ELC 4383 RF/Microwave Circuits I
Laboratory #1
Frequency and Time Domain Representations

Note: This lab procedure was originally written by Dr. Larry Dunleavy at the University of South Florida and has been modified for use at Baylor University. The original laboratory exercise is copyright 2004 by the University of South Florida and has been used/modified by permission.

Printed Name:_______________________

Lab Partner(s): _____________________________

Please read the reminder on general policies and sign the statement below. Attach this page to your Post-Laboratory report.

General Policies for Completing Laboratory Assignments:

For each laboratory assignment you will also have to complete a Post-Laboratory report. For this report, you are strongly encouraged to collaborate with classmates and discuss the results, but the descriptions and conclusions must be completed individually. You will be graded primarily on the quality of the technical content, <u>not the quantity</u> or style of presentation. Your reports should be neat, accurate and concise (the Summary portion must be less than one page). <u>Laboratory reports are due the week following the laboratory experiment</u>, unless notified otherwise, and should be turned in at the start of the laboratory period. See the syllabus and/or in-class instructions for additional instructions regarding the report format.

This laboratory report represents my own work, completed according to the guidelines described above. I have not improperly used previous semester laboratory reports, or cheated in any other way.

Signed: ______________________________

ELC 4383 RF/Microwave Circuits I - Laboratory #1

Frequency and Time Domain Representations[1]

Laboratory Assignment

The basic setup will consist of 2 vector network analyzers (VNA) to produce sinusoidal waveforms, an oscilloscope to measure in the time domain, and a signal analyzer (SA) to measure in the frequency domain.

Part I: SA Measurement of 300MHz CW signal.

(What you should see: You should be able to display spikes corresponding to the 300MHz fundamental signal and perhaps some harmonics spaced at equal intervals. You will record the frequency and amplitude of these frequency components under various spectrum analyzer settings.)

The test configuration for this part is shown below. This connection will require a DC block to be attached to the SA.

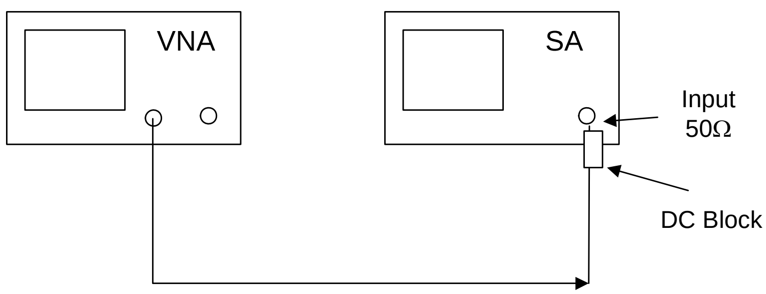

Figure 1: Configuration for frequency domain measurement of VNA CW test signal using a signal analyzer.

1. Turn on the VNA and press PRESET.
2. Connect the VNA to the spectrum analyzer input through a DC block as shown in Figure 1. Set the vector network analyzer to provide a CW signal at 300 MHz with a power of -20 dBm**.** Note that in order to set the SA signal to 300MHz the start and stop frequencies must both be set to 300MHz. Set the SA center frequency to 300MHz and record the frequency and amplitude of each peak visible on the SA screen in Table 1.

[1] Dr. Larry Dunleavy originally developed this laboratory procedure for the University of South Florida WAMI Lab and it was later modified by Dr. Charles Baylis for use at Baylor University.

Table 1. Observed signal peaks with CW 300 MHz signal and full-span frequency display (pre-set)

FREQ. OF PEAK (MHz)	AMPLITUDE OF PEAK (dBm)	COMMENTS

3. Place a marker on the 300MHz signal peak displayed on the SA, explore the effects of varying the SA's internal attenuator settings. Push AMPTD (Amplitude) then push the ATTENUATION soft key. Increase the attenuation from the default value of 10 dB to 20, 30 and 40 dB.

OBSERVATIONS: What effects does varying the attenuator setting have on the displayed marker amplitude value at 300MHz?

