# ECE478 Lab 2 Report

Representation of Signals and Systems using MATLAB

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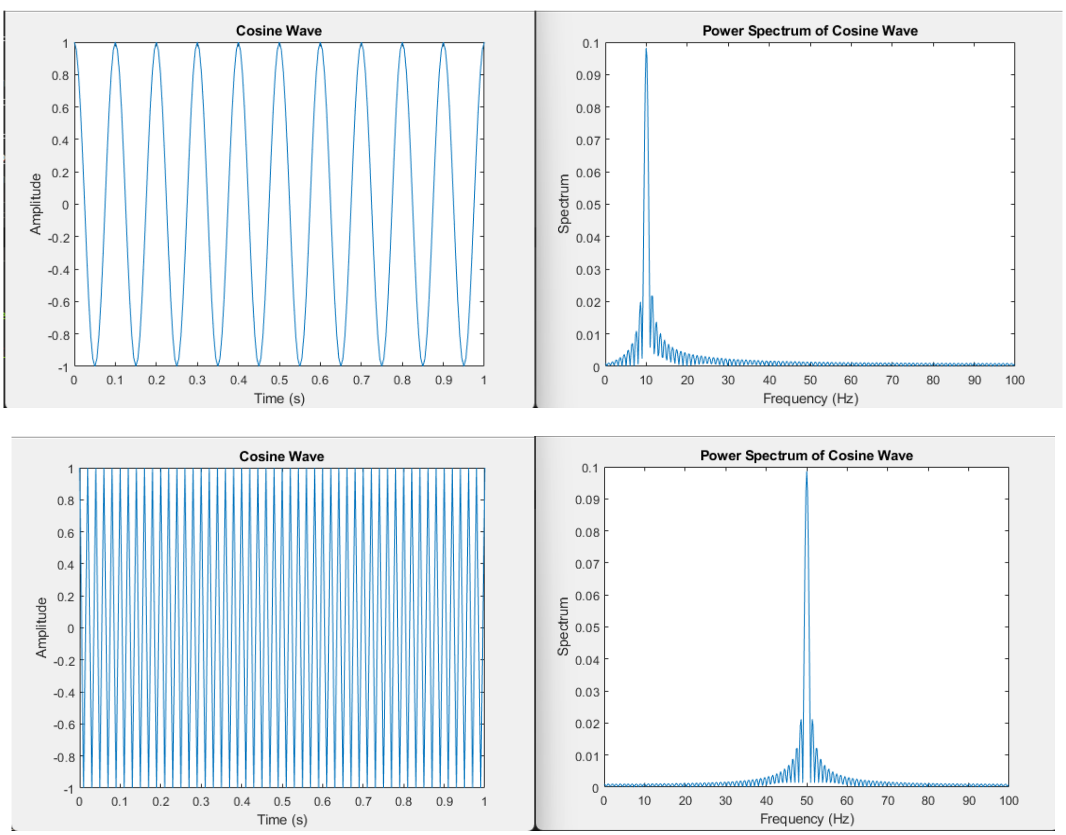
ABSTRACT:

The following software experiment explored frequency analysis algorithms (Fast Fourier Transform) to model systems and quickly simulate them in MATLAB. Then, equipped with this skill, we move forward to analyzing the triangle wave and how it responds to a simple modulation scheme.

