

UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE

Department of Electrical and Computer Engineering

EXPERIMENT 10 – SPECTRUM ANALYSIS

OBJECTIVES

In this experiments students will use a spectrum analyzer to observe real signals in the frequency domain and observe important relationships between time and frequency domain characteristics of various classes of signals.

MATERIALS/EQUIPMENT NEEDED

NI ELVIS II

EMONA SIGEx Signal & Systems add-on board

Assorted patch leads

Two BNC – 2mm leads

INTRODUCTION

By understanding the frequency domain characteristics of various signal types, we can further develop our ability to think in both the time AND frequency domain when considering signals. The two go hand in hand and it is essential for the engineer to be well versed in both. Having hands-on experience with signals and their spectrums will consolidate the theory, particularly of broad spectrum signals, in a way that supports the learning of telecommunications principles. Signals and their spectrum are the foundation for several other fields of study.

PRELAB

1. What is the conversion equation for a linear voltage scale to a logarithmic scale?
2. What linear ratio does a -6dB gain equals?

PROCEDURE

Setting up the NI ELVIS/SIGEx Board

1. Turn on the PC (if not on already) and wait for it to fully boot up.
2. Turn on the NI ELVIS unit but not the Prototyping Board switch yet. You should observe the USB light turn on (top right corner of ELVIS unit).
3. Turn on the NI ELVIS Prototyping Board switch to power the SIGEx board. Check that all three power LEDs are on. If not call the instructor for assistance.
4. Launch the “SIGEx Rx_x.exe” Main VI.
5. When you’re asked to select a device number, enter the number that corresponds with the NI ELVIS that you’re using.
6. You’re now ready to work with the NI ELVIS/SIGEx bundle.
7. Select the Exp 9 tab on the SIGEx SFP.

Note: To stop the SIGEx VI when you’ve finished the experiment, it’s preferable to use the STOP button on the SIGEx SFP itself rather than the LabVIEW window STOP button at the

top of the window. This will allow the program to conduct an orderly shutdown and close the various DAQmx channels it has opened.

Spectrum of the Impulse Train

1. Connect the pulse generator to the BASEBAND LPF per Figure 10-1.
2. Settings are as follow:
 - a. PULSE/CLK GENERATOR: 500 Hz; DUTY CYCLE=0.1 (10%)
 - b. SCOPE: Timebase 40 ms; Rising edge trigger on CH1; Trigger level=1V
 - c. Connect CH1 to input, CH0 to output of BASEBAND LPF. Ensure FFT: Y-scale set to Linear mapping.

