NET 2007 Laboratory 1

Spectrum Analysis of Waveforms

(Adapted from SYSC3501 HW1 Lab 1)

Objective

The purpose of this experiment is to examine the spectral characteristics of a number of standard waveforms that are used for communications.

Prelab

Please read this manual prior to going to the lab. Prepare a prelab report containing:

1. A brief description in your own words of what you will be doing the lab (max. 5 lines).
2. Practice some conversions. Show your work and the units of your final answer.
   a) 0.02W in dBm
   b) You have two signals, each at -20dBm. What is the sum of their powers in dBm?
3. Using a resistance of 1 Ohm, what is the power [dBm] of a sine wave with an amplitude of 0.2V?
4. What is the expected power of the first three frequency components of a square wave with an amplitude of 0.2V? (the first one was done in class)
5. Define what is meant by the "duty cycle" and show a diagram of a 75% duty cycle.

This will significantly help you to understand the lab and to prevent experimental mistakes. Each individual student has to prepare his / her own prelab, no copies are allowed. The prelabs will be checked by the TA's during the lab session. If the quality of the prelab is not satisfactory, or if the student has not done the prelab, 20% will be deducted from the total for this lab.

Equipment Required

- 1 spectrum analyzer
- 2 dual-trace oscilloscopes
- 1 signal source & BNC-T connectors

Procedure

Record your station number. Follow the steps thoroughly. Do not go onto the next step until you have finished the previous one.

Part 1 – Setup and Calibration of the Spectrum Analyzer

All labs begin by calibrating the spectrum analyzer.

Calibration Settings

Connect the X (CH 1) and Y (CH 2) oscilloscope inputs to the spectrum analyzer X and Y outputs, respectively using a BNC –T connector.

Set up the frequency domain oscilloscope:

a. **X-Y** mode
   (It is oscilloscope specific how this is set up – there may be multiple settings required to be set to X-Y)

b. Ch 1 and Ch 2 inputs to
   i. 1 volt per division
   ii. calibrated
   iii. DC coupling
   iv. not inverted

Set the spectrum analyzer as follows

1. MARKERS: 0 (red button out) and 1 M (1MHz)
2. INPUT: 1 Mohm (button out)
3. MAXIMUM INPUT: 0 dBm
4. FREQUENCY RANGE: 0-30MHz (out)
5. OUTPUT LEVEL: turn knob to CAL
6. OUTPUT SCALE: LOG (10 dB/volt)
7. OUTPUT:
   a. MEM: out
   b. MODE: out
   c. PLOTTER: out, out

Calibrating the spectrum analyzer

1. Ensure the oscilloscope and the spectrum analyzer are powered on. If anything is connected to the spectrum analyzer input, disconnect it

2. Set FREQUENCY SPAN Hz/V: 1 M on the spectrum analyzer

   This sets the spectrum analyzer to output 1MHz/V. Since the oscilloscope is set to output 1V/DIV, the output on the oscilloscope's horizontal axis now corresponds to 1MHz/DIV – the vertical grid lines are spaced apart in intervals of 1 MHz along the x-axis. Since there are 5 divisions to the left and right of centre, the oscilloscope output now displays the spectrum between -5MHz and +5MHz.

3. Adjust the coarse and fine TUNING knobs in the spectrum analyzer to put the largest tone (spike) in the centre of the X-axis on the oscilloscope display.

   This spike is the reference signal at 0 Hz. The goal is now to more accurately centre this reference signal on the oscilloscope.

   Note that the signal will drift: you will have to re-tune to 0 Hz as the lab progresses. Once the system has been powered up for a while, this drift will slow down, but may still be present.

4. Repeat step 3 for values of FREQUENCY SPAN equal to 200 kHz/V, then 50 kHz/V, and finally 10 kHz/V.

   Each step to a smaller kHz/V is zooming in on 0 Hz. Once at 10KHz/V, the oscilloscope displays only the spectrum between -50 KHz and 50 KHz.

