EELE445 - Lab 2 Pulse Signals

PURPOSE

The purpose of the lab is to examine the characteristics of some common pulsed waveforms in the time and frequency domain. The repetitive pulsed waveforms used are similar in behavior to the real world binary digital signals that will be explored later on.

REFERENCE SOURCES

> When you repeat an energy signal that has a Fourier Transform, at some rate R=1/T, each spectral component (the DC term, fundamental, and all harmonics) take on relative amplitudes which are samples, at multiples of R, from the Fourier Transform of the single signal. If you look at the spectrum of the repeating pulses on the FFT using the linear vertical scale, you will see that the amplitudes of the first 25 harmonics take on the shape of a sinc function with first axis crossing at 5 MHz. Note that the zeroes in the sinc function at each multiple of 5 MHz mean that the 5th, 10th, 15th, etc harmonics each have zero amplitude. The FFT display shows only the amplitude, so the negative going part of the Fourier Transform is shown positively.

Couch example 2-6 , example 2-13, Parseval's Theorem, and the Mathcad pulse waveform program.

PRE-LAB

Use your textbook or the mathcad waveform on the website to answer the following:

- Define Duty Cycle D, pulse repetition rate R, pulse width τ, and period T, for a repetitive pulse signal.
- Explain how a square wave has no even harmonics by considering the spectrum of a general pulse waveform with a duty cycle of 50% (Sa function)
- Find the power and rms voltage for a repetitive rectangular pulse waveform of amplitude A, pulse width τ, and period T from the v(t) waveform.
- Determine the magnitude spectrum (c_n coeff) for a 1 MHz, 0 to 2 volt rectangular repetitive pulse with a duty cycle of D=50%. (Note: this the same as a square wave of amplitude +/- 1V with a DC offset (c_o=1v) of 1 volt. From the c_n , compute the spectrum values in $Vrms_n$ P_n (R=1) and P_{dBV} (R=1 ohm) $_n$ you expect to see on a spectrum analyzer.
- Repeat your magnitude calculations of the pulsed waveform but for a D=1/5 ratio.
- Be able to explain the effects on the spectrum of a repetitive pulse for:
  - Changes in the pulse width τ with T constant
  - Changes in the pulse repetition rate T with τ constant
  - Changes in the amplitude of the pulse with τ and T constant

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METHOD:

Rectangular Pulse waveform Duty Cycle D=1/2=50%

1) Set the signal generator for a 0 volt to 2 volt 1 MHz rectangular pulsed waveform (D=50%) output. Observe the signal on an oscilloscope (500mV/div, 250Ms/sec, DC coupled, full BW, N=10,000). Display the signal with the FFT on a linear vertical scale, rect window, maximum frequency range (0 to 125 MHz).
   a) Record the DC offset, and pulse amplitude from the time waveform. What is the total normalized power of the waveform?
   b) Record and sketch the spectrum from DC to 10 MHz using the Vrms linear scale. You will use these values for calculations in your report. What is the ratio of the voltage of the fundamental to the voltage of the third harmonic? How does this compare to the theoretical value?
   c) What is the ratio of the voltage of the third harmonic to that of the 5th harmonic?
   d) Explain why we say the amplitude of the harmonics decrease as 1/n where n is the harmonic number using the Fourier series.
   e) Change the FFT vertical scale to 10 dB/DIV with 0 to 125 MHz span. Notice how the amplitudes of the harmonics decrease as 1/n at lower harmonics, and then decrease in amplitude much faster for higher n. Explain this effect.
   f) Change the duty cycle from D=50 to D=50.1 and watch the amplitude of the 2^{nd} harmonic. Should the second harmonic be present? Record the amplitude of the fundamental and the 2^{nd} harmonic in Vrms. Compare the ratio of V2/V1 measured to what the theoretical ratio should be in your report.

Rectangular Pulse waveform Duty Cycle D=1/5=20%

2) Reset the generator and scope to 1). Change the **duty cycle** of the wave form to 1/5 (20%). Observe the waveshape on a scope. This could represent a digital signal with a repeating bit pattern of (10000).
   a) Find the power in the waveform from the scope as you did in 1)
   b) Record and sketch the spectrum from DC to 10 MHz using the Vrms linear scale. You will use these values for calculations in your report. Sketch the FFT display. Be sure the DC term is shown. Remember that the first amplitude null of the spectrum occurs at $1/\tau$. Make a list of the amplitudes in Vrms out to 10 MHz. Determine what percent of the total pulse power is transmitted through a channel whose frequency response is that of a low pass filter with cut-off at 5 MHz (5 MHz does get through). This should be $1/\tau$ bandwidth.
   c) For your report, plot the percent of the pulse power for bandwidths from 0 Hz to 25 MHz. Remember that the power that gets through the channel is the summation of the squared Vrms values of each of the different signal components that are within the bandwidth, i.e. the DC term, fundamental, and in this case the 2nd, 3rd, and 4th harmonics. See the Mathcad program for additional help.

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Rectangular Pulse waveform Duty Cycle D=1/2=50%

d) Record the DC, and pulse amplitude from the time waveform. What is the total normalized power of the waveform?

e) Record and sketch the spectrum from DC to 10 MHz using the Vrms linear scale. What is the ratio of the voltage of the fundamental to the voltage of the third harmonic? How does this compare to the theoretical value?

f) What is the ratio of the voltage of the third harmonic to that of the 5th harmonic?

g) Explain why we say the amplitude of the harmonics decrease as 1/n where n is the harmonic number using the Fourier series.

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h) Change the FFT vertical scale to 10 dB/DIV with 0 to 125 MHz span. Notice how the amplitudes of the harmonics decrease as 1/n at lower harmonics, and then decrease in amplitude much faster for higher n. Explain this effect.

i) Change the duty cycle from D=50 to D=50.1 and watch the amplitude of the 2^{nd} harmonic. Should the second harmonic be present? Record the amplitude of the fundamental and the 2^{nd} harmonic in Vrms. Compare the ratio of V2/V1 measured to what the theoretical ratio should be in your report. Hint: ratio of the C2/C1 coefficients.

Rectangular Pulse waveform Duty Cycle D=1/5=20%

a) Find the power in the waveform from the scope as you did in 1)

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b) Sketch the FFT display. Be sure the DC term is shown. Determine what percent of the total pulse power is transmitted through a channel whose frequency response is that of a low pass filter with cut-off at 5 MHz (5 MHz does get through). This should be $1/\tau$ bandwidth. Hint: $\Sigma(V_{nrms})^2/(<v(t)^2>)*100$

c) plot the percent of the pulse power for bandwidths from 0 Hz to 25 MHz. Remember that the power that gets through the channel is the summation of the squared Vrms values of each of the different signal components that are within the bandwidth, i.e. the DC term, fundamental, and in this case the 2nd, 3rd, and 4th harmonics. See the Mathcad program for additional help.

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Tektronix Spectrum Analyzer with Pulse waveform Duty Cycle D=1/2=50%

a) Record the DC, and pulse amplitude from the time waveform. What is the total normalized power of the waveform?

b) Record and sketch the spectrum from DC to 10 MHz using the Vrms linear scale. What is the ratio of the voltage of the fundamental to the voltage of the third harmonic? How does this compare to the theoretical value?

c) What is the ratio of the voltage of the third harmonic to that of the 5th harmonic?