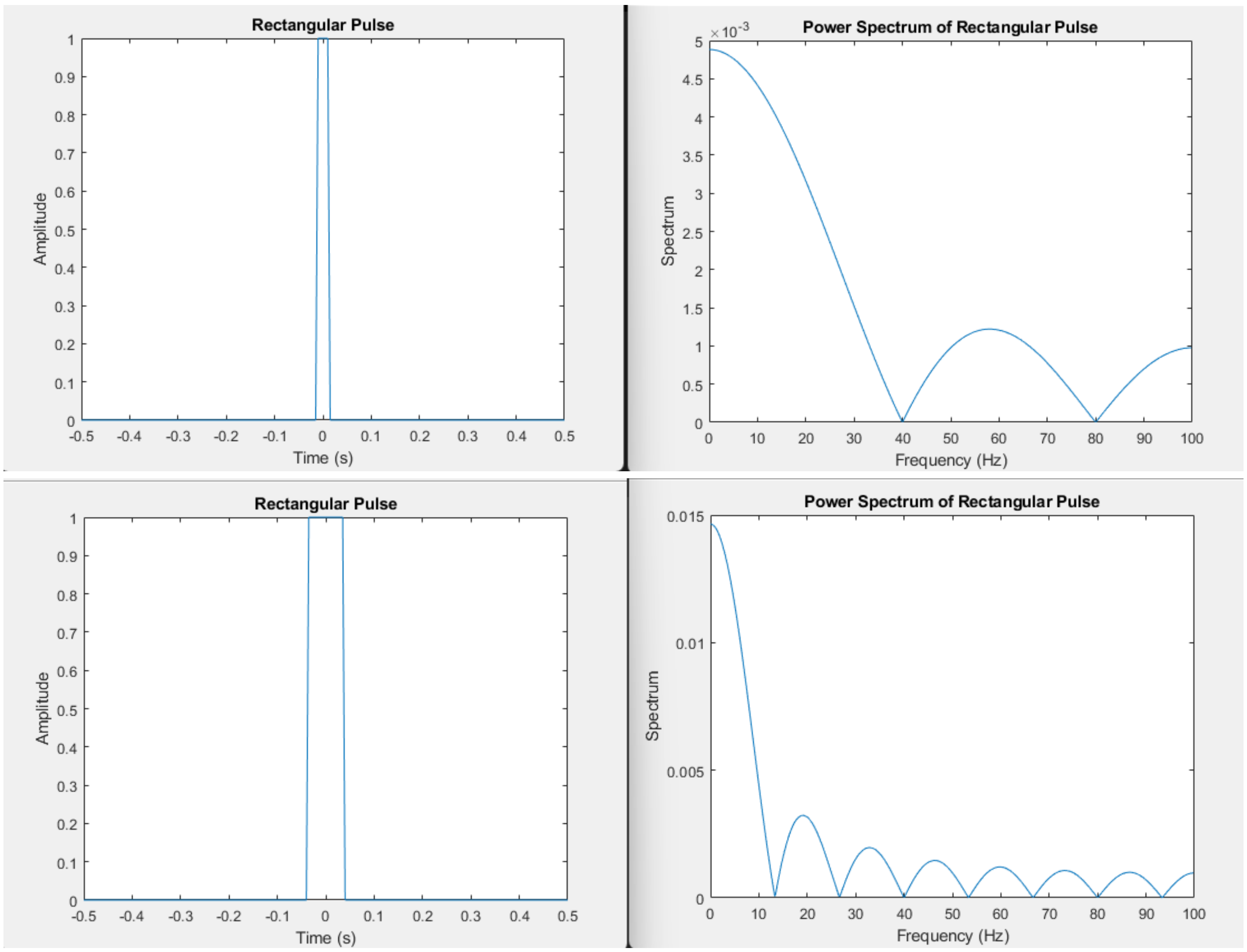
# EXAMPLES

## Exercise 1 (Example 01: Cosine Wave):



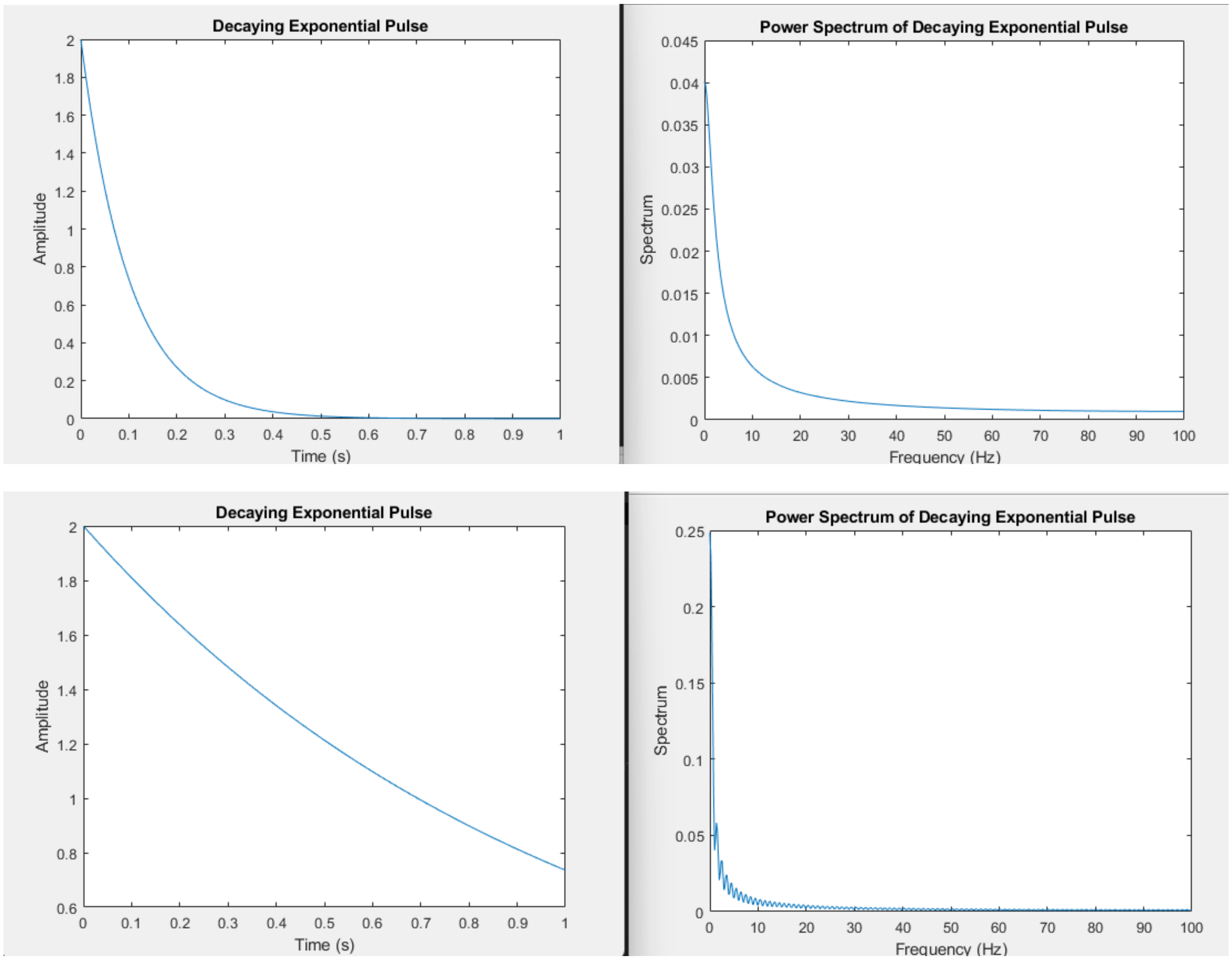
Here, we can see cosine waves and their amplitude spectrums. The first cosine has a frequency of 10Hz, and we via a change of variable shift the main frequency content to 50Hz with the second cosine wave.

