Lab 10 - BPSK Modulation

Edward Enriquez
ECE 4705-L

Introduction:

Background Theory

Binary phase shift keying (BPSK) is a digital modulation scheme. It represents the '1' logic as an in phase (0° phase shift) sinusoid and a '0' logic as a phase shifted (180° phase shift) sinusoid. Below are the equations representing each binary bit in BPSK.

$$s_1(t) = A_c cos(2\pi f t) \quad 0 \leq t \leq T_b \ for\ binary\ 1$$

$$s_0(t) = A_c cos(2\pi f t + \pi) \quad 0 \leq t \leq T_b \ for\ binary\ 0$$

Phase shift keying in general represents a sequence of bits as a specific phase shifted carrier. For example, 8-PSK encodes 3 bits using 8 distinct phase shifts. Variations of this common phase shift keying scheme is differential phase shift keying or DPSK where a '1' bit will cause a phase change from the previous bit, but a '0' bit will cause no phase change from the previous bit.

Prelab:

A binary phase shifted signal could be thought of as the product of a simple sinusoidal carrier with the message digital signal, so long as the digital signal is centered at 0 and alternates from -1V and 1V. Thus when the digital signal is low, the carrier will be multiplied by -1V creating a 180° phase shift and when the digital signal is high, the carrier will be multiplied by 1V creating no shift in the sinusoidal carrier.

Since the BPSK signal is the product of the carrier and the digital stream, the spectrum of a BPSK signal will be the convolution of the signals' spectra. The spectrum of the carrier is simply two peaks at f_c and $-f_c$ with a magnitude of half the amplitude carrier. The digital bit stream could be approximated as a ½ duty cycle square wave with 0 DC offset. The spectrum of the digital stream will thus be a series of peaks at every other integer multiple of the square wave's fundamental frequency. There will be no peak at 0 Hz as the DC offset is removed. Convoluting these two spectrums together, we get the same sinc scaled peaks from the square wave but shifted to the carrier frequency. There will be no peak at the carrier frequency as there was no peak at 0 Hz before the convolution.

Lab:

In the lab a 10kHz squarewave and 50kHz squarewave was modulated using PSK. The sinusoidal carrier was set to 500kHz. The signal generation and modulation was performed on the Rigol DG Digital Generator.

