Laboratory Assignment: S-Parameter Measurement

Names: ______________________ ______________________

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Objective

This laboratory assignment explores the measurement of s-parameters using the Network Analyzer in the microwave laboratory. The exercises described here will help familiarize or refresh students with s-parameter measurement, one of the most important aspects of microwave engineering.

Preparation

Before coming to the laboratory to perform this assignment, the students should prepare the following:

- Complete the laboratory assignment for using the spectrum analyzer. Although the network analyzer's function and interfaces are different than the spectrum analyzer, they share many similar operational details. Becoming familiar with frequency, sweep, and resolution parameters will help significantly in this lab assignment.
- Bring a USB thumb drive to the laboratory for capturing network analyzer output.

Write-Up

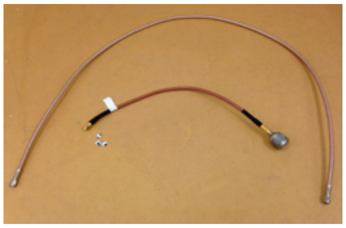
The students performing this laboratory do *not* need to prepare a stand-alone laboratory report for this assignment. All work may be neatly shown on this document, with any supplemental answers to questions attached. Be sure to include all group member names on this sheet.

Equipment Guide

network analyzer

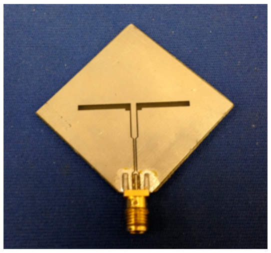
connectors/adapters

calibration kit



assorted coaxial cables

mystery sample jars



5.8 GHz slot antenna

monopole antenna

Procedure

Part I: Return Loss Measurement

1. Turn on the network analyzer and allow several minutes for the equipment to initialize and warm-up. Attach the grounding strap to your wrist. Place an N-type-to-SMA adapter on port 1 of the network analyzer.
2. In your cupboard should be an 860 MHz monopole antenna. Attach this to Port 1 for an s_{11} measurement.
3. Change the sweep to cover the bands 500 MHz through 8 GHz. Measure the return loss at the start of the long coaxial cable that connects the monopole.

Capture the screen output and attach a labeled graph to this lab document. What is the physical explanation for all the periodic nulls across this wide bandwidth?

Use the spacing between the nulls to estimate the value of relative permittivity used for the coaxial cable. (Hint: you will need a tape measure. There should be one in a station cabinet underneath.)

4. For antennas, return loss is measured as $-10 \log_{10}|s_{11}|$. Typically, more return loss is *better* as this indicate smaller reflections. This power must be going *somewhere*; if the antenna is an efficient radiator, then the power must be transmitted into space. That is not guaranteed, however, since the return loss does not tell us anything about the antenna's radiation efficiency. For example, some power transmitted from cable to antenna may be lost as Ohmic heating on the antenna's metallic surface and nearby materials. However, measurement of a low return loss is the first step in verifying proper antenna operation over a band.

Discounting the periodic nulls, what is the *exact* resonant frequency of this antenna (the minimum return loss)? If we require 10 dB return loss for adequate radiation, estimate the usable bandwidth for this antenna.

5. Measure the broadband return loss for one of the 6 GHz antennas (small patch or slot with SMA connector) connected directly to the network analyzer with an adapter.

Capture the screen output and attach a labeled graph to this lab document. Based on the 10-dB return loss criterion, what is the center frequency and bandwidth for the chosen antenna?

6. Add an SMA cable of your choice between your antenna and the analyzer and repeat the measurement. After recording a broadband capture, use the calibration kit to reference the measurement to the end of the cable. Repeat the capture.

Capture the screen outputs for the calibrated and uncalibrated s_{11} measurements and attach the labeled graphs to this lab document. Do you see a similar phenomenon to the capture in part (2) for the uncalibrated measurement? Were you able to remove this with the 1-port calibration.

Part II: Insertion Loss

1. Any good microwave engineer will measure the return loss of cables before using them in a scientific measurement.

Capture, graph, and attach the output of the insertion loss of one cable. Graph this data on a semi-log scale (dB insertion loss on the vertical scale, linear frequency on the horizontal scale). How much loss (in dB/decade of frequency) do the long SMA cables experience?

2. Now attach the two 6 GHz slot antennas (or two 6 GHz patch antennas) directly to ports 1 and 2 of the network analyzer. Use only adapters – no cables. In the final configuration, the two antennas should be facing one another with just 6 inches separating them. Set the network analyzer to continuously sweep the network analyzer across the 5-6.5 GHz bands.

   Place "Mystery Jar A" in between the antennas and note the change in s21 parameters. Record the graph. Repeat this for "Mystery Jar B". Do *not* open the jar lids – they are superglued closed.

Capture, graph, and attach the labeled output of the s21 measurement from the analyzer for the mystery jars. If you are told that one of the jars is filled with water, while the other is filled with nearly pure isopropyl alcohol, which letter corresponds to which liquid? Explain your reasoning. (This may require some offline research.)

Name 4 physical factors that complicate a direct measurement of medium permittivity and/or conductivity of the substance in the jars.