## Exercise 2 (Example 02: Rectangular Pulse):

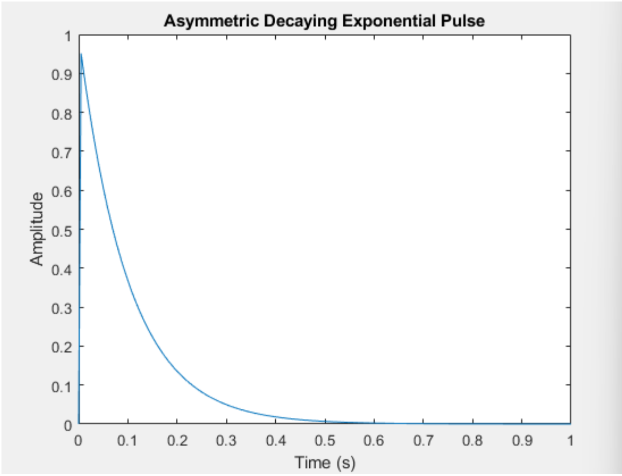


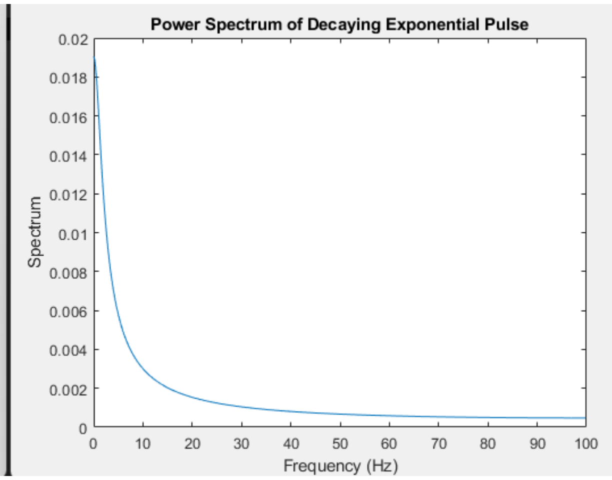

Here I increase $T_0$ from 0.025 to 0.075, which widens the signal in the time-domain, but the signal response inversely in the frequency domain, as the bandwidth narrows. This highlights the tug-and-pull of the two domains; time-duration is inversely proportional to bandwidth.

# Exercise 3 (Example 03: Exponential Decaying Pulse):



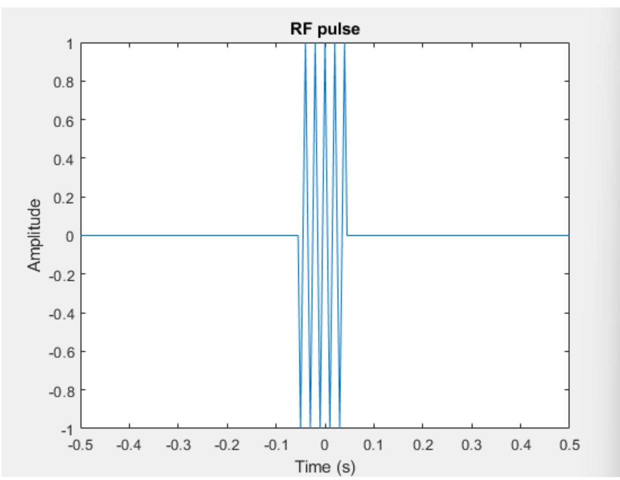

Here the value a for the decaying exponential drops from 10 to 1. The slower the decay of the signal in the time-domain, we see tighter frequency content, and more oscillations in the amplitude spectrum itself.

