ELEG 4143: Project 01: Amplitude-Shift Keying (ASK) Signal Frequency Distribution

Due: September 9, 2022

In Amplitude-Shift Keying, also called On-Off Keying (OOK), binary data is encoded with double-sideband suppressed carrier (DSB-SC) modulation, $\phi(t) = m(t)\cos(2\pi f_0 t)$, where binary "1" turns on the carrier signal and a binary "0" turns it off. In this case, the message signal, m(t), is a rectangular pulse as shown in Figure 1. ASK modulation is typically used in fiber optics.

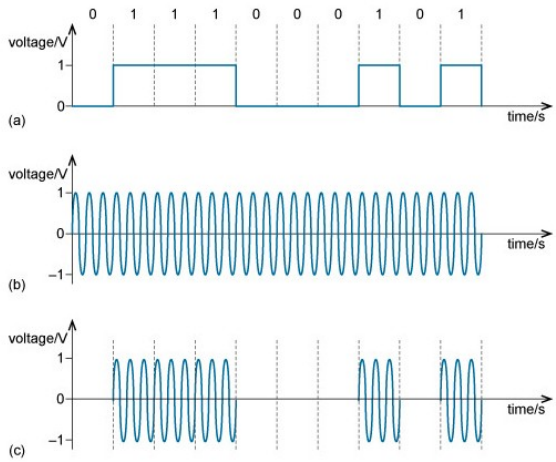

Figure 1: Amplitude-Shift Keying waveforms.[1]

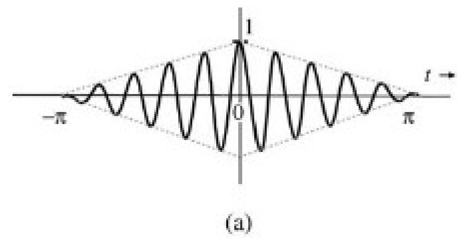

Figure 2: Triangular ASK pulse.[2]

The ASK modulation requires a bandwidth for transmission based on the duration and shape of the pulse. In this project the bandwidth requirements will be investigated for both the rectangular and triangular shaped pulses. An example of the triangular shape ASK pulse is shown in Figure 2.

In double-sideband suppressed carrier communications the frequency distribution, or spectrum, of the modulated signal, equation 1, is shown in equation 2 where M(f) is the Fourier Transform of m(t).

$$\phi(t) = m(t)\cos(2\pi f_0 t) \tag{1}$$

$$\Phi(f) = \frac{1}{2}\left[M(f+f_0) + M(f-f_0)\right] \tag{2}$$

Use the signal parameters provided in problem 3.3-7 as shown in Figure 2. The carrier frequency is $\omega_0 = 10$ rad/sec and $\tau = 2\pi$.

The spectrum of the triangular and rectangular pulses in ASK modulation are shown in Figures 3 and 4. The spectra are compared in Figure 5. Note that the rectangular pulse spectrum has center peak that is narrower than the triangular pulse spectrum, the side-lobes in the triangular pulse spectrum fall off more rapidly than in the rectangular pulse spectrum. Therefore a triangular shaped ASK pulse signal would require less bandwidth to transmit information than a rectangular shaped ASK pulse signal.

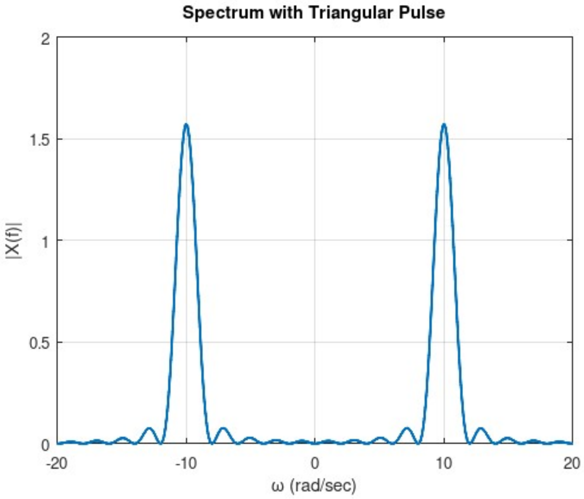

Figure 3: Triangular pulse ASK spectrum.

