Lab 5 - The Spectrum Analyzer

Objectives

To become acquainted with the Spectrum Analyzer.

Equipment

Tektronix 7L5 Spectrum Analyzer
Tektronix TM504 Combined Instrument
Tektronix 2215A Oscilloscope
1 Mini Circuits 20 dB Attenuator

Pre-Lab

Long ago we learned to compute the spectrum of a periodic signal by using the Fourier Series. We have in our lab Spectrum Analyzers which are equipment that can display the spectrum of a signal in real-time. The Tektronix 7L5 spectrum analyzer can easily be used to view the spectrum of any signal in lab. The 7L5 displays its signals as a one-sided spectrum in dB and is calibrated in Vrms. We will use it to display the sine and square waves used in last week's lab, but first we must learn how to convert the Fourier Series coefficients used last week to the dB's displayed by the 7L5.

In class we saw that any periodic signal can be written as:

$$x(t) = \sum_{n=-\infty}^{\infty} c_n e^{j2\pi n f_0 t}$$

Since the spectrum analyzer deals only with "real" signals, we know that $c_n = c_{-n}^*$. Also, the phase is not shown, only $2|c_n|$. Writing out a few terms of x(t) above gives:

$$\cdots + c_{-2}e^{-j2\pi 2 f_0 t} + c_{-1}e^{-j2\pi 1 f_0 t} + c_0 + c_1 e^{j2\pi 1 f_0 t} + c_2 e^{j2\pi 2 f_0 t} + \cdots$$

Note the c_n terms come in pairs. Since we have a real signal these terms can always be combined to give:

$$2|c_n| \cos(2pnf_0 t + \angle c_n)$$

The spectrum analyzer displays the $2|c_n|$ terms, called a one-sided spectrum. The analyzer is calibrated to display RMS voltages, so we have to divide the "peak" voltage by $\sqrt{2}$ to get the RMS value of the term:

$$\frac{2|c_n|}{\sqrt{2}} = \sqrt{2}|c_n|$$

The last step is to convert to dB which gives the formula needed to convert from the Fourier Series coefficients to the value displayed on the analyzer:

$$20\log\left(\sqrt{2}|c_n|\right) \text{ dBV}$$

For the pre-lab compute the dBV for the first 7 coefficients of:

1. $x_1(t) = 0.4 \cos(2\pi 20000t)$,

2. $x_2(t)$ = -0.4 to 0.4 volt square wave of period 50 µs.

3. $x_3(t)$ = -0.4 to 0.4 volt triangle wave of period 50 µs.

Present each in a table in your lab notebook. Turn in a photocopy of your pre-lab during the lecture before lab.

Read the first two sections of *The Spectrum Analyzer: Operating Principles and Instructions.* Pay particular attention to the "Cautions" on the first page.

Procedure

Before connecting any input to the spectrum analyzer, be sure that the *TerminZ* switch is set to provide an input impedance of *1 MW* The spectrum analyzer is a little more robust when its input impedance is high, and will not be subject to damage from *small* DC voltages.

Follow the calibration steps in section 2 of *The Spectrum Analyzer: Operating Principles and Instructions.* Be sure to calibrate the spectrum analyzer after every time you turn it on.

Observe the following signals on the spectrum analyzer. When doing so, remember to adjust the `Reference Level` control until the input signal spectrum can be observed on the CRT.

Use the `Dot Frequency` control to position the dot over the center of the input signal spectrum. Finally, the `Frequency Span/Div` can be reduced to expand the display around the dot frequency. The smaller the frequency span per division, the broader the input spectrum will appear on the screen. With the `Resolution` control set on coupled and the `Time/Div` control set to auto, the spectrum analyzer will automatically set the resolution and sweep speed. The resolution and sweep speed can be altered manually, but caution should be observed, since the display may not remain calibrated.

1. Use the signal generator to generate a *sine wave* of frequency 20 kHz and amplitude 0.4 V. Use the oscilloscope and counter to set up the sine wave. Now observe the sine wave on the spectrum analyzer. Measure the amplitude and frequency. Compare to your pre-lab computations. Are they as expected?

   Experiment a bit: vary the frequency and the amplitude of the sinusoid and observe how the spectrum analyzer display changes.

   Instructor Verification

2. Use the signal generator to generate a *square wave* of period 50 µs and amplitude of 0.4 V. Using the spectrum analyzer measure the level of the first seven harmonics. Compare with your pre-lab values.

3. Use the signal generator to generate a *triangle wave* of period 50 µs and amplitude 0.4 V. Use the spectrum analyzer to measure the level of the first seven harmonics.

4. Use the signal generator to generate a square wave having a period of 50 µs, amplitude of ±0.4 V, and a duty cycle of 10%. (The "duty cycle" is the pulse width divided by the period.) Measure the spectrum using the spectrum analyzer. Compare the spectrum with the spectrum of the square wave. Take data that will allow you to *quantitatively* answer the following two questions:

   a) What happens to the spectrum when the pulse width is increased with the pulse period held constant?

   b) What happens when the pulse width is held constant and the pulse period is decreased?

   Pay particular attention to the frequency spacing between spectral lines, and to the lowest frequency at which the envelope of the spectral lines is zero.

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Report

Present your data, theoretical results, and answers to the questions posed under Procedure above in a memo.

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Staple this page to the end of your Lab Memo.

Name: ________________________ Date: ____________________________

part 1 Cosines	
part 4 pulses	