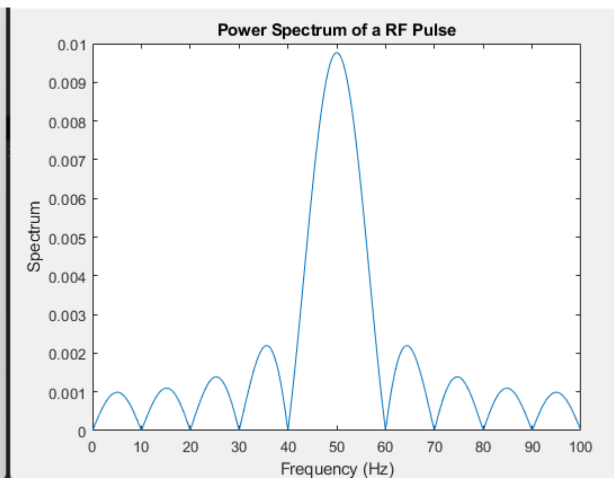


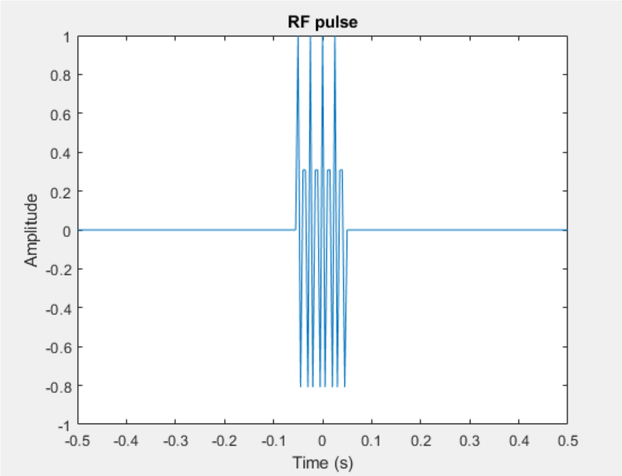



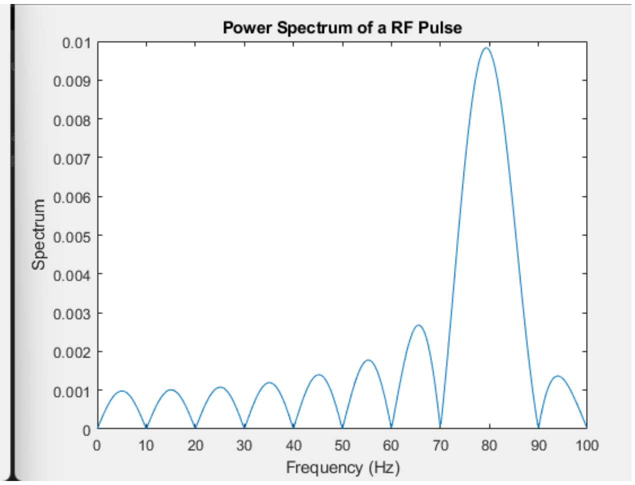

This is the time-domain signal and amplitude spectrum for the asymmetric double exponential function.

## Exercise 4 (Example 04: Frequency Shifting):





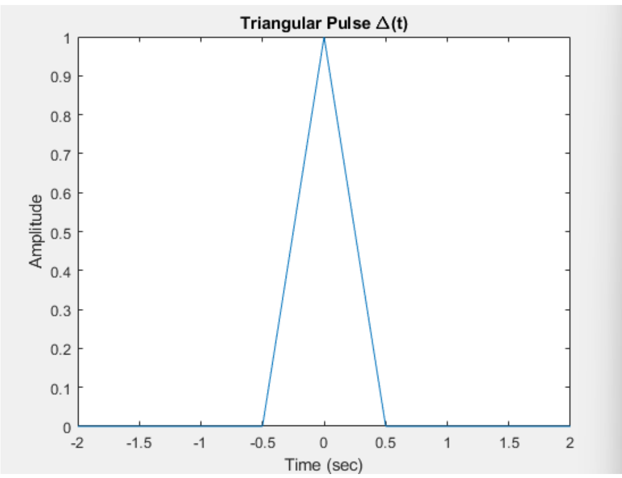

Here we have two rectangular pulses that are multiplied by cosine waves to shift their frequency content. Both in the frequency domain, which have positive sinc amplitude spectrums, move away from the baseband to 50Hz and 80Hz, respectively.

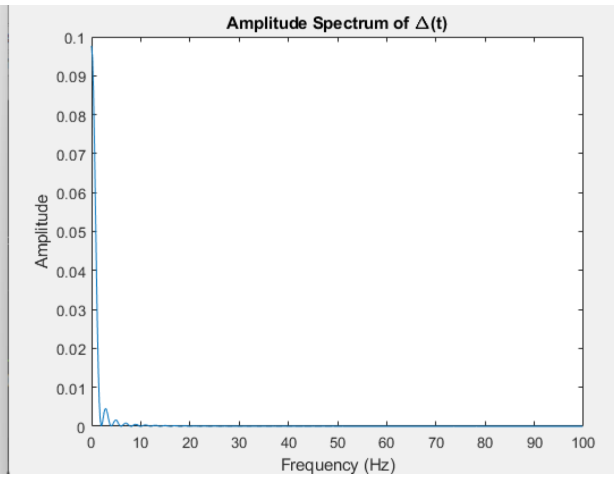
# LAB EXERCISE: RF Pulses...

