Objectives

1. Foster the ability to learn new measurement techniques and the operation of sophisticated test equipment independently.

2. Introduce vector network analysis of systems operating at high frequencies (above 1000MHz).

3. Reinforce and illustrate certain theoretical principles.

Rules

You must obey certain special rules in the use of the network analyzer. The analyzer and its accessories (calibration kit and measurement cables) are VERY expensive and VERY sensitive. Proper behavior in the lab and appropriate care in the use of the equipment is essential. Do NOT violate the trust that is placed in you when are provided access to this equipment.

1. The network analyzer and accessories are located on a lab table in the S*ProCom² Lab in 701CS. You are being given access to the room for this lab experiment, and must obey the normal rules for being in a lab.

2. You will notice the network analyzer is on an anti-static mat. The analyzer, the measurement cables, and any device being measured must be on the mat, and the mat must be connected to the ground of the instrument. Anyone who touches the analyzer or anything connected to it must be careful to touch the ground or wear an anti-static wriststrap (which you can get from the EE lab technicians) to protect the instrument. You may NOT move the instrument somewhere else, or remove documentation or accessories from the lab area.

3. When connecting and disconnecting components, remember to turn ONLY the hex nuts. You can damage the components of the calibration kit or the cables if you don’t follow this instruction. For purposes of the measurements you will be performing, hand-tight should be sufficient. You can also use a wrench if you like. Yes, if you do not make the connections tight enough, they can get loose and lead to poor measurements. However, if you overtighten, you could damage the components (by wearing down the threads- yes they are that sensitive).

4. ABSOLUTELY no eating or drinking in the vicinity of the instrument. No sticky fingers either.
5. You are going to be measuring passive devices only. There is a reason for this. If you are interested in trying to measure an active device, you MUST get additional hands-on training with the instrument (ask Dino Melendez, for example) before you will be trusted to do that.

Assignment

You may work individually or in pairs (not groups larger than two). I only need one report per group. Each person, however, is responsible for being able to use the network analyzer properly, so if you work with a partner, you must be sure to get enough hands-on practice yourself to get comfortable with the instrument. I will be meeting with each of you individually for you to demonstrate that you know how to use the instrument, and know how to INTERPRET the measurements you are making (i.e., relating theory to practice). I will let you bring a short set of notes to the meeting- a few bullet points perhaps; I won’t let you rifle through pages of stuff.

First I am outlining the general procedure. Below I will give you the PARTICULAR measurements I want you to make, and the content of the report you will submit.

Preparation:

Prepare the device to be measured, and cables. Give thought to adapters and connectors you will use.

Set the frequency range for the measurements you will be taking, using the buttons on the Stimulus section of the front panel.

Calibrate the instrument for two-port measurements. Remember FIRST to specify the Cal Kit (the code is stamped on the cal kit box). Do reflection and through calibration, but skip isolation.

Figure out how to obtain different display formats (log-magnitude, phase, Smith chart, etc.) and measurement formats (e.g., mag/phase vs. R+jX on Smith chart). Also learn how to place and read markers, including multiple markers. There are a number of ways to navigate through menus and enter data.

The network analyzer can only be connected to two ports at the same time; additional ports on the device you are measuring should be broadband terminated. When you are measuring $S_{11}$ or $S_{22}$, you should still keep the device connected to the two input ports of the analyzer, and trust the analyzer to provide the proper termination internally.

Learn how to put multiple displays on one screen. Also learn how to put data in the memory trace. You can use this, for example, to subtract a memory trace from the measured data (e.g., to compute amplitude and phase imbalance).

Learn how to store “snapshots” of the display screen as images on a memory stick you can attach to the USB port of the instrument; ideally, you will add titles or other notations to the snapshots. The instrument is NOT connected to the internet, and I do not want it connected to the internet.

Measurement:

Perform the complete set of measurements I outline below. You can report results in tables. It is probably easiest for you to record values by hand, but I want you to type up the results. Feel free to use the analyzer itself to perform computations (e.g., using markers to read values in dB). The number of significant figures you should report is one more than as they
appear in the spec sheets for the device, or less if the instrument gives you fewer significant figures (if some digits do not appear “stable” then don’t include them as significant figures). Include representative snapshots- say one example of a Smith chart to measure a reflection coefficient, one example of a magnitude and phase measurement (say both on one screen capture), and one or two examples where you use the data memory feature (e.g., to measure amplitude or phase imbalance). I don’t need a screen capture of EVERY measurement you perform.

**Measurement: MiniCircuits ZAPDQ-2-S**

The ZAPDQ-2-S is a two-way power splitter, with nominal operating range $1.0 - 2.0 \text{GHz}$, with SMA connectors. It is “in theory” a lossless reciprocal three-port. The spec sheet has been provided to you.

In theory, the input power is equally split to the two outputs; the “idealized model” of the power splitter would yield exactly $3 \text{dB}$ insertion loss for each output, but in reality you will note the insertion loss is about $1 \text{dB}$ more than this “ideal.” Even with this additional loss, ideally there should be equal power emerging at the two outputs; the amplitude imbalance measures how closely this ideal is achieved. Similarly, there is ideally a $90^\circ$ phase difference; deviation from this is phase imbalance.

Calibrate the network analyzer over the range $0.8 - 2.2 \text{GHz}$. This is intentionally beyond the nominal operating range.

When you provide the snapshots, the traces shown should be over the full measurement range. Otherwise, I want each of the measurements listed below performed at 5 frequencies: $0.85, 1.1, 1.5, 1.9, 2.15 \text{GHz}$. The first and last are outside the nominal range; I want you to examine the values here, and see how much the specifications are “violated.” The other three frequencies are in the “low”, “middle” and “high” end of operation of the device.

Measure the magnitude of each of the 9 scattering parameters (in dB), and report the results in a matrix for each of these frequencies. Also write a matrix for the “ideal” device, and matrices obtained from the device specifications (at the three frequencies in the normal range of operation); when the specs indicate a range, or are not given at the exact frequency of your measurement, just report “nominal” values or interpolate from provided specs. Also indicate which of your measurements are outside of specified ranges or tolerances.

You will note the specs report VSWR, not return loss. For purposes of creating the matrix of $|S_{ij}|$ coefficients, convert the specified VSWR values to return loss in dB.

That being said, I also want you to measure VSWR (directly with the instrument- i.e. via marker functions) at each of the ports, at each of the five frequencies, and compare with specs.

You will also note that the specs do not include transmission coefficients in the reverse direction, explicitly. For purposes of creating the “ideal” matrix, assume reciprocity. When you do measurements, I want you to measure $S_{ij}$ and $S_{ji}$ separately; hopefully there will be no difference, but if there is (within the significant figures you are retaining), report that.

Measure the amplitude imbalance, phase imbalance, and isolation at these five frequencies as well, and again compare with specifications. (I want you to use the data/memory feature of the analyzer to do this).

The only commentary that is needed is indicating if measurements are in specs, or, if out of specs, how far out. Also, for measurements outside the nominal frequency range, indicate
how rapidly the device falls out of specs.
Other information that should be provided: the Model number of the network analyzer, the
cal kit, and the device you are measuring; the frequency range of your measurements. Give
me one snapshot showing one of the displays you get using this feature.
Please note that some of the measurement may be difficult to obtain accurately. Obtaining
some results out of specs will not, in and of itself, lower your grade. I am expecting
reasonable quality, not perfection. If you are getting some measurements way off, or a lot
of measurements out of spec, you are probably doing something wrong. Probably the most
difficult thing to obtain correctly is the phase imbalance, between if there is a difference in
path length (i.e., relative position of reference plane) it can cause significant error.