Lab 9 - FSK Modulation Edward Enriquez
ECE 4705-L

Introduction:

Background Theory

Frequency shift keying (FSK) is a modulation scheme for encoding a digital bit stream into an analog carrier. This type of modulation changes the frequency of the carrier signal depending on whether the current state of the bit stream is binary “1” or binary “0”. This is similar to FM modulation with the condition that the message signal only has two discrete values and changes from each value instantaneously. Some of the same properties which are used to describe FM modulation could be used to describe FSK, like max frequency deviation and frequency sensitivity. In both cases, the instantaneous frequency of the modulated signal at any given point in time is proportional to the voltage of the message signal by the equation $f_i(t) = f_c + k_f m(t) = f_c + \Delta f$. Δf is the frequency deviation which varies with the signal and k_f is the frequency sensitivity factor. In an FM modulated signal, Δf would be a continuous function, but in FSK Δf could only be two values as the digital message could only be high or low. In practice, the bit stream is shifted down so that the high and low of the bit stream could correspond to voltages of the same magnitude but different signs. This is done so that the corresponding frequencies of the modulated signals could be equidistant to the original carrier frequency. In the lab, an FSK could be constructed using an VCO oscillator with the preprocessed digital signal as the input. The spectrum of a FSK modulated wave will be the spectrum of a square wave copied at two distinct instantaneous frequencies.

Prelab

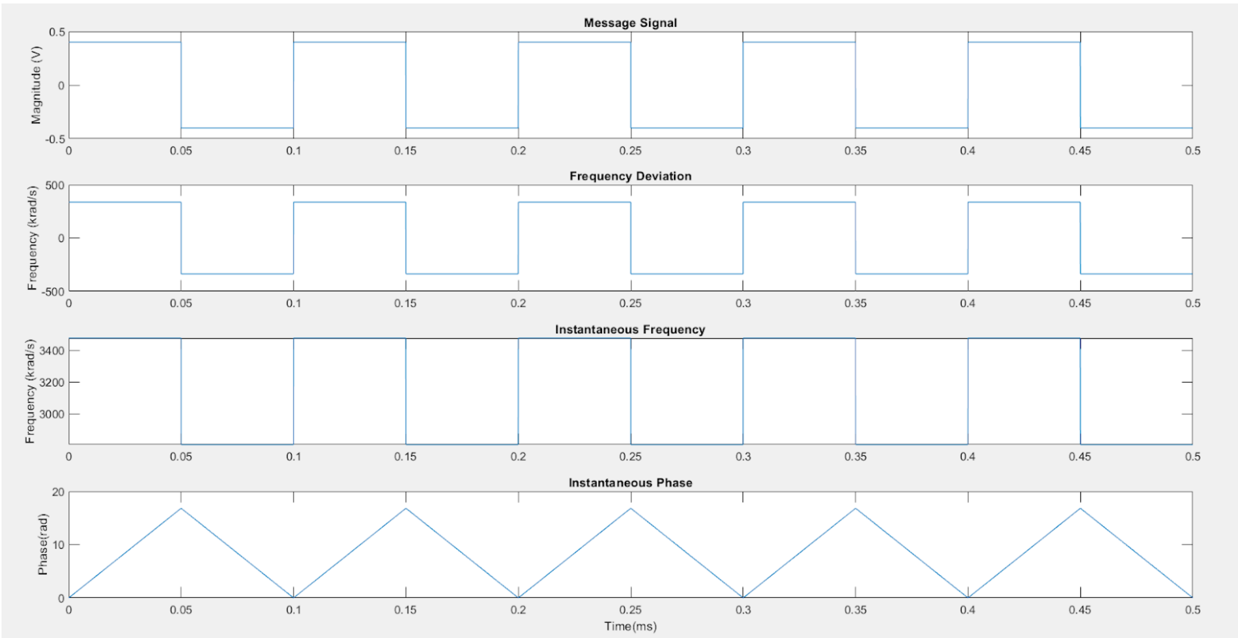
In the prelab, the frequency deviation, instantaneous frequency, instantaneous phase, modulated signal, and spectrum plots were all calculated.