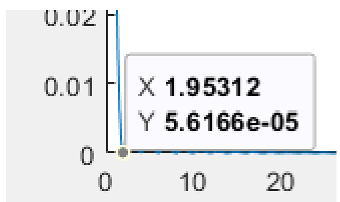
```
% ECE478 LAB 2
% ENGINEER: CHASE LOTITO

Fs = 200;                   % SAMPLE FREQ.
t = -2:1/Fs:2;              % LINEAR SPACE FOR TIME
T0 = 1;                     % WIDTH OF TRI PULSE
x = tripuls(t, T0);         % GENERATE TRI PULSE
xprime = tripuls(t/2, T0);

% PLOT THE TRIANGULAR PULSE
figure(1);
plot(t, x);
title('Triangular Pulse \Delta(t)');
xlabel('Time (sec)');
ylabel('Amplitude');

nfft = 1024;                % FFT LENGTH
X = fft(x, nfft);           % PERFORM FFT on x(t)
X = X(1:nfft/2);            % TAKE POSITIVE SPECTRUM`
mx = abs(X/nfft);           % AMPLITUDE SPECTRUM
f = (0:nfft/2-1)*Fs/nfft; % FREQ. VECTOR

% PLOT AMPLITUDE SPECTRUM
```

```
figure(2);
plot(f, mx);
title('Amplitude Spectrum of \Delta(t)');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% MODULATE VIA FREQ TRANSLATION
fc = 50;
y = x .* cos(2 * pi * fc * t);
yprime = xprime .* cos(2 * pi * fc * t);

% PLOT MODULATED TIME DOMAIN SIGNAL
figure(3);
plot(t,y);
title('\Delta(t)cos(2\pif_ct)');
xlabel('Time (sec)');
ylabel('Amplitude');

nfft = 1024;            % FFT LENGTH
Y = fft(y, nfft);       % PERFORM FFT on x(t)
Y = Y(1:nfft/2);        % TAKE POSITIVE SPECTRUM`
my = abs(Y/nfft);       % AMPLITUDE SPECTRUM
f = (0:nfft/2-1)*Fs/nfft; % FREQ. VECTOR

% PLOT MODULATED AMPLITUDE SPECTRUM
figure(4);
plot(f, my);
title('Amplitude Spectrum of \Delta(t)cos(2\pif_ct)');
xlabel('Frequency (Hz)');
ylabel('Amplitude');


% FOR THE /\(T/2) SIGNAL

% PLOT MODULATED TIME DOMAIN SIGNAL
figure(5);
plot(t,yprime);
title('\Delta(t/2)cos(2\pif_ct)');
xlabel('Time (sec)');
ylabel('Amplitude');

nfft = 1024;            % FFT LENGTH
Yprime = fft(yprime, nfft);       % PERFORM FFT on x(t)
Yprime = Yprime(1:nfft/2);        % TAKE POSITIVE SPECTRUM`
myprime = abs(Yprime/nfft);       % AMPLITUDE SPECTRUM
f = (0:nfft/2-1)*Fs/nfft; % FREQ. VECTOR
```