What effects does varying the attenuator setting have on any other aspect of the SA display? (You should see some effect on the "noise floor")

4. Set the center frequency of the SA to 300MHz and set the "Span" to 20MHz by pressing the SPAN soft key and entering 20MHz.

5. Use the SA peak search soft key again and re-measure the amplitude of the 300MHz test signal. Record the frequency and amplitude observed. Note that the amplitude should be around -20 dBm. Check the reference level (value of the top of the SA display grid) by pressing the AMPTD soft key and then the reference level soft key. With the reference level set to 0 dBm, the signal maximum should be two divisions below the top of the screen.

Table 1. Observed freq. and amplitude of reference signal after zooming.

FREQ. OF PEAK (MHz)	AMPLITUDE OF PEAK (dBm)	COMMENTS

6. Set the SA's frequency to 600 MHz and SPAN to 20MHz. Use the peak search key again and re-measure the amplitude of the 600MHz 2nd harmonic of the test signal. Record the frequency and amplitude observed. Compare the freq. and amplitude values obtained in parts 5 and 6 with those of part 2.

Table 2. Observed freq. and amplitude of 2nd harmonic of reference signal after zooming.

FREQ. OF PEAK (MHz)	AMPLITUDE OF PEAK (dBm)	COMMENTS

Additional comments on observations:

Part II: SA Measurement of two signals close in frequency.

(What you should see: The ability to clearly identify two signals that are close in frequency as separate signals depends strongly on the measurement settings on the signal analyzer. You will explore the effect of the span and resolution bandwidth settings on this type of measurement. The resolution bandwidth is really the key in this case, but the two settings are linked within the SA.)

The test configuration for this part is shown below. This connection will require two VNA's and a Weinschel power splitter to attach the VNA's to the SA.

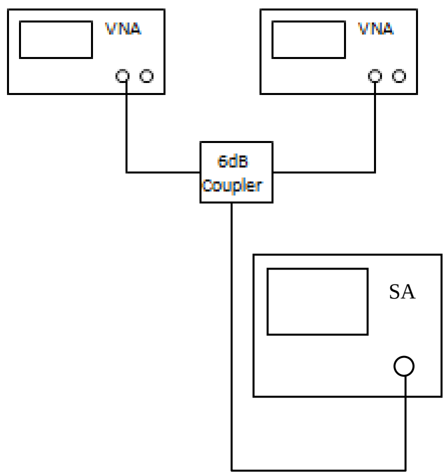

Figure 2: Configuration for frequency domain measurement of two VNA CW test signals using a signal analyzer.

1. Set-up the SA for a 300MHz center frequency and a 20 MHz span. Push FREQUENCY 300 MHz, and SPAN 20MHz. Use a Weinschel 93549 Model power splitter to combine cables attached to VNA 1 and VNA 2.

2. Activate the second VNA as a CW (continuous wave) RF source at a frequency of 301.0MHz and a power of -5dBm.
   a. Press "PRESET" on the VNA, next select FREQUENCY – CW and set the frequency, to begin with, to 301.0MHz. You should be able to view the signal clearly in the display. Place a marker on the peak.

b. Adjust the power level to a setting of -5 dBm, by selecting POWER on the VNA and then the LEVEL soft key. You can use the knob or the keypad to enter the desired power level.

c. You should notice some flickering in the displayed signal. The analyzer is in a sweep mode even though we have asked it to give us a CW signal. Stabilize the signal by selecting, HOLD on the TRIGGER menu of the VNA.

3. Both signals should now be input through the combiner to the SA. This will establish two signals at each signal analyzer input that differ by 1MHz. Turn the RF off and on for the VNA 2 source by selecting POWER and the RF ON/OFF key. With the specified SA settings you should be able to see two signal peaks on the SA. Record the frequency and amplitude of the two peaks corresponding to the two signal sources.

Table 3. Observed signal peaks with dual inputs from VNA and CAL OUT reference. (SA Center freq. = 300MHz, SPAN = 20MHz).