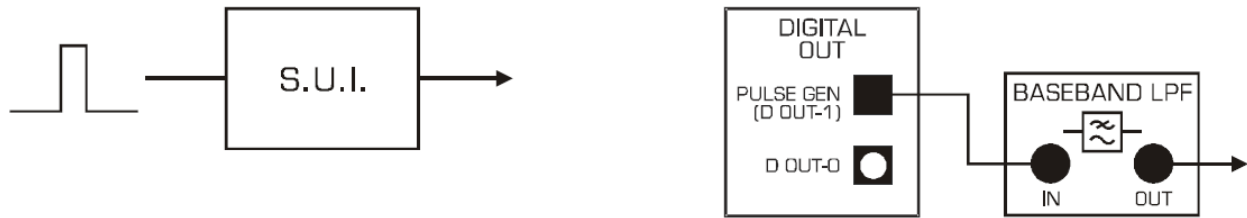
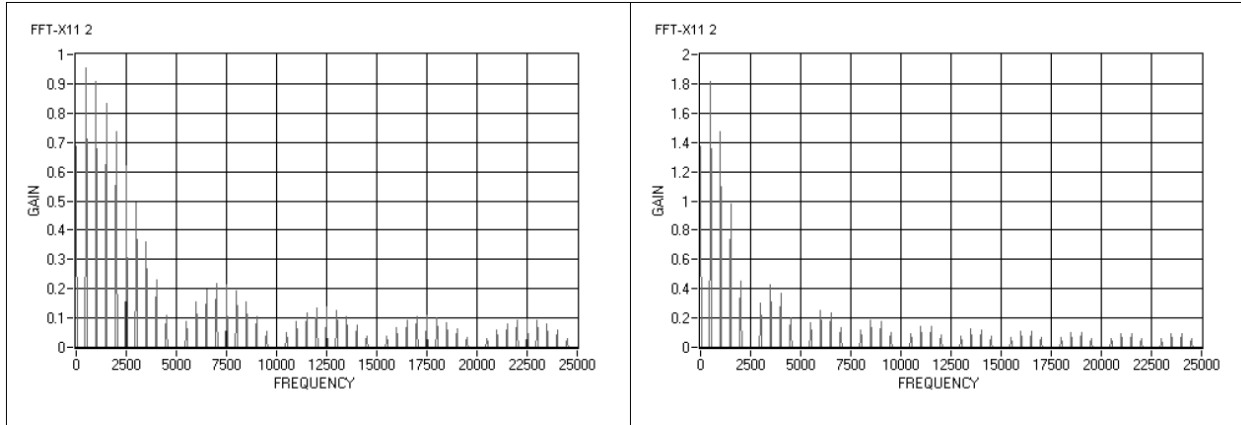


Figure 10-1 Pulse Source to Baseband Low Pass Filter

3. Observe the pulse train on the scope. Measure the width and repetition interval, and confirm that these are as you would expect for the settings on the PULSE GENERATOR you have selected.
4. Observe the spectrum of this pulse train. The spectrum analyser should be set for a linear frequency axis and linear scale for the vertical axis. Vary the timebase, which in return varies the frequency scale, to provide a convenient balance between range and resolution in the frequency display.
5. You can also switch between this experiment's tab and the ZOOM FFT TAB for more control over the FFT display if you prefer without disrupting any settings.
6. Note that the spectrum consists of discrete components. Confirm that the interval between components is determined by the pulse frequency.
7. Question: At what frequencies do the nulls occur at?
8. Increase the width of the pulse, to double, but not the frequency, by varying the duty cycle of the pulse train. Set the PULSE GENERATOR DUTY CYCLE to 0.2 (20%)
9. Confirm that the frequency interval between nulls is determined by the pulse width.
10. Question: What is the mathematical relationship between null spacing and the pulse width?
11. Confirm that the spacing of the individual components of the spectrum, ie: its harmonics, have not changed with the double width pulse.



(a)

(b)

**Figure 10-2 (a) Spectrum of Single Width Impulse with Linear Scaling
(b) Spectrum of Double Width impulse with Linear Scaling**

12. Make suitable measurements of the spectrum amplitude to show that the shape of the envelope is of the form $\sin(x)/x$ for both impulse widths. Confirming the ratio of envelope peaks would be one important characteristic to check.
13. Verify that the general form of the spectrum is not affected by the clock frequency ie: that it still maintains the $\sin(x)/x$ shape.
14. Question: What are the characteristics of the $\sin(x)/x$ form that you are looking for?
15. Now, reduce the width of the pulse, but not the frequency, by again varying the duty cycle of the pulse train. Set the PULSE GENERATOR DUTY CYCLE to 0.02 (2%)
16. Confirm that the frequency interval between nulls is determined by the pulse width ? You may need to vary the scope timebase to alter the FFT frequency display range.
17. Try a final reading with a duty cycle of 1 %. Set the PULSE GENERATOR DUTY CYCLE to 0.01 (1%)
18. Question: What is the general trend that you are observing as the duty cycle tends towards 0?
19. Question: Using the various findings so far, what shape you expect the spectrum of a single pulse, that is, a pulse train with very large separation between pulses, to have?