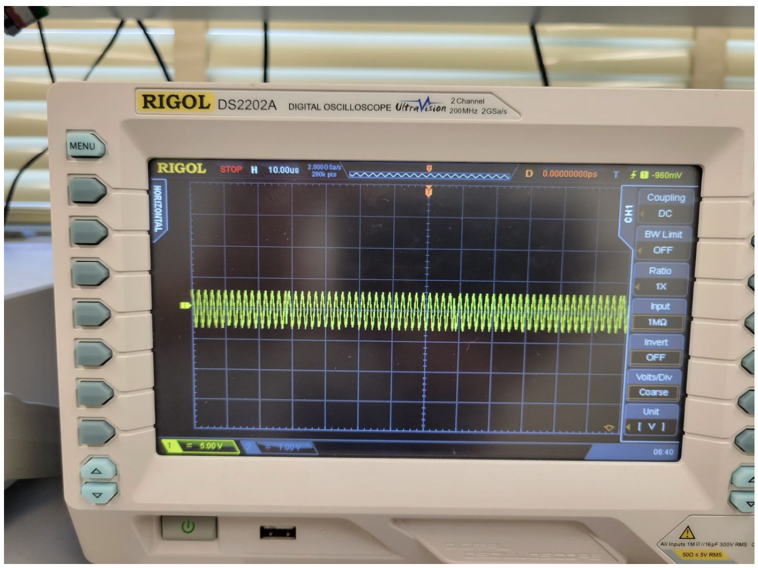

Figure 1 - PSK Modulated 10kHz Square Wave

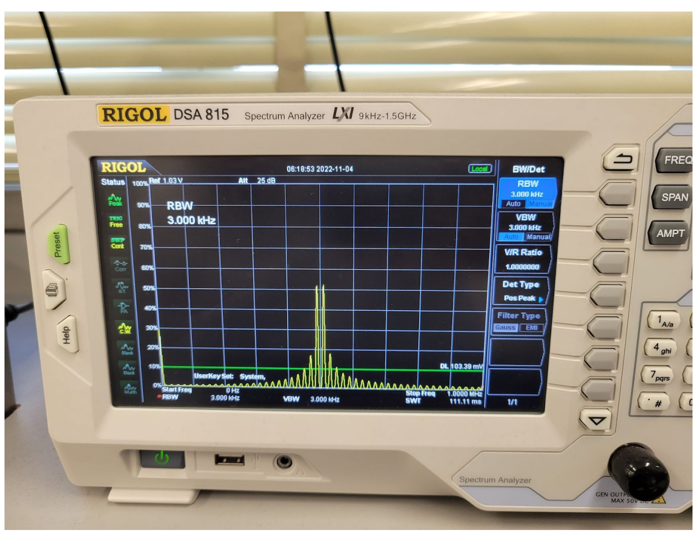

Figure 2 - PSK Modulated 10kHz Square Wave Spectrum

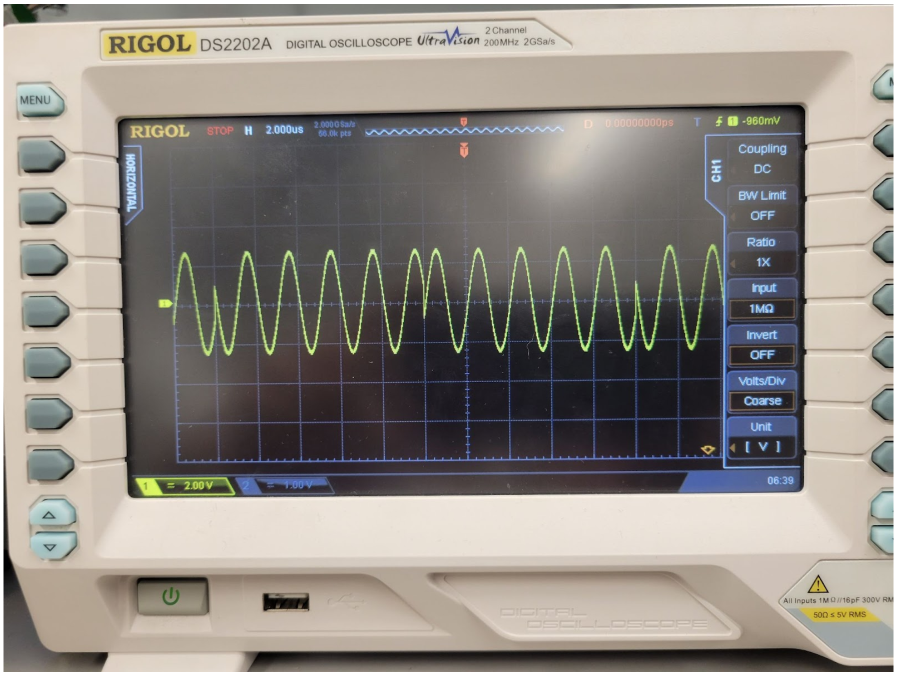

Figure 3 - PSK Modulated 50kHz Square Wave

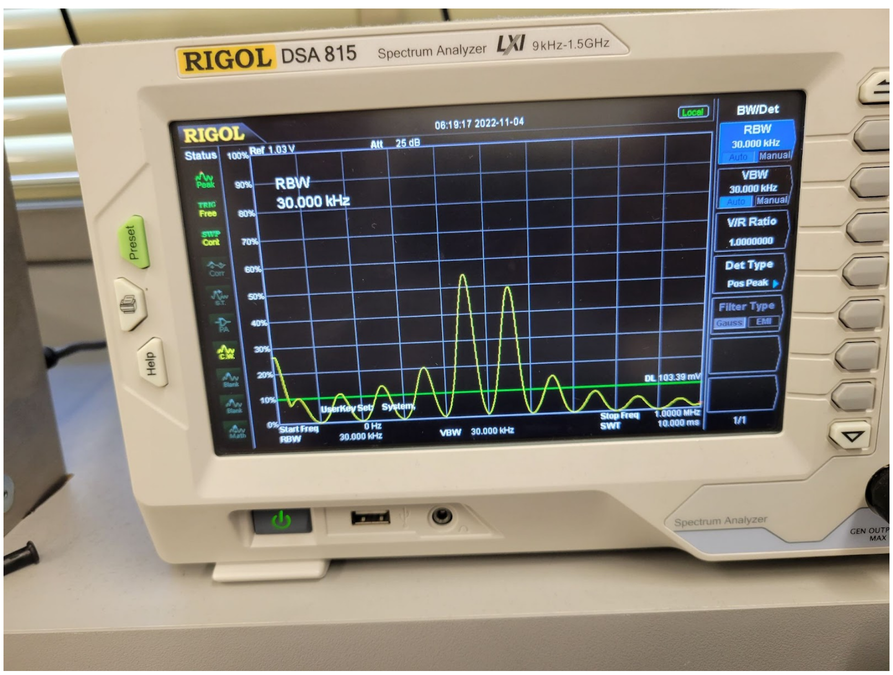

Figure 4 - PSK Modulated 50kHz Square Wave Spectrum

Conclusion:

Both the spectrum of the 10kHz and the 50kHz squarewave show the expected sinc scaled peaks centered at the carrier frequency of 500kHz. As discussed above, this is due to the convolution of the digital signal's discrete sinc spectrum with the carrier's singular peak spectrum. As there was no DC offset in the digital signal, there is no center peak at 500kHz.

The peaks of the 10kHz modulated wave were closer together than those of the 50kHz modulated wave. This is because the peaks are separated by every other multiple integer of the digital signal's fundamental frequency. The larger the fundamental frequency, the more far apart the peaks will become; the spectrum spreads out more.

Increasing the frequency or bit rate of the digital signal will spread its spectrum in the frequency domain. In communication, this is sometimes done on purpose. A digital signal can be made to run at a higher rate than the rate of transmitted data. This is called spectrum spreading and a common way to do it is by XORing the original signal with a higher bit rate digital signal which outputs a pseudorandom code. Usually the pseudorandom code is sent at a bit rate which is an integer multiple of the original signal's bit rate so that each bit of the original signal is XORd with a full copy of the code. Spreading spectrum methods are done to prevent interference, prevent jamming, lower signal power density, and to enable forms of multiple-access communication.

One such form of multiple-access communication is CDMA (code-division multiple access). This is where each signal to be sent is processed and spectrum spread with a particular code unique to the signal. The codes are mutually orthogonal to each other. This allows the signals to be sent over the same channel and still be able to be decoded and distinguished from one another. The process of embedding the code in the processed signal will cause spectrum spread.