FREQ. OF PEAK (MHz)	AMPLITUDE OF PEAK (dBm)	COMMENTS

4. Using the arrow keys, increase the SPAN while keeping the center frequency fixed at 300MHz. Note that the resolution bandwidth automatically changes with the SPAN setting to keep the sweep time approximately constant. This is what we want to happen for this part.

OBSERVATION: For what span setting can you no longer distinguish between the two signals?

What is the corresponding (automatic) setting for the resolution bandwidth? (You can find this easily by pushing BW after you have the SPAN set).

5. Set the SPAN back to 20MHz. Increase the resolution bandwidth, while keeping the span and center frequency fixed. Do this by pressing BW then use the arrow keys or knob to increase the value of the resolution bandwidth.

Observation: For what minimum value of resolution bandwidth can you no longer distinguish that there are two frequencies present in the display?

6. Now decrease the resolution bandwidth using the arrow or knob functions.

Observation: For what the maximum value of resolution bandwidth can you clearly distinguish the two signals?

Part III: SA Measurement of VNA signal at varied frequency and amplitude.

(What you should see: this part will give you experience, or practice, with setting up various amplitude and frequencies using the VNA as a signal source, and then finding and measuring the resulting output signal using the SA. You should see correlation between the settings of the VNA and the measurements on the SA.)

The test configuration for this part is shown below. This connection will require a DC Block to be attached to the SA.

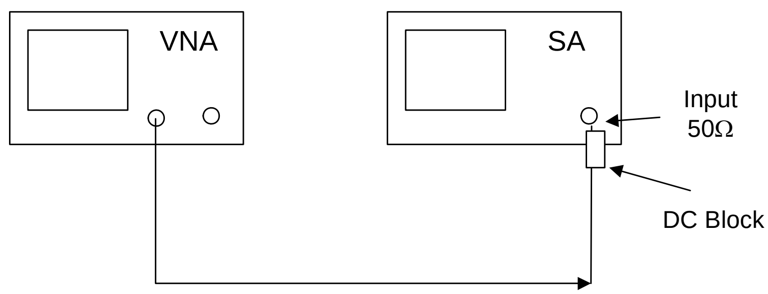

Figure 3. Test configuration for measurement of VNA as a single frequency source.

1. Remove the T-junction and connect the VNA 2 test signal directly to the SA as shown in the figure 3.

2. Push PRE-SET on the signal analyzer. Next set 20 dB internal attenuation of the SA to help ensure that the SA remains in its linear operating region. Also, set the reference level to 10 dBm.

3. Using analogous procedures as in the previous part, set the VNA test signal to CW mode and a frequency of 50 MHz with a power of 0dBm. Stabilize the signal by selecting, on the VNA, MENU then with soft keys TRIGGER then HOLD. Under the POWER menu make sure the RF is ON.

4. On the SA set the center FREQUENCY to coincide with the VNA CW test signal frequency and set the SPAN to correspond to a 10% value of the center frequency. For instance, if the center frequency set to 50 MHz, the span should be 5 MHz. Use the PEAK SEARCH and/or MARKER keys to identify the observed frequency and amplitude peaks corresponding to the 50 MHz (5 MHz) VNA test signal.

5. Repeat steps 3 and 4 for varied test signals in order to make the measurements indicated in the table shown below. To do this you will be changing the frequency, and in some cases power level on the VNA, and the center frequency and span settings on the SA.

Table 4. Observed frequency and amplitudes for varied VNA CW test signals.

VNA Test Frequency (MHz)	VNA Power Level Setting (dBm)	SA Measured Peak Frequency (MHz)	SA Measured Amplitude (dBm)	Comment
50	0			
50	-3			
100	0			
100	-3			
300	0			
500	0			

OBSERVATIONS:

By how much does the SA measured signal amplitude drop at 50 and 100MHz when the VNA power level setting is reduced by 3 dB?

Other comments and observations:

Part IV: Oscilloscope Measurement the VNA signal at varied frequency and amplitude.