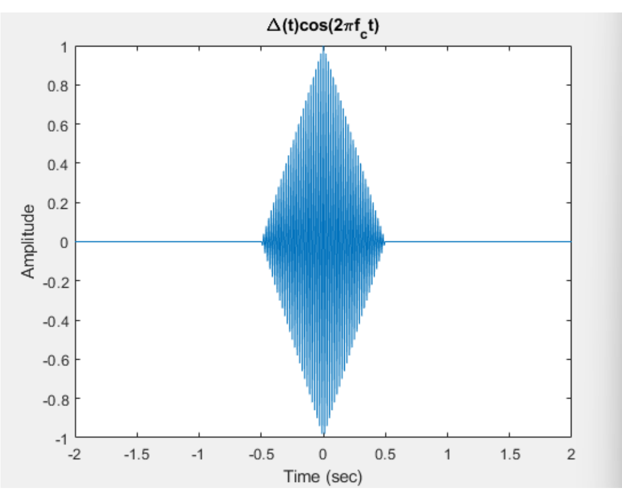
```
% PLOT MODULATED AMPLITUDE SPECTRUM
figure(6);
plot(f, myprime);
title('Amplitude Spectrum of \Delta(t/2)cos(2\pif_ct)');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```

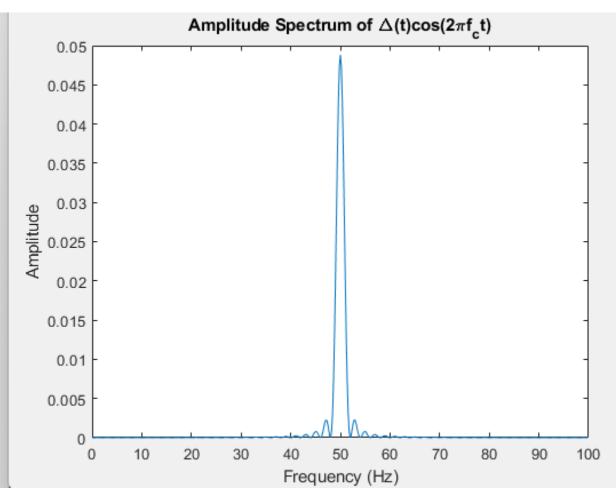


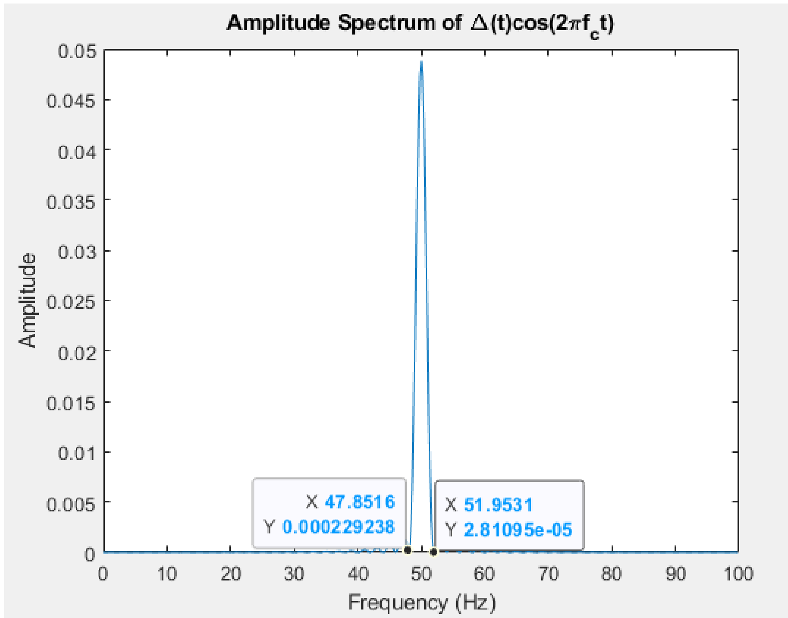




Here, for the triangular signal as a baseband signal which has a bandwidth of 1.953 Hz, where theoretically, the bandwidth should be 2 Hz. So, the minimum bandwidth requirement for this signal is 1.953Hz.

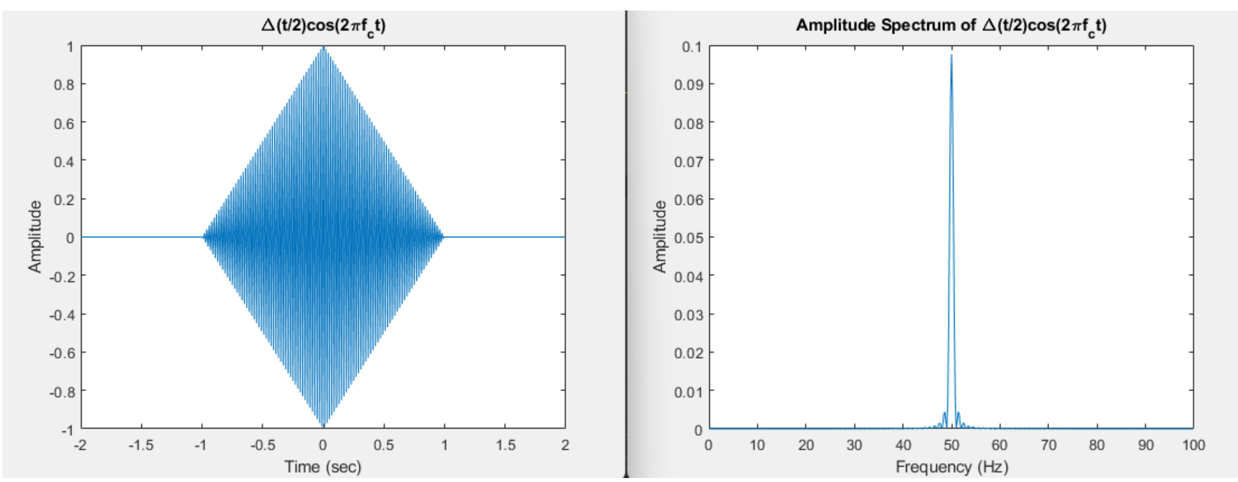


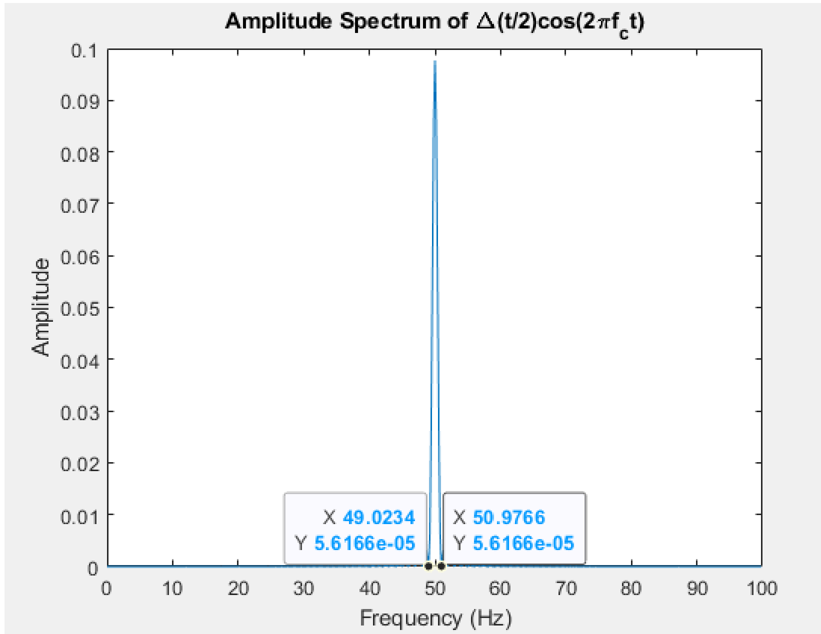
Here we can see the modulated triangular pulse which is shifted in the frequency domain to 50Hz (1680 kHz was too large to capture given the discrete nature of our program)–turning the frequency content into a bandpass signal.




Here, we see the null-to-null bandwidth is 4.1015 Hz, requiring a channel of width at least 4.1015 Hz to capture most of the frequency content of the modulated signal.




Here is the time-domain signal and amplitude spectrum of the modulated triangular pulse which was doubled in width in the time-domain. As expected, the stretched time-signal is shrunk in the frequency-domain.




Here, the shrunk frequency domain representation now only takes up a null-to-null bandwidth 1.953 Hz. So, as the time-domain signal is doubled in width, the bandwidth is halved. This saves critical bandwidth resources to send effectively the same information.

The Federal Communications Commission (FCC) tightly regulates the electromagnetic spectrum for wireless communications as communications channels are vital to modern infrastructure and scarce. Because of this, bandwidth is incredibly costly, so its use needs to be highly optimized.

In designing this communications system, it is more likely that I would design it to transmit the wider triangular pulse, as it saves double the space in the communications channel. However, it costs more energy, as the carrier needs to be sustained over twice the signal in the time-domain, which has environmental impacts (depending on the content of the energy source at hand). We cannot get a free lunch here, so in more critical applications, more energy needs to be spent to pack more information in smaller bandwidths.

In a large and complex society, we must as one people sacrifice energy resources to have tighter communications, which is infrastructure built by engineers to save lives and allow for more people to become connected. On the world front, bandwidth-efficient communications are vital to globalism–contested or not.