ECE 306L - FOURIER SERIES - LAB 3
THE SPECTRUMS OF PULSE TRAINS - PART II

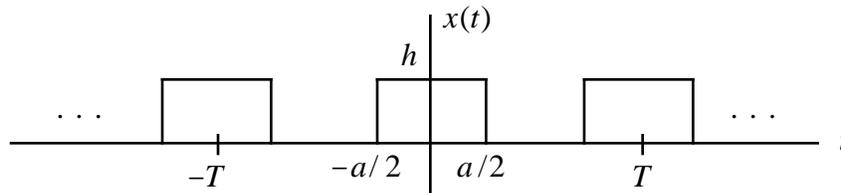**FALL 2006**   **FELZER/KANG**

OBJECTIVE

The objective of this lab is to see how changing the period and pulse width of a pulse train affects its spectrum and as a result its bandwidth.

PRELAB

1. Given the following pulse train

   of period T, pulse width a and amplitude h

   a. Sketch the magnitude of the envelope $X_{env}(f)$ of the Fourier Coefficients X_k
   b. Make use of the fact that

$$X_{env}(f) = \frac{ha}{T} \text{sinc}(fa)$$

   to show that the zero crossover points are the frequencies k/a for integers k

   c. Express the frequencies f_k of the spectral lines X_k in terms of the period T

2. The objective of this problem is to see how doubling the amplitude h of a pulse train $x(t)$ with pulse width $a = 0.5$ msec and period $T = 1$ ms affects its spectral plot

   a. Sketch the pulse train $x_1(t)$ with $h = 2$ and $x_2(t)$ with $h = 4$ on separate graphs
   b. Make use of Matlab to plot the magnitudes of the envelopes $\left|X_{env}(f)\right|$ for $x_1(t)$ and $x_2(t)$ on the same graph
   c. Describe how doubling the amplitude of the pulse train affected the amplitude and zero crossover points of $X_{env}(f)$
   d. Now plot the magnitudes of the envelopes $\left|X_{env}(f)\right|$ on separate graphs and draw in the magnitudes of the first ten spectral lines
   e. How did doubling the amplitude of the pulse train affect the locations of the spectral lines
   f. Use Matlab to obtain the amplitudes c_k in dBV of the first ten spectral lines of the of the one-sided spectrums of the two pulse trains

3. The objective of this problem is to see how doubling the period T of a pulse train $x(t)$ with pulse width $a = 0.5$ msec and amplitude $h = 2$ affects its spectral plot

   a. Sketch the pulse train $x_1(t)$ with $T = 1$ msec and $x_2(t)$ with $T = 2$ msec on separate graphs
   b. Make use of Matlab to plot the magnitudes of the envelopes $\left|X_{env}(f)\right|$ for $x_1(t)$ and $x_2(t)$ on the same graph
   c. Describe how doubling the period of the pulse train affected the amplitude and zero

crossover points of $X_{env}(f)$

    d. Now plot the magnitudes of the envelopes $|X_{env}(f)|$ on separate graphs and draw in the magnitudes of the spectral lines

    e. How did doubling the period of the pulse train in half affect the locations of the spectral lines

    f. Use Matlab to obtain the amplitudes c_k in dBV of the first ten spectral lines of the of the one-sided spectrums of the two pulse trains

4. The objective of this problem is to see how cutting in half the pulse width a of a pulse train with amplitude $h = 2$ and period $T = 1$ msec affects its spectral plot

    a. Sketch the pulse train $x_1(t)$ with $a = 0.5$ msec and $x_2(t)$ with $a = 0.25$ msec on separate graphs

    b. Make use of Matlab to plot the magnitudes of the envelopes $|X_{env}(f)|$ for $x_1(t)$ and $x_2(t)$ on the same graph

    c. Describe how cutting the pulse width of the pulse train in half affected the amplitude and zero crossover points of $X_{env}(f)$

    d. Now plot the magnitudes of the envelopes $|X_{env}(f)|$ on separate graphs and draw in the magnitudes of the spectral lines

    e. How did cutting the pulse width of the pulse train in half affect the locations of the spectral lines

    f. Use Matlab to obtain the amplitudes c_k in dBV of the first ten spectral lines of the of the one-sided spectrums of the two pulse trains

LAB

1. The objective of these measurements is to see how doubling the amplitude h of a 1/2 duty cycle pulse train $x(t)$ with period $T_o = 1$ ms affects its spectral plot

    a. Display the pulse train with amplitude $h = 2$. Do a screen capture for your report

    b. Display 5 to 10 cycles of the pulse train on the scope and then use the scope's FFT function to measure the frequencies and amplitudes (in dBV) of the first ten harmonics of its one-sided spectrum. Save screen captures for your report. Use Excel to create a table of frequency versus amplitude dBV. Then use Matlab to make a one-sided spectral plot

    c. Now display the pulse train again but this time with amplitude $h = 4$. Do a screen capture for your report

    d. Display 5 to 10 cycles of the pulse train on the scope and then use the scope's FFT function to measure the frequencies and amplitudes (in dBV) of the first ten harmonics of its one-sided spectrum. Save screen captures for your report. Use Excel to create a table of frequency versus amplitude dBV. Then use Matlab to make a one-sided spectral plot

2. The objective of these measurements is to see how doubling the period of a 1/2 duty cycle pulse train $x(t)$ with pulse width $a = 0.5$ msec and amplitude $h = 2$ affects its spectral plot

    a. Display the pulse train with period $T_o = 1$ ms. Do a screen capture for your report

    b. Display 5 to 10 cycles of the pulse train on the scope and then use the scope's FFT function to measure the frequencies and amplitudes (in dBV) of the first ten harmonics of its one-sided spectrum. Save screen captures for your report. Use Excel to create a table of frequency versus amplitude dBV. Then use Matlab to make a one-sided spectral plot

    c. Now display the pulse train with period $T_o = 2$ ms. Do a screen capture for your report.

    d. Display 5 to 10 cycles of the pulse train on the scope and then use the scope's FFT

function to measure the frequencies and amplitudes (in dBV) of the first ten harmonics of its one-sided spectrum. Save screen captures for your report. Use Excel to create a table of frequency versus amplitude dBV. Then use Matlab to make a one-sided spectral plot

3. The objective of these measurements is to see how reducing the duty cycle of a pulse train $x(t)$ with period $T_o = 1$ ms and amplitude $h = 2$ affects its spectral plot

   a. Display the pulse train with pulse width $a = 0.5$ ms. Do a screen capture for your report
   b. Display 5 to 10 cycles of the pulse train on the scope and then use the scope's FFT function to measure the frequencies and amplitudes (in dBV) of the first ten harmonics of its one-sided spectrum. Save screen captures for your report. Use Excel to create a table of frequency versus amplitude dBV. Then use Matlab to make a one-sided spectral plot
   c. Now display the pulse train with pulse width $a = 0.25$ ms. Do a screen capture for your report.
   d. Display 5 to 10 cycles of the pulse train on the scope and then use the scope's FFT function to measure the frequencies and amplitudes (in dBV) of the first ten harmonics of its one-sided spectrum. Save screen captures for your report. Use Excel to create a table of frequency versus amplitude dBV. Then use Matlab to make a one-sided spectral plot

POSTLAB

1. Compare your calculated and measured spectrums. Put your results in clearly labeled Tables

2. Make use of your results to determine how doubling the amplitude h of the pulse train affects the following parameters. Put your results in one Table
   a. The amplitude of the envelope
   b. The zero crossover frequencies of the envelope
   c. The locations of the spectral lines

3. Make use of your results to determine how doubling the period T of the pulse train affects the following parameters. Put your results in one Table
   a. The amplitude of the envelope
   b. The zero crossover frequencies of the envelope
   c. The locations of the spectral lines

4. Make use of your results to determine how cutting in half the pulse width a of the pulse train affects the following parameters. Put your results in one Table
   a. The amplitude of the envelope
   b. The zero crossover frequencies of the envelope
   c. The locations of the spectral lines

5. Given a 1/2 duty cycle pulse train $x(t)$ with height $h = 2$, pulse width $a = 0.5$ msec and period $T = 1$ ms
   a. Sketch the pulse train
   b. Find the average normalized power P_N of $x(t)$
   c. Make use of Matlab to find the number of harmonics that must be included in the following finite sum approximation of $x(t)$

$$x(t) = \sum_{k=-N}^{N} X_k e^{j2\,kf_o t}$$

   for 95% of the average normalized power of $x(t)$. Make use of the fact that

$$P_N = \sum_{k=-}^{} |X_k|^2$$

    d. What is the cutoff frequency of an ideal lowpass filter that passes enough harmonics for 95% of the power to reach the output

6. Repeat Problem (5) for the pulse train with the same pulse width and period but twice the height $h = 4$

7. Repeat Problem (5) for the pulse train with the same pulse width and height but twice the period $T = 2$ ms

8. Repeat Problem (5) for the pulse train with the same height and period but half the pulse width $a = 0.25$ ms

9. Summarize your results in Problems (6)-(8) in a Table

10. What can you conclude from your Table in Problem (9). In particular
    a. How does increasing h affect the number of harmonics required to pass 95% of the pulse train's power
    b. How does increasing T without changing a affect the number of harmonics required to pass 95% of the pulse train's power
    c. How does decreasing a without changing any of the other parameters affect the number of harmonics required to pass 95% of the pulse train's power