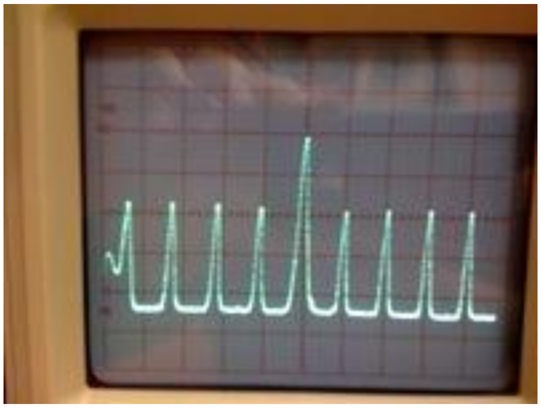
5. Adjust the CALIBRATION CONTROL so that the spectrum analyzer's CENTER FREQUENCY LEDs show 0 MHz

6. set MARKERS: 1 (on) and 10 kHz
7. adjust SPAN so that the markers line up with the grid lines on the oscilloscope; the fifth marker to the left and right of the centre reference spike should be just at the edge of the screen.

   You may find that the negative and positive frequencies are not equally spaced. Prioritize adjusting the positive frequencies.

The spectrum analyzer now displays the power spectrum on the oscilloscope. The left edge of the X axis on the oscilloscope represents –10 kHz, the center represents 0 kHz, and the right represents 10 kHz. The Y axis on the oscilloscope corresponds to the power in units of 10 dB per DIV.

Your final display may look something like this:



Part 2 –Waveforms in the Time Domain and Frequency Domain

Two oscilloscopes will be used: one to view the signals in time domain, and the other as the spectrum analyzer display.

Equipment Settings

Setup the spectrum analyzer:

1. MARKERS: 0
2. MAXIMUM INPUT: 10 dBm
3. INPUT : 50 Ohm
4. FREQUENCY SPAN Hz/V of 10 K

Setup the function generator:

1. Output function: sinusoidal
2. Output range: 10 KHz or 50K, depending on availability
3. Attenuation: On (usually provides -20dB attenuation)
4. DC Offset: Off / Min
5. Variable duty cycle: off/min
6. Output level / amplitude: min
7. Invert: off
8. Sweep: internal
9. Frequency: 1.0 (Since we are using the 10K range, 1 corresponds to 10KHz)

Analyzing a sinusoid

1. Using a BNC-T connector, connect the output of the signal source to an oscilloscope and to the input of the spectrum analyzer.

   You now have two copies of the same signal applied to the oscilloscope and the spectrum analyzer.

2. Adjust the output level of the signal generator until the signal on the time domain oscilloscope shows a Vp amplitude of 0.2V. Measure the period of the sinewave by measuring the time between positive zero crossings (or peaks, but zero crossings are usually more accurate). Compute the frequency (f = 1/T) and adjust the period using the frequency dial on the function generator until the frequency is exactly 10 KHz.

   Make a plot of the time-domain oscilloscope output. All plots must include x and y axis names, scales, and units.

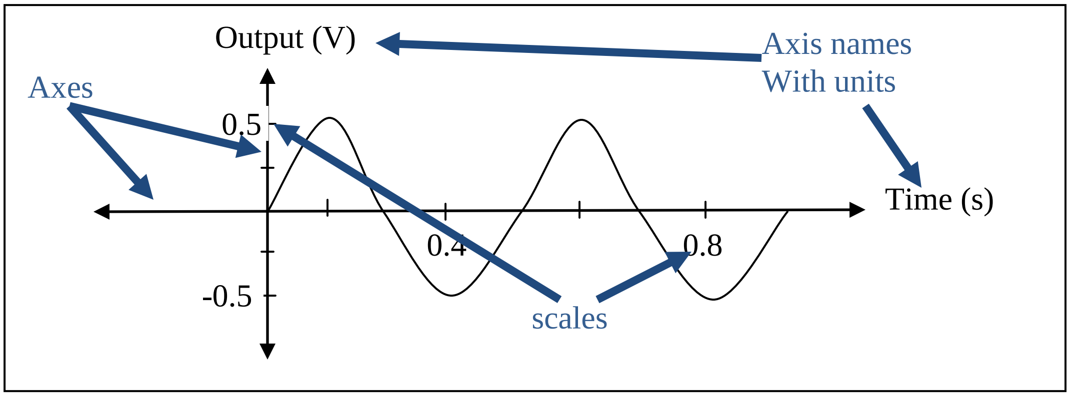


Figure: What a plot should include

3. Observe the spectral components of this signal on the screen of the frequency domain oscilloscope (you may have to re-centre the analyzer, as it continues to drift).