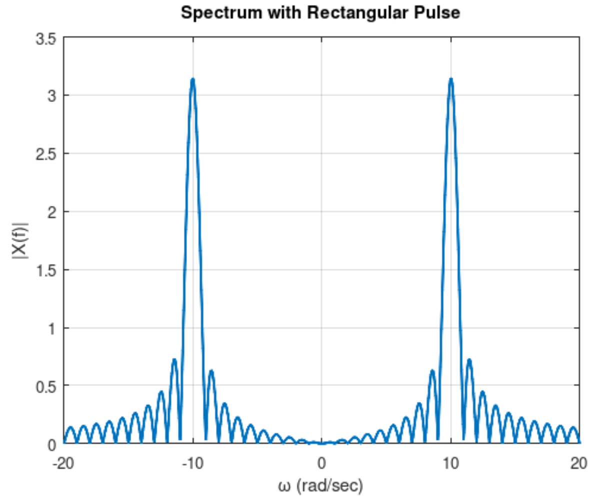

Figure 4: Rectangular pulse ASK spectrum.

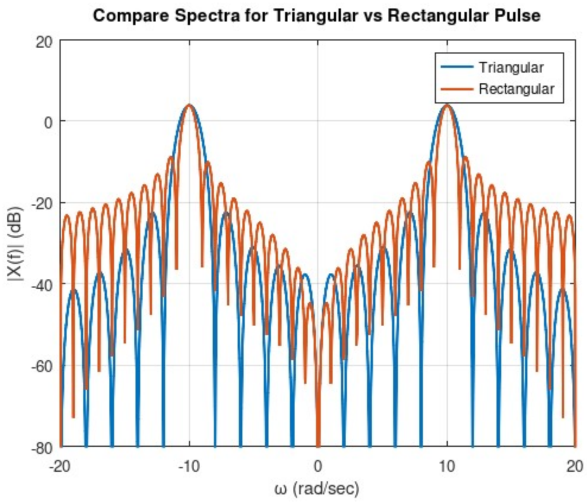

Figure 5: Comparison of triangular and rectangular shaped pulses in ASK communication.

The equation for the triangular ASK spectrum is given in equation 3 with τ=2π.

$$\begin{aligned} X1(f) &= \frac{1}{2}\left[M(f+f_0) + M(f-f_0)\right] \\ &= \frac{\tau}{4}\left[sinc^2\left(\frac{\pi\tau}{2}(f+f_0)\right) + sinc^2\left(\frac{\pi\tau}{2}(f-f_0)\right)\right] \\ &= \frac{\pi}{2}\left[sinc^2\left(\pi^2\left(f+\frac{10}{2\pi}\right)\right) + sinc^2\left(\pi^2\left(f-\frac{10}{2\pi}\right)\right)\right] \end{aligned} \tag{3}$$

And the equation for the rectangular ASK spectrum is given in equation 4.

$$\begin{aligned} X2(f) &= \frac{\tau}{2}\left[sinc(\pi\tau(f+f_0)) + sinc(\pi\tau(f-f_0))\right] \\ &= \pi\left[sinc\left(2\pi^2\left(f+\frac{10}{2\pi}\right)\right) + sinc\left(2\pi^2\left(f-\frac{10}{2\pi}\right)\right)\right] \end{aligned} \tag{4}$$

The MATLAB code to produce the triangular ASK spectrum, Figure 3, is provided. Add code to create the code to create the rectangular ASK spectrum, Figure 4, and the comparison as shown in Figure 5. The magnitude of spectrum of the rectangular ASK signal will be twice that of the triangular ASK signal spectrum. The magnitude of rectangular ASK spectrum was reduced by a factor of two to allow the peak magnitudes for both to be the same as shown in Figure 5. All figures must have titles, x and y axis labels and legends where appropriate.

Important, Recall in MATLAB: $sinc(x) = \frac{\sin(\pi x)}{\pi x}$

```
%% Project 1 – 2022
% Find the Spectrum of Triangular and Rectangular modulated pulses and compare
clear; close all; clc;
w0 = 10;            % Carrier frequency (rad/sec)
f0 = w0/(2*pi);     % Carrier frequency (Hz)
Wmax = 20;          % Maximum frequency (rad/sec)
Fmax = Wmax/(2*pi); % Max frequency (Hz)

%% Triangular Pulse
f = linspace(-Fmax,Fmax,1000);
% Remember in MATLAB sinc(x) = sin(pi x)/(pi x)
X1 = (pi/2)*(sinc(pi*(f + f0)).^2 + sinc(pi*(f - f0)).^2);
figure()
plot(2*pi*f, abs(X1), 'LineWidth',2);grid      % x-axis in rad/sec
xlabel('\omega (rad/sec)'); ylabel('|X(f)|')
title('Spectrum with Triangular Pulse')

%% Rectangular Pulse
%  Add code beginning here
```

Publish the results as a single pdf document and upload to Blackboard. One submission per group.

References:

1. 1.4 Amplitude-shift keying (ASK), OpenLearn, https://www.open.edu/openlearn/science-maths-technology/exploring-communications-technology/content-section-1.4
2. B P Lathi, Zhi Ding. Modern Digital and Analog Communications (5th ed). Oxford University Press, 2018.