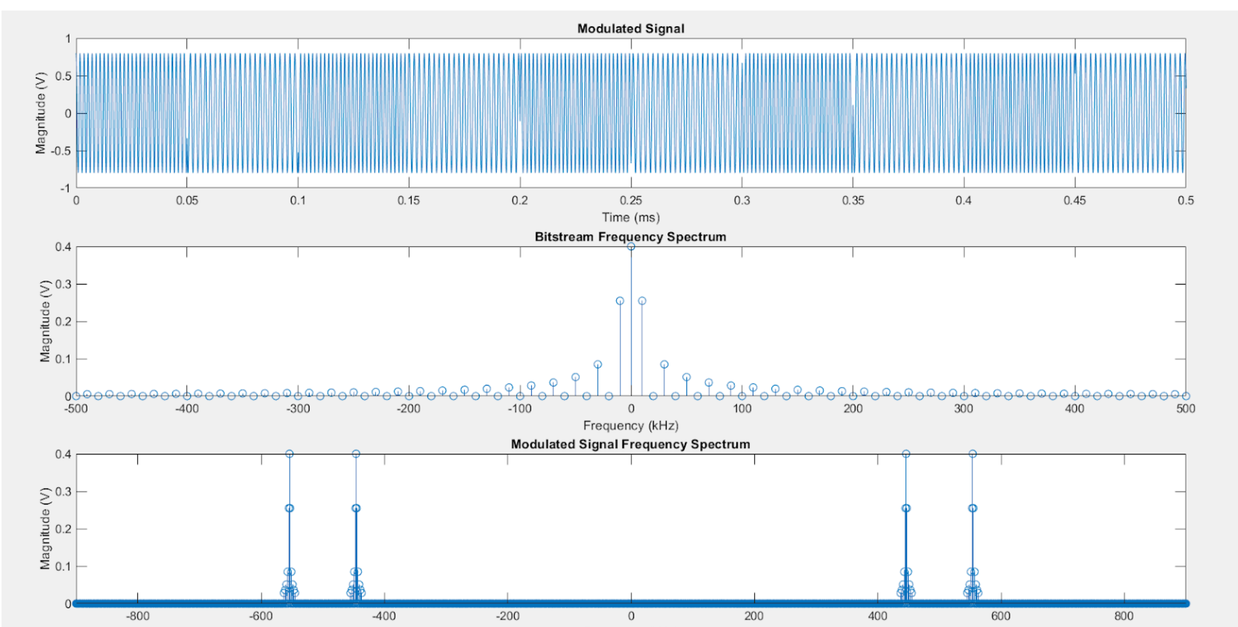
With a given k_f or f_d value of 134 kHz/V and a value of .4V and -.4V corresponding to binary "1" and "0", the Δ_ω (angular frequency sensitivity) was found to be $(2\pi \frac{rad}{cycle})\,(134 \frac{kHz}{V}) = 841,946 \frac{rad/s}{V}$. This means the maximum frequency deviation will be $(2\pi \frac{rad}{cycle})(134kHz)(.4V) \simeq 337,000 \frac{rad}{s}$. The frequency deviation will alter from $337,000 \frac{rad}{s}$ and -$337,000 \frac{rad}{s}$ depending on the bit value.

With a carrier frequency of 500kHz or angular frequency of $3,141,592 \frac{rad}{s}$, the instantaneous frequency jumped from values $3,141,592 \frac{rad}{s} + 337,000 \frac{rad}{s} = 3,478,592 \frac{rad}{s}$ and $3,141,592 \frac{rad}{s} - 337,000 \frac{rad}{s} = 2,804,592 \frac{rad}{s}$.

The instantaneous phase is equal to the frequency deviation times the integral of the message signal. The integral of the message signal for a given bit is the period of a single bit multiplied by its voltage value. With a square wave frequency of 10kHz, each bit takes .05ms. This means the area under each bit (integral of each bit) is $(.00005\, s)(.4V) = .00002\, Vs$. Multiplying by Δ_ω we get $841,946 \frac{rad/s}{V}\,(.00002\, Vs) = 16.838\, rad$. This is the maximum value for the instantaneous phase. For every bit of an alternating bit stream, the instantaneous phase will increase linearly to this value for binary "1" then decrease to 0 rad for binary "0".