Spectrum of the Filtered Impulse Train

1. Return to the original single width pulse settings.
2. Settings are as follow:
 - a. PULSE/CLK GENERATOR: 500 Hz; DUTY CYCLE=0.1 (10%)
 - b. SCOPE: Timebase 40 ms; Rising edge trigger on CH1; Trigger level=1V
 - c. Connect CH1 to input, CH0 to output
3. Observe the scope display of the pulse response at the BASEBAND LPF channel output.

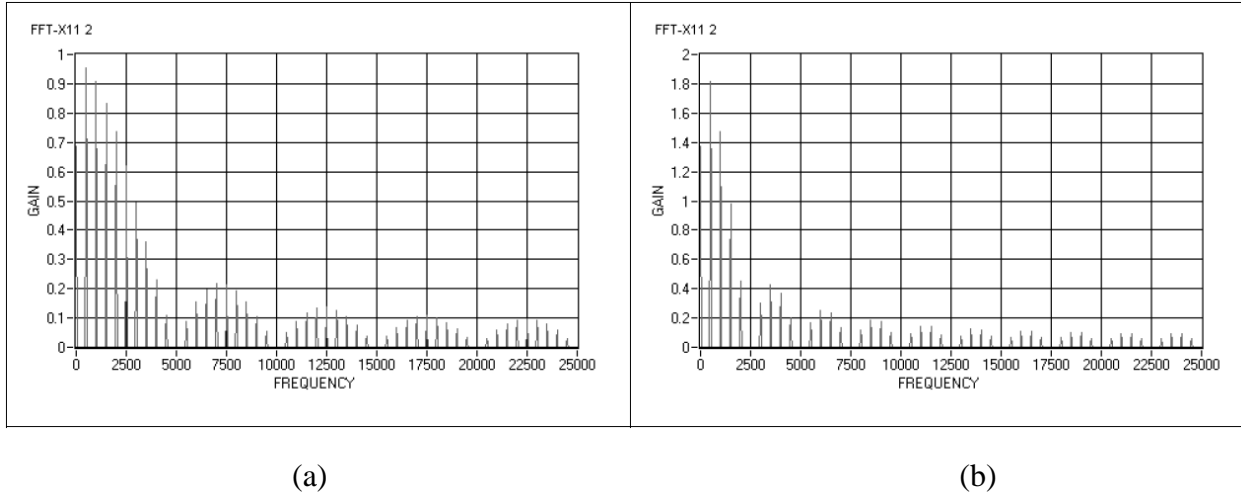


Figure 10-3 (a) Impulse after Filtering (b) Post-filter Spectrum

4. Ensure that the pulse width is narrow enough such that the filtered pulse output is the impulse response of the channel.
5. Observe the frequency response of this output and compare with the response of the unfiltered input train. This is most easily done by viewing input and output simultaneously on both channels of the scope. Sketch these responses in Graph 10-1.
6. Determine and plot the response characteristic of the BASEBAND LPF. This will be the ratio of the output to the input. If you have viewed the frequency responses using a log/dB scale on the vertical axis, then this process is a straightforward subtraction of input from the output. Modify the FFT display Y scale Mapping settings to be set to Logarithmic for these measurements.

Duty Cycle and Sampling

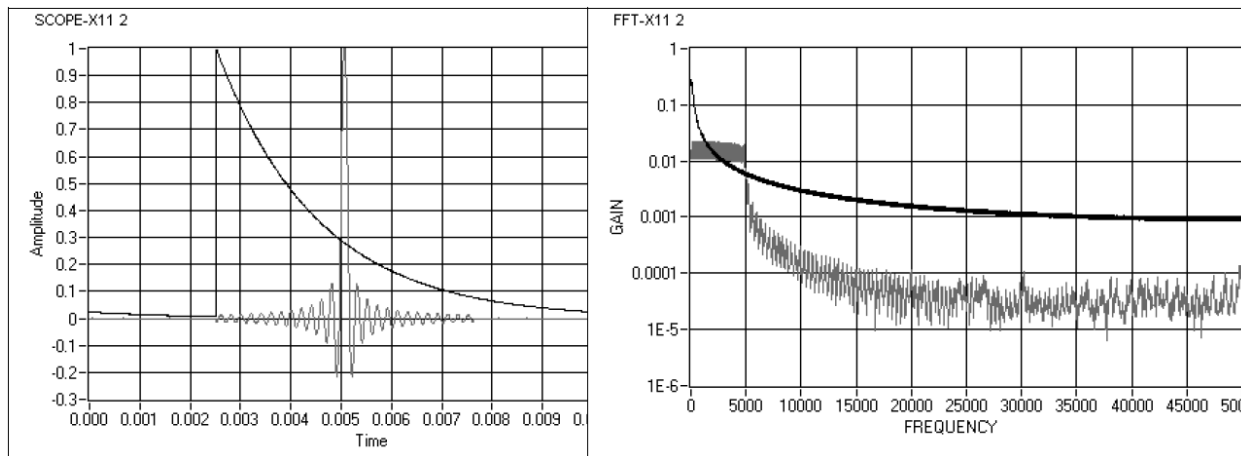
In the section above you have determined the frequency response of a periodic pulse train with variable duty cycle. This is the typical signal used as a sampling pulse train. It suffices at this point to emphasize that the spectrum of the sampling signal will be interacting with the message to be sampled, hence it is imperative to be familiar with it and its characteristics.

1. Start with a square wave from the PULSE GENERATOR, frequency = 500Hz, set to duty cycle = 50%. Slowly reduce the duty cycle from 50, to 40, then 30 and finally 20%, and observe the occurrence of even harmonics. You should realise that at 20% you have the same spectrum studied above and you should have an insight into the origin of the harmonics present.

“Sinc Pulse” Trains

A rectangular shaped signal in the time domain results in “sinc function” shaped frequency response spectrum. In this part of the experiment we investigate the spectrum of pulse with $\sin(x)/x$ shaping in the time domain i.e. a sinc function in time. For convenience we will use a repetitive train of sinc pulses.

2. A sinc pulse train is available at the ANALOG OUT : DAC-1 module. View this signal with a SCOPE channel in both the time and frequency domain.
3. Settings are as follow:
 - a. SCOPE: Timebase = 10ms, Trig level = 0.5V
4. With this signal we have a unique situation where the spectrum is finite. In order for this to occur this sinc pulse must itself be infinite in the time domain, and in fact a true single sinc pulse is only asymptotically limited in time. That is, it tends to zero in both positive and negative time directions. In this experiment we have made an approximation by repeating the pulse in a train and terminating the oscillations after about 20 cycles.
5. Question: At what time instants does the sync pulse have a zero crossings?
6. Sketch both the sinc pulse and its spectrum in a Graph 10-2, and annotate the diagrams of all the relevant measurements.



(a)

(b)

Figure 10-4 (a) Sinc Pulse and its Bandlimited Spectrum; (b) Exponential Pulse for Comparison

7. As per the steps taken above in the impulse section, apply this sinc pulse train to the BASEBAND LPF module and observe its input and output in both the time and frequency domain. Plot the output frequency response on Graph 10-2.
8. It is also interesting to see the difference in response between the BASEBAND LPF and the TUNEABLE LPF. Pass the sync pulse train through the TUNEABLE LPF and slowly reduce the -3dB cutoff frequency to the same as that of the BASEBAND LPF as found above. Notice the difference in the roll off rate.

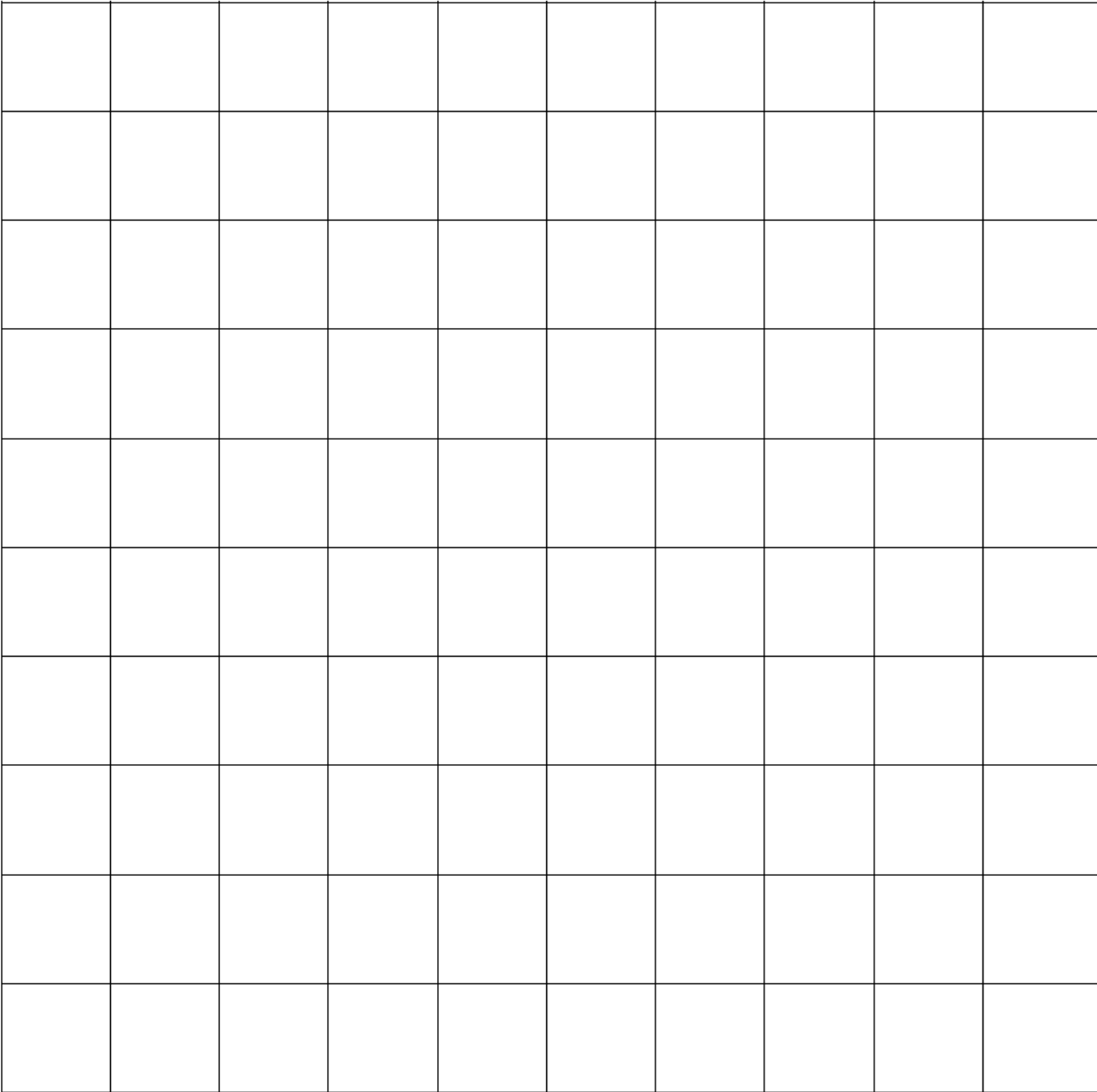
DATA/OBSERVATIONS

Graph 10-1 Impulse Train Responses

INSTRUCTOR'S INITIALS:

DATE:

Graph 10-2 Sync Pulse Train Time and Frequency Response



INSTRUCTOR'S INITIALS:

DATE:

POSTLAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. Answer all the questions that are included in the procedure.