(What you should see: you will now measure a CW signal in the time domain on an oscilloscope. You should see agreement between the O-Scope and SA frequency measurements at low frequency, but will see differences at higher frequencies.

The test configuration for this part is shown below. This connection will require a BNC-SMA adapter to be attached to the oscilloscope.

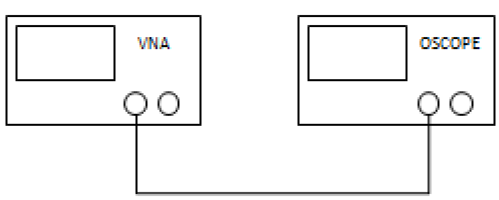

Figure 4. Configuration for time domain measurement of VNA CW test signal using oscilloscope.

1. Connect a cable directly between the VNA output and the Ch1 input connector of the oscilloscope.

2. Set-up the VNA for a CW test frequency of 50 MHz, with a power level setting of 0 dBm. (Set the trigger to CONTINUOUS, the trigger source to EXTERNAL, and the start/stop frequencies to 50 MHz.)

3. Zoom in to get a good view of the signal using the OSCOPE, then adjust the vertical and horizontal position and scale as needed to see a sinusoidal signal with a few signal periods in the display.

4. Use the vertical line cursors to determine the period T of the displayed signal and calculate the frequency as f= 1/T.

OBSERVATION: T= ________ s f = ________ Hz

5. Use the horizontal line cursors to determine the peak-to-peak voltage levels.

OBSERVATION Vpp (1MΩ coupling) = ________ mV

You should notice difficulty in making the measurements at 300MHz and 500MHz than at lower frequencies. Comment on this in the space provided in and/or below the table.

Table 6. Summary of Oscilloscope Amplitude and Frequency Measurements.

VNA Test Frequency (MHz)	VNA Power Level Setting (dBm)	OSCOPE Meas. Frequency (MHz) f_o +/- Δ	OSCOPE Measured Vpp 1MΩ	Comment
50	0			
50	-3			
100	0			
100	-3			
300	0			
500	0			

By what factor does the peak voltage Vpk (= Vpp/2) change when the power drops by 3 dB?

Additional comments and observations:

Part V: Oscilloscope Measurement of Composite Signal (2 Sinusoids).

The goal of this part is to visualize a pair of combined CW signals in the time domain. You will see that the composite waveform contains harmonic content from both signal sources.

The test configuration for this part is shown is shown in Figure 5. A T-junction will be provided as part of this setup. Note that the inclusion of this component introduces additional loss into the system.

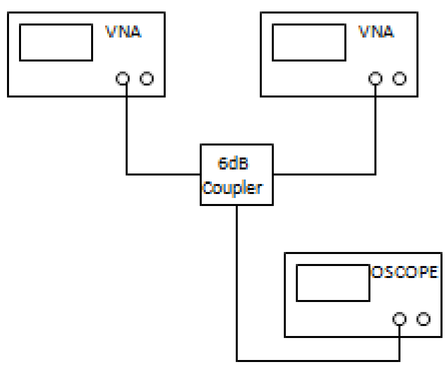

Figure 5. Two-tone Test Setup for Time Domain Measurement

1. Set one VNA to provide a 50 MHz CW signal at a power of 0 dBm and the other to provide a 60 MHz CW signal at a power of 0 dBm.

2. Display the combination of two sinusoidal signals on the Oscilloscope.

3. Note you have represented on the scope a signal that could mathematically be represented by

$$s_0(t) := A_0 \cdot \cos\left(2\cdot\pi\cdot f_0\cdot t + \theta_0\right) \qquad s_1(t) := A_1 \cdot \cos\left(2\cdot\pi\cdot f_1\cdot t + \theta_1\right)$$

$$s(t) := s_0(t) + s_1(t)$$

Where $s_0(t)$ and $s_1(t)$ are the two signals. Try determining A_0 and A_1 separately by first disconnecting one, then the other from the T-junction.

Observations: What values do you estimate for A_0 and A_1 for your measurement configuration? A_0 = ____________ A_1= _____________