From previous labs we know that the spectrum of a ½ duty cycle square wave will be sinc peaks at every other multiple integer of the signal fundamental frequency or in this case 10kHz. For the FSK signal, this same spectrum will be shifted to the two instantaneous frequencies. In the plots below angular frequency is used for the time domain plots (y-values), but cyclic frequency is used in the frequency domain plots (x-values).





Lab:

In the lab, the 10kHz square wave was inputted into the VCO with a carrier frequency of 500kHz. The resulting signal is shown in the oscilloscope. The spectrum of the output signal was also captured. Then the amplitude of the square wave was altered to compare the effects in both the time domain and frequency domain.

Figure 1 - Controlled FSK Modulated Signal

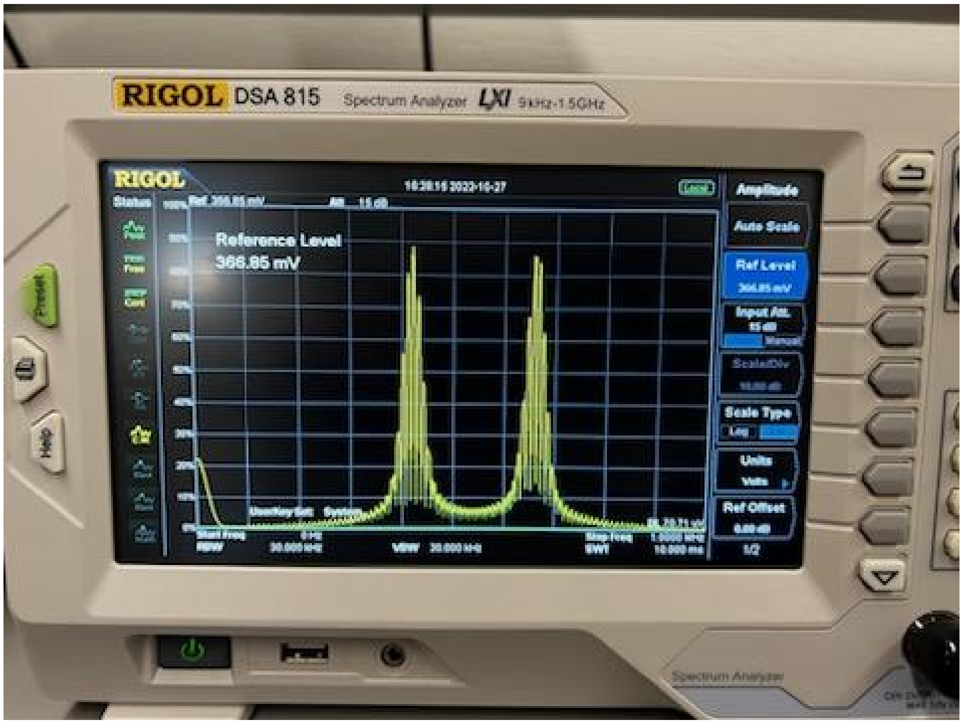


Figure 2 - Controlled FSK Modulated Signal Spectrum

Figure 3 - Lowered Amplitude Square Wave Properties

Figure 4 -Lowered Message Amplitude FSK Modulated Signal

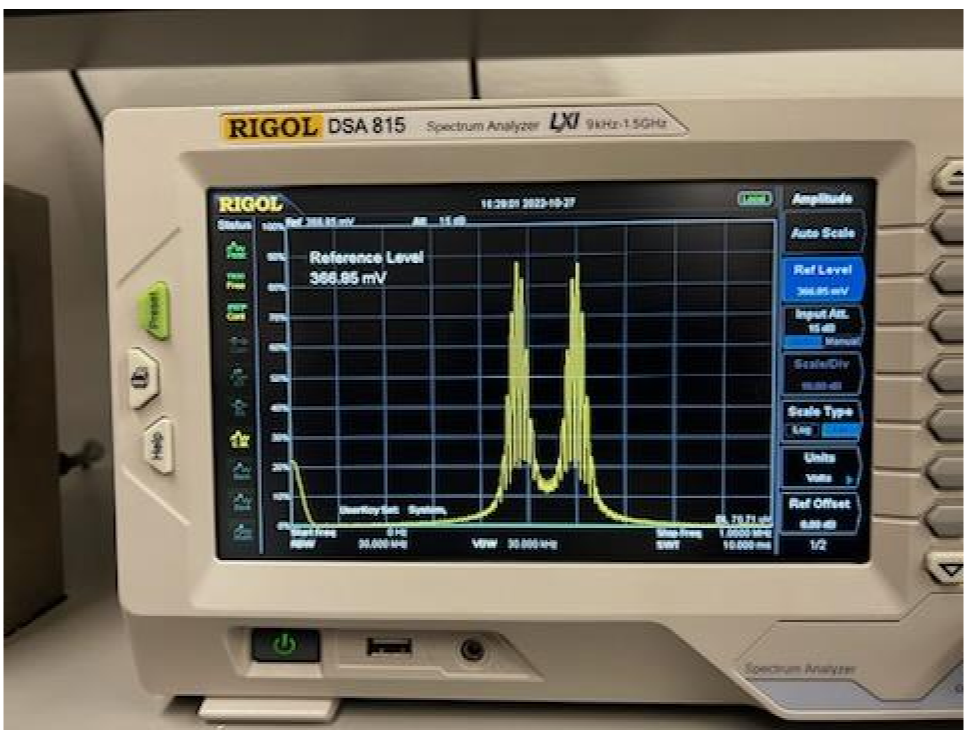


Figure 5 -Lowered Message Amplitude FSK Modulated Signal Spectrum

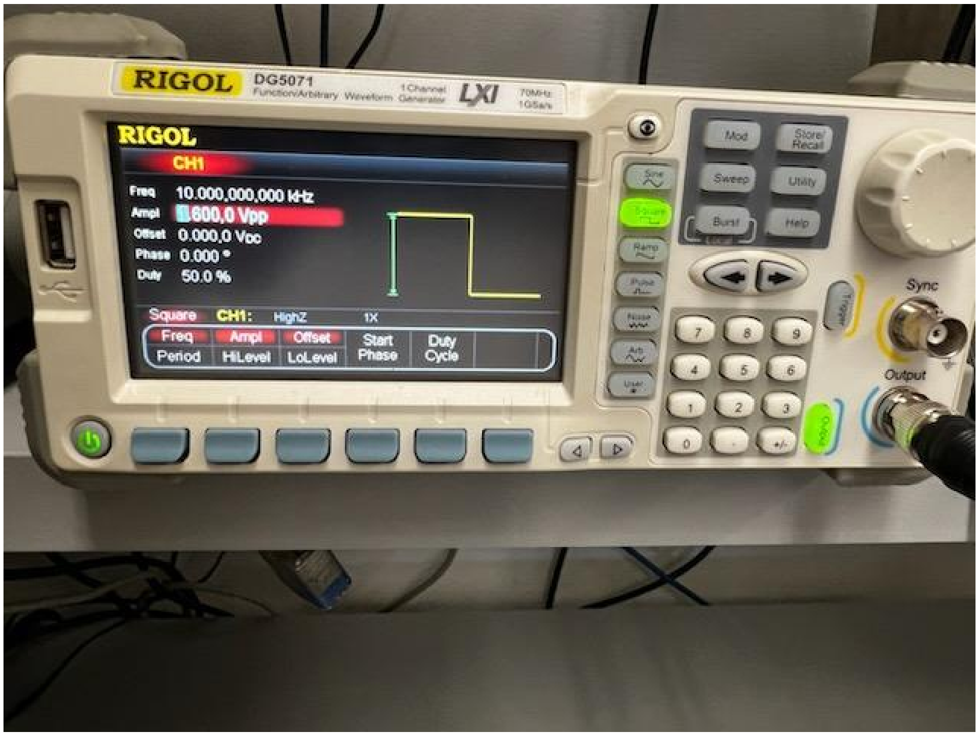


