ECE 4705 Lab
Experiment 8 – FM Modulation and Demodulation
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ECE4705L_03

ECE 4705L **EXPERIMENT 8**

FM MODULATION AND DEMODULATION[1]

INTRODUCTION

A. Background Theory
   a. Why do we Sample?
      The purpose behind sampling is to be able to take a continuous-time signal and translate it to a discrete-time signal that is copied at multiples of a carrier signal frequency. We can sample at certain frequency rates

OBJECTIVE

The objective of this experiment is to understand FM modulation and demodulation.

EQUIPMENT

HP3312A Spectrum Analyzer, Krohn-Hite Filter, Oscilloscope

PRE-LAB

Assume that the sampling rate is 5 times the baseband bandwidth, (i.e. f_s= 5B = 50kHz).

1. Plot the two-sided amplitude spectrum of a single-tone modulated FM wave when the modulation index is:

(a) $\beta = 2$ (b) $\beta = 5$ (c) $\beta = 10$

Let the frequency of the modulating signal be 10 kHz, the amplitude of the carrier be 1 V, and the frequency of the carrier be 250 kHz.

2. Design a simple FM detector utilizing only the ECE 4705 laboratory equipment and simple components of your own.

[1] Based on a lab from Dr. James Kang

PRE-LAB & DISCUSSION

1. Plot the two-sided amplitude spectrum of a single-tone modulated FM wave when the modulation index is:

(a) $\beta = 2$

1. $f_m = 10\text{ kHz}$ $\quad f_c = 250\text{ kHz}$ $\quad A_c = 1$

$$J_n(\beta) = \frac{1}{\pi}\int_0^{\pi} \cos(\beta \sin x - nx)\,dx$$

a) $\beta = 2$

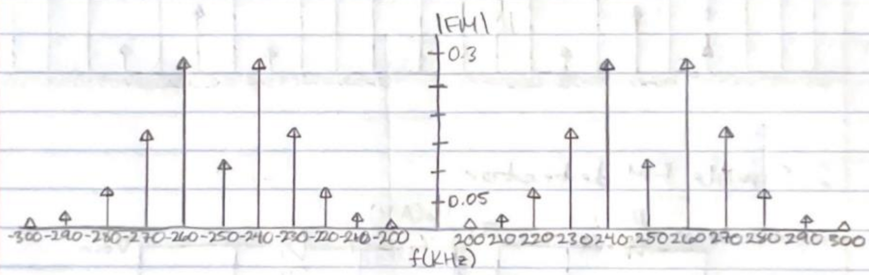
$$FM(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta)\cos[(\omega_c + n\omega_m)t]$$

$$= \sum_{n=-\infty}^{\infty} J_n(2)\cos[(2\pi 250K + n2\pi 10K)t]$$

$$J_n(2) = \frac{1}{\pi}\int \cos(2\sin x - nx)\,dx$$

for $-5 < n < 5$

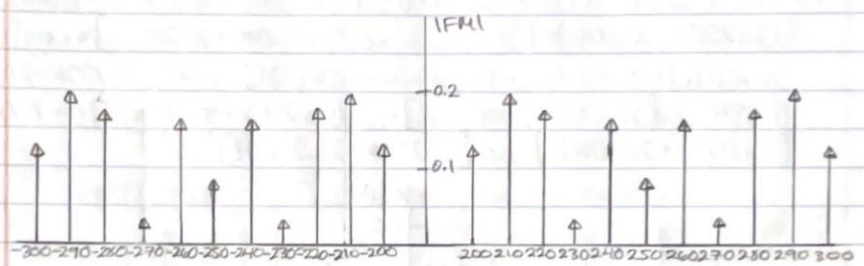
$$FM(t) = 0.2239\cos(2\pi 250Kt) + 0.5767\{\cos[(2\pi 250K + 2\pi 10K)t] - \cos[(2\pi 250K - 2\pi 10K)t]\} + 0.3528\{\cos[(2\pi 250K + 2\pi 20K)t] + \cos[(2\pi 250K - 2\pi 20K)t] + 0.1289\{\cos[(2\pi 250K + 2\pi 30K)t] - \cos[(2\pi 250K - 2\pi 30K)t]\} + 0.034\{\cos[(2\pi 250K + 2\pi 40K)t] + \cos[(2\pi 250K - 2\pi 40K)t]\} + 0.007\{\cos[(2\pi 250K + 2\pi 50K)t] - \cos[(2\pi 250K - 2\pi 50K)t]\}$$



(b) $\beta = 5$

b. $\beta = 5$ $\quad J_0(5) = -0.1776$

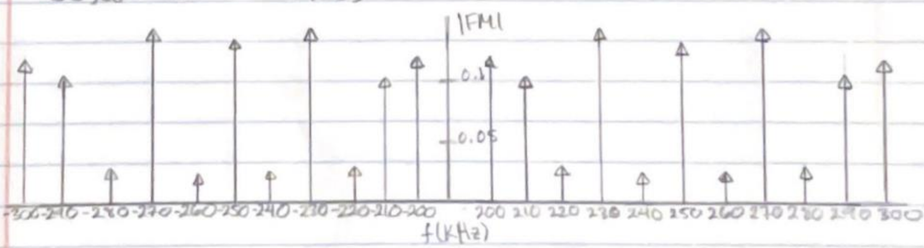
$$FM(t) = -0.1776\cos(2\pi 250Kt) + (-0.3276)\{\cos[(2\pi 250K + 2\pi 10K)t] - \cos[(2\pi 250K - 2\pi 10K)t] + 0.0466\{\cos[(2\pi 250K + 2\pi 20K)t] + \cos[(2\pi 250K - 2\pi 20K)t]\} + 0.3648\{\cos[(2\pi 250K + 2\pi 30K)t] - \cos[(2\pi 250K - 2\pi 30K)t]\} + 0.3912\{\cos[(2\pi 250K + 2\pi 40K)t] + \cos[(2\pi 250K - 2\pi 40K)t]\} + 0.2611\{\cos[(2\pi 250K + 2\pi 50K)t] - \cos[(2\pi 250K - 2\pi 50K)t]\}$$



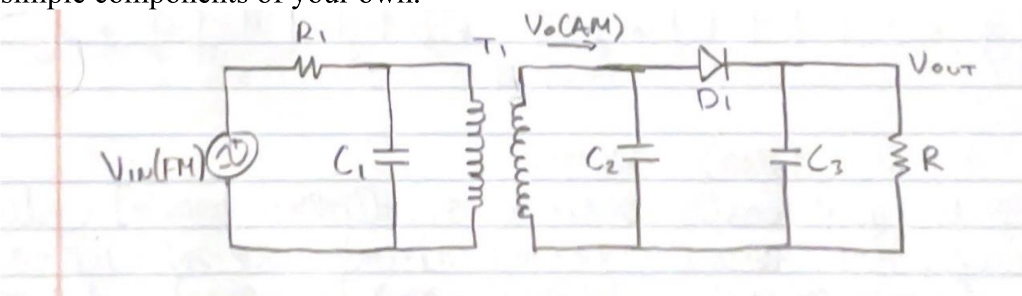
(c) $\beta = 10$

c) $\beta = 10 \quad J_0(10) = -0.2459$

$$FM(t) = -0.2459\cos(2\pi 250Kt) + 0.0435\{\cos[(2\pi 250K + 2\pi 10K)t] - \cos[(2\pi 250K - 2\pi 10K)t]\} + 0.2546\{\cos[(2\pi 250K + 2\pi 20K)t] + \cos[(2\pi 250K - 2\pi 20K)t]\} + 0.0584\{\cos[(2\pi 250K + 2\pi 30K)t] - \cos[(2\pi 250K - 2\pi 30K)t]\} + (-0.2196)\{\cos[(2\pi 250K + 2\pi 40K)t] + \cos[(2\pi 250K - 2\pi 40K)t]\} + (-0.2341)\{\cos[(2\pi 250K + 2\pi 50K)t] - \cos[(2\pi 250K - 2\pi 50K)t]\}$$



2. Design a simple FM detector utilizing only the ECE 4705 laboratory equipment and simple components of your own.



LAB

1. Each HP 3312A has an internal voltage controlled oscillator (VCO) with unique characteristics. First, characterize your VCO's frequency deviation constant, f_d in Hz / V, by taking data and plotting output frequency vs dc voltage amplitude. Set the carrier frequency of the HP 3312A to 250 kHz and the amplitude of the carrier to 1V (that's 2V peak-to-peak!) Apply a series of dc voltages to the rear 'VCO' input of the HP 3312A (see Fig. 1)

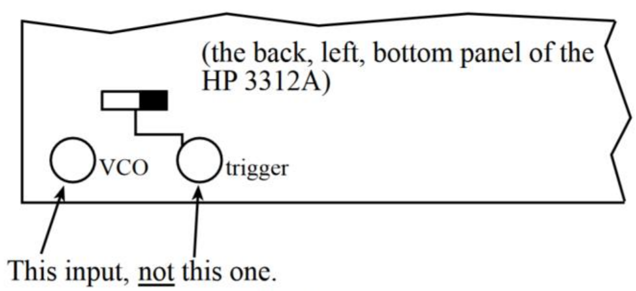
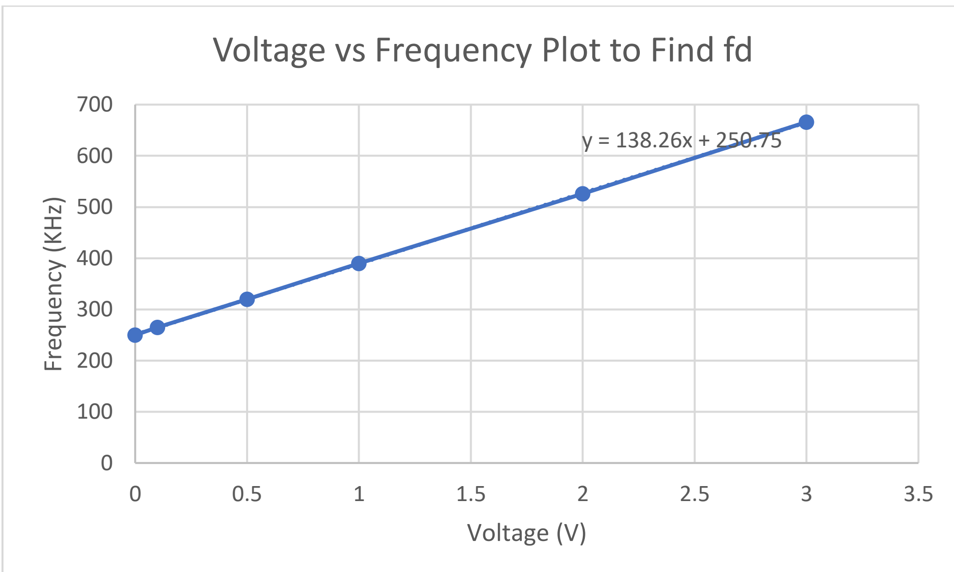


Fig. 1

Six to eight dc voltage steps between 0 and 3V should be enough.

Trial	**Voltage**	**Frequency (KHz)**
1	0	250
2	0.1	265
3	0.5	320
4	1	390
5	2	526
6	3	666

Plot out frequency vs. voltage on a scatter plot (frequency on y-axis), and then fit a linear curve to your data and show the equation (all with Excel's curve fitting functionality). The slope of the line will be your f_d value. Before you proceed, show your instructor the f_d value you got, to make sure no mistakes were made.



From the plot, we can see that our slope/corresponding f_d value is about 138.26 KHz. Using the frequency f_d based off the data given in the lab is 135.92 KHz, we can calculate the percent error:

$$\% \, Error = \frac{|f_{d,given} - f_{d,calc}|}{f_{d,given}} * 100$$

$$\% \, Error = \frac{|135.92 - 138.26|}{135.92} * 100$$

$$\% \, Error = 1.722\%$$

Here we can see that the percent error of our calculated frequency deviation is less than 5% off the given frequency deviation making it well within the acceptable range of error.

