*** *along with your 600MHz calculated results.* You do not need to type-out the entire 800MHz solution provided the same methodology was utilized at both frequencies.

5. A "***Smith Chart Section***" containing the **complete** Smith Chart based solutions. Each frequency solution must be performed on a separate Smith Chart. The charts must be explicitly labeled such that every procedural operation is clearly shown on the charts including rotational direction/distance. You must label and specify the numerical value of any point plotted on or read from the Smith Charts along with any other data obtained directly from the Smith Charts during the solution procedure.

6. A **single results table** showing and comparing (by relative difference) the results obtained by utilizing ***both*** solution methodologies at both of the required frequencies. Only compare the results of one solution method to the other at each frequency. ***Do not*** directly compare the 600MHz results to the 800MHz results.

7. A brief **discussion** of the results as well as both the merits and the limitations of each technique.

NOTE: RECORD AND SAVE BOTH OF YOUR FINAL IMPEDANCE VALUES AS THEY WILL BE REQUIRED DURING THE COMPLETION OF LAB EXPERIMENT #6.

Load Assignments – Fall 2019

Load#	Student
1	Abiola, Oluwaseun
2	Almanza, Eric
3	Ashu, Joseph
4	Berete, Sere
5	Bethea, Jalen
6	Cameron, John
7	Campos, Alex
8	Copeland, John
9	Cutshall, Jonathan
10	Deju, Wolde
11	Dubberly, Michael
12	Dudman, Austin
13	Edehomon, Jonathan
14	Ford, Levi
15	Funkeso, Melese
16	Hampton, Kevin
17	Hayes, Red
18	Hicks, Tyler
19	Holmes, Byron
20	Jordan, Sierra
21	Kloeblen, Trace
22	Le, Tuu Thanh
23	Martin, Desroy
24	McGinnis, Doug
25	Muhammad, Najim
26	Oden, Brooke
27	Pike, Tiffani
28	Porteous-Punch, Daquan
29	Portillo-Rodriguez, Jorge
30	Rey, Kyle
31	Reyes, Marvin
32	Robinson, Brian
33	Slough, Joshua
34	Thomas, Latravious
35	Toe, Paterne
36	Tran, Dennis
37	Varghese, Julien
38	Weiss, Christopher
39	Wilde, Randy
40	Wilson, Jarmar