Figure 6 -Increased Amplitude Square Wave Properties

Figure 7 -Increased Message Amplitude FSK Modulated Signal

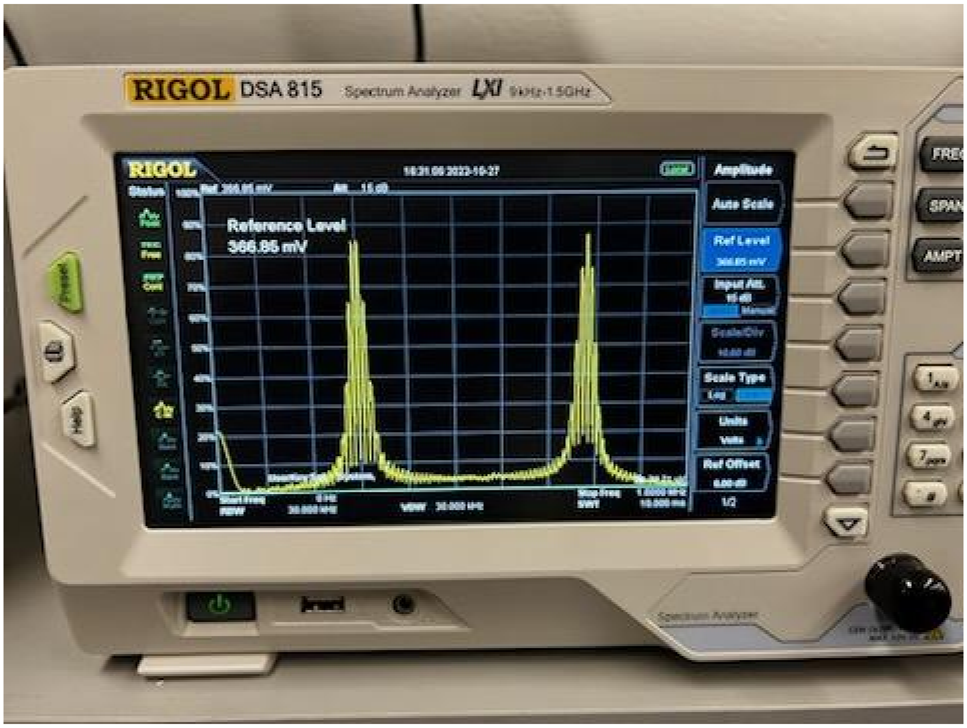


Figure 8 -Increased Message Amplitude FSK Modulated Signal Spectrum

Conclusion/Analysis:

The modulated signals in the time domain demonstrated the expected FSK characteristics regardless of message amplitude. The signal alternated between a low and high frequency value depending on whether the message was high or low at a given point. The frequency spectrum for the controlled case had the two sinc function spectra centered at the two instantaneous frequencies of the modulated signal. Each peak of the sinc spectra were 10kHz apart.

When the message amplitude was decreased, it was more difficult to distinguish the changes in frequency. This is because as the amplitude decreased, the maximum frequency deviation also decreased as the message maximum is directly proportional to frequency deviation by sensitivity factor k_f. This means that the frequency which the modulated signal takes for a low or a high bit is not much different from the original carrier frequency and embedded digital stream is harder to distinguish. In the frequency domain, the two peaks of the original spectrum came closer together. This makes sense as discussed in the background theory, the peaks are centered at the two distinct instantaneous frequencies of the modulated signal. Since the frequency deviation has decreased and the instantaneous frequencies are the carrier frequency plus or minus the frequency deviation, the difference of the two frequencies decreases. This means the peaks will come closer together. Lowering the amplitude will decrease the total bandwidth.

When the message amplitude increases, the difference in the two frequencies becomes more clear. The reasoning is the same for the case of the decreased amplitude. Since amplitude is directly related to frequency deviation, as the amplitude increases, the frequency deviation increases. This increase in frequency deviations causes the two present frequencies to be further from the original carrier so they are more distinct from each other. Similarly in the frequency domain, since the two present frequencies are further away from each other, the peaks also have become further away from each other. Increasing the amplitude will increase the total bandwidth.