   The spectral components represent the power spectrum of the signal. The spike at frequency zero acts as a reference whose level is equal to the value of the MAXIMUM INPUT switch of the spectrum analyzer in dBm (W). Using this reference level, obtain the power content of the spectral components of the signal in dBm (W). Note that with the settings of 1 Volt/div for the Y input of the scope and 10 dB/V for the OUTPUT SCALE of the spectrum analyzer, each vertical division of the scope corresponds to 10dB.

   Make a plot of the spectrum shown on the frequency domain oscilloscope. Note the power levels of the spectral components and the important frequencies.

   Compare the spectrum (power levels and frequencies of the components) with the theoretical spectrum of a sine wave.

4. Change the amplitude of the input signal to 800 mV (0.8V).

   Plot the new spectrum, and compare the power levels again to theory.

   How did the spectrum change compared with the previous result?

5. Keeping the amplitude of the signal at 0.2 V, increase the frequency to 50 KHz.

   You will have to change your FREQUENCY SPAN setting to observe this signal properly on the spectrum analyzer.

   Observe and plot the power spectrum, paying particular attention to the locations of the components along the frequency axis. You may wish to turn on the markers to check your results.

Now, decrease the frequency of the input signal to 5 kHz, and again **observe and plot its power spectrum**. **Were the frequency locations of the observed spectral frequencies consistent with theory?**

If the phase of the sine wave is changed, would you expect the power spectrum to change? Why?

Analyzing a square wave

1. Make sure that the input signal to the spectrum analyzer has a frequency of 10 kHz and an amplitude of 0.2 V.

   Observe the power spectrum of the signal and plot the spectrum between -50 KHz and +50 KHz (10KHz/V frequency span). Notice that there is power only in certain harmonics of the fundamental frequency.

   Question 5: Using your results from Question 4 of the pre-lab, compare the theoretical power spectrum with the observed spectrum. Compare also the frequencies of the components. Comment on any discrepancies.

Lab Submission

Prepare a report in pdf format. The report must be typed, although diagrams may be hand drawn and inserted into the report as pictures. The report follows this outline:

Title Page

- Lab number and title of the lab, both partners' names, date the lab was completed, final submission date, equipment setup number

Introduction

- Introduce the objective of the lab in one or two sentences (in your own words: do not paraphrase or copy the introduction provided by the lab manual).

Method

- Include a block diagram of the equipment that was used and how they were connected.
- Describe in your own words what you did during the lab, paying particular attention to 'why' this was done (do not list the equipment settings that were required unless you consider any to be important to the explanation).

Results

Include any plots (either a handrawn picture or one drawn on the computer) you were asked to make and answer all of the questions.

- A plot must include
  - the name of each axis and the units of each axis
  - a numerical scale along each axis so that a reader can estimate values

    - the plot itself
- Plots cannot be photos of the oscilloscope output (if you wish to take photos during the lab, you may do so, but make sure your record all of the information you will need to interpret it for drawing later)

Conclusions

- What did you learn?

Report submission is via WebCT. Only one partner needs to submit the report.

Marking Scheme - /10: 2 marks for the prelab, 8 as follows:

Note: if the report includes any sentences copied or paraphrased from this manual, 4 marks will be subtracted from the total.

8	The report is complete and demonstrates a good understanding of the equipment used and the lab methodology. Results are complete and accurate (plots include all required features), and answers to questions display proper reasoning and match the recorded results.
6	The report is complete and demonstrates an adequate understanding of the equipment used and the lab methodology. Results are complete but may have missed important details (plots include most of the required features). Answers to the questions are adequate.
4	The report is barely adequate: all sections are included, but one or more sections are poorly executed or demonstrate only limited understanding of the lab methodology. The results may be incomplete, and answers to questions may lack adequate reasoning.
2	The report is very poorly completed: sections are missing, results are incomplete and understanding of the material is not demonstrated.
0	Not handed in or the material handed in is not the lab report.