University of Rhode Island Department of Electrical and Computer Engineering

ELE 436: Communication Systems

Experiment 1: Intro to Spectrum Analysis

1 Introduction

This exercise will serve as an introduction to the spectrum analyzer, an instrument that takes an electrical waveform as its input and displays the frequency components (the spectrum) of that signal. The concept of spectrum analysis is probably familiar to you from knowledge about sound, light, radio, and television. The equvialent mathematical method for finding the spectrum of a time-domain signal is to map that signal to the frequency domain using the Fourier transform. The spectrum of a signal is often defined as the magnitude of its Fourier transform.

We will begin our adventure into spectrum analysis by discussing the case of a sinusoidal signal. What do you expect the spectrum of a sinusoid to look like?

2 The SR 770 Spectrum Analyzer

The following procedure will lead you step by step through the process of setting up the Stanford Research SR770 FFT Network/Spectrum Analyzer to view the spectrum of our sinusoidal test signal in real-time.

1. **Generate a sinusoid:** Use a function generator to create a sinusoid of **20 kHz**. Keep the amplitude small! (50mV - 500mV)

2. **Connect** the function generator to the spectrum analyzer's **A** Input using a BNC to BNC cable.

3. Set up the spectrum analyzer:

    - Turn the analyzer on while holding down the [←] (backspace) key. Continue holding down backspace until the Calibrating Offset message appears on the display. (This will take about 15 seconds.) When the power is turned on with the backspace key depressed, the analyzer returns to its default settings.
    - Once the Calibrating Offset message has cleared, press the **AUTO RANGE** button from the **ENTRY** group. This will allow the analyzer to automatically set its input range to agree with the generated signal.

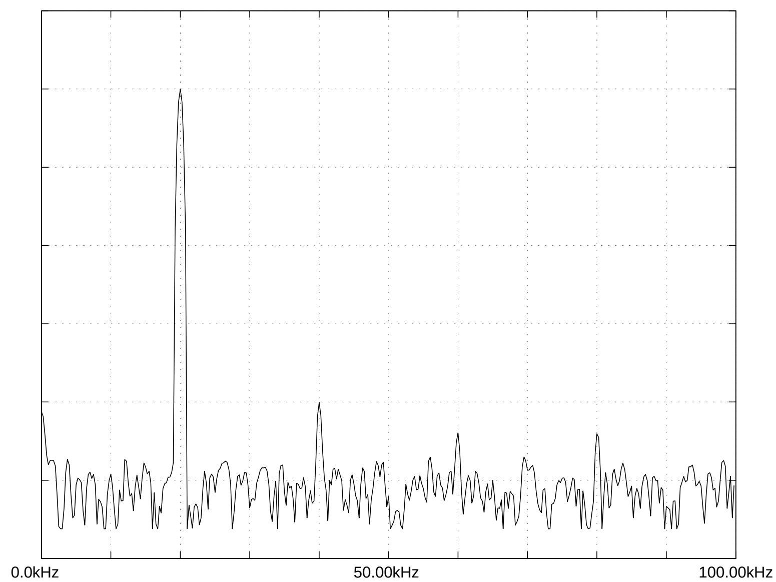

Figure 1: Spectrum of 20kHz sinusoid displayed on a log magnitude scale.

- You should now see a large spike towards the left of the screen. From the **MARKER** group (below the center knob), press **MAX/MIN**. This centers the marker on the largest frequency component of the signal. The marker readout above the graph will display the frequency of the signal (20 kHz). Notice that the amplitude is in dB. We will now change to a linear scale.
- Hit the **MEAS** (measure) button from the **MENU** group. The dark gray buttons directly to the right of the analyzer's display are called the *softkey* buttons. Each softkey is associated with a setting or option described on the analyzer's display. Hit the **Display Menu:** softkey. Next, to change the display from log to linear scale, press the **Linear Mag** softkey.
- Press **AUTO SCALE** from the **ENTRY** group. You should see an impulse (spike) at 20 kHz displayed with a linear magnitude.

4. Vary the frequency of $x(t)$ (the input) over the the range of 10 - 30 kHz. Observe how the impulse relocates to the corresponding frequency on the spectrum analyzer. Press **MAX/MIN** from the **MARKER** group to verify that the correct frequency is displayed.

5. Sometimes you may want to zoom in on a particular frequency range. To do this, press **FREQ** from the **MENU** goup. Press the **Span** softkey, and then turn the knob counter-clockwise to narrow the span. The span can also be adjusted by pressing the **SPAN** $\downarrow$ or **SPAN** $\uparrow$ buttons from the **ENTRY** group.

3 Transform of a Sinusoid

Suppose we have a sinusoidal signal:

$$x(t) = A\ cos(2\pi f_0 t) \tag{1}$$

$x(t)$ can be expressed in terms of complex exponentials using Euler's formula

$$x(t) = \frac{A}{2}\left[e^{j2\pi f_0 t} + e^{-j2\pi f_0 t}\right] \tag{2}$$

One can now easily find the transform of $x(t)$. Given that

$$e^{j2\pi f_0 t} \leftrightarrow \delta(f - f_0) \tag{3}$$

we can find $X(f)$

$$X(f) = \frac{A}{2}[\delta(f - f_0) + \delta(f + f_0)] \tag{4}$$

Therefore when $x(t)$ is a cosine, $X(f)$ is two impulses, one at $+f_0$ and the other at $-f_0$.

4 Questions

1. Using Euler's formula and equation (3), find the transform of a sine wave.

$$x(t) = sin(2\pi f_0 t)$$

2. Using Euler's formula and equation (3), find the transform of a cosine with an unknown phase.

$$x(t) = cos(2\pi f_0 t + \phi)$$

3. Recall that the spectrum of a signal is the magnitude of its Fourier transform. Prove that the spectrum of the cosine from problem 2 is always the same regardless of the value of ϕ.