# EE 435

# S-Parameter Measurement Using the Vector Voltmeter

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In this lab you will measure the S-parameters of several multi-port devices using the vector voltmeter. Measurements will be done both manually and under computer control. The HPIB interface allows easy stepped frequency measurements of S-parameters, letting you investigate the properties of microwave networks over a wide range of frequencies.

NOTE: BE SURE THAT YOU AND YOUR LAB PARTNER ARE GROUNDED THROUGH WRIST-STRAP CONNECTORS. THE VECTOR VOLTMETER INPUT CIRCUITS ARE STATIC SENSITIVE!

## Procedure

Be sure to bring a floppy disk to each ECE 435 lab. You will need this to store the data you take during lab.

Students should split into four groups of two (or occasionally three). Since there are only six directional couplers, two groups will do the $S_{11}$ and $S_{22}$ measurements while the other groups do the $S_{12}$ and $S_{21}$ measurements.

A) Manual measurements

Refer to the included section "S-parameter Measurement Technique." Measure $S_{11}$, $S_{12}$, $S_{21}$, and $S_{22}$ for the 20-cm airline at 1.0 GHz. Perform the necessary calibration calculations first by hand, and then repeat using the automatic calibration feature (see page from HP manual). Compare the results to make sure you have performed the calculations correctly.

B) Automatic measurements

The Visual BASIC program **VS.EXE** controls the HP 8657B signal generator and the HP 8508A vector voltmeter, allowing automated measurements of the S-parameters to be easily made. Turn on your computer. Log on as **student** with the password **student**. You will have access to all areas of the computer, but can only write to the directory **c:\temp** and to the floppy disk. If you save files to the directory **c:\temp** and want to keep them, you must transfer the data to disk since the **c:\temp** directory will be regularly purged.

Click on the **VS** icon to start the S-parameter program. The program is menu driven and should be self-explanatory.

Measure $S_{11}$, $S_{12}$, $S_{21}$ and $S_{22}$ for the 20 cm airline through the range of frequencies from 100 to 2000 MHz, at every 50 MHz. For each S-parameter, print out a plot of the complex parameters as functions of frequency, and save the files to your floppy disk. If you forget to make a plot, you can always recall your file. Also, record the numerical values of the S-parameters at 100, 1000 and 2000 MHz.

Measure $S_{21}$ and $S_{11}$ for the 20 dB attenuator, stepping from 100 MHz to 2000 MHz at every 50 MHz. Make a plot each S-parameter vs. frequency. Record the values of the S-parameters at 100 MHz and 2000 MHz. Save the files to your floppy.

Measure $S_{21}$ and $S_{11}$ for the low-pass filter, stepping from 100 MHz to 2000 MHz at every 50 MHz. Make a plot of each S-parameter vs. frequency. Record the values of the S-parameters at 100 MHz and 2000 MHz. Save the files to your floppy.

Measure $S_{21}$, $S_{12}$ and $S_{11}$ for the circulator, stepping from 100 MHz to 2000 MHz at every 50 MHz. Make a plot of each S-parameter vs. frequency. Record the values of the S-parameters at 100 MHz and 2000 MHz. Save the files to your floppy. Note that there is only one circulator, so you will have to share. Also note that you may have to use a strange combination of adapters to attach the circulator. Remember that where you attach the calibration short effects the reference plane of the S-parameters.

<u>Report</u>

1. Write down the S-parameter matrix for the 20 cm airline at 1000 MHz, first from the manual measurements and then from the automatic measurements. Comment. Using the S-parameter matrix, determine whether the airline is a reciprocal device and whether it is a lossy device.

2. Using the phase plots from the swept-frequency measurements of the airline, determine the distance in centimeters between the two ports of the airline (hint: look at the slope of the phase curve). Does this match the physical length?

3. Write down the S-parameter matrix for the attenuator at 1000 MHz, assuming it is a reciprocal device. From the matrix determine if the attenuator is a lossy device. Explain physically the magnitude and phase plots of $S_{21}$. Examine the magnitude plot of $S_{11}$. Does this plot show a behavior you would want in an attenuator?

4. Examine the plots for the low-pass filter. Comment on the behavior of the filter. How well does it work?

5. Write down the S-parameter matrix for the circulator at 2000 MHz assuming that the device is physically symmetric: $S_{11}=S_{22}=S_{33}$, $S_{12}=S_{23}=S_{31}$, $S_{21}=S_{32}=S_{13}$. Is this a reciprocal device? Does it act like a circulator should? From the plots of the S-parameters, determine at what frequency the circulator begins to perform as it should.

## EQUIPMENT LIST

## VECTOR VOLTMETER MEASUREMENT OF S-PARAMETERS

| | |
|---|---|
| 1 | HP 8657B signal generator |
| 1 | HP 8508A vector voltmeter with 85082A input module |
| 2 | HP 778D dual directional couplers |
| 1 | N(F)-BNC(F) adapter |
| 6 | N(M)-BNC(F) adapters |
| 4 | N(M) 50 $\Omega$ terminations |
| 2 | N(F)-N(F) adapters |
| 1 | N(M)-N(M) adapter |
| 1 | GR 50 $\Omega$ termination |
| 1 | N(M)-GR adapter |
| 1 | N(F)-GR adapter |
| 1 | GR WN short circuit termination |
| 1 | N(M) short circuit termination |
| 1 | GR 20 cm airline |
| 1 | GR 20 dB attenuator |
| 1 | GR 874-F1000 low-pass filter |
| 1 | EK1238 circulator (from research lab) |
| 2 | grounding wrist straps |
| | BNC cables as needed |

NOTES:

1. Type N cables can be substituted for BNC cables with the elimination of several N-BNC adapters.

2. There will not be sufficient components for four complete stations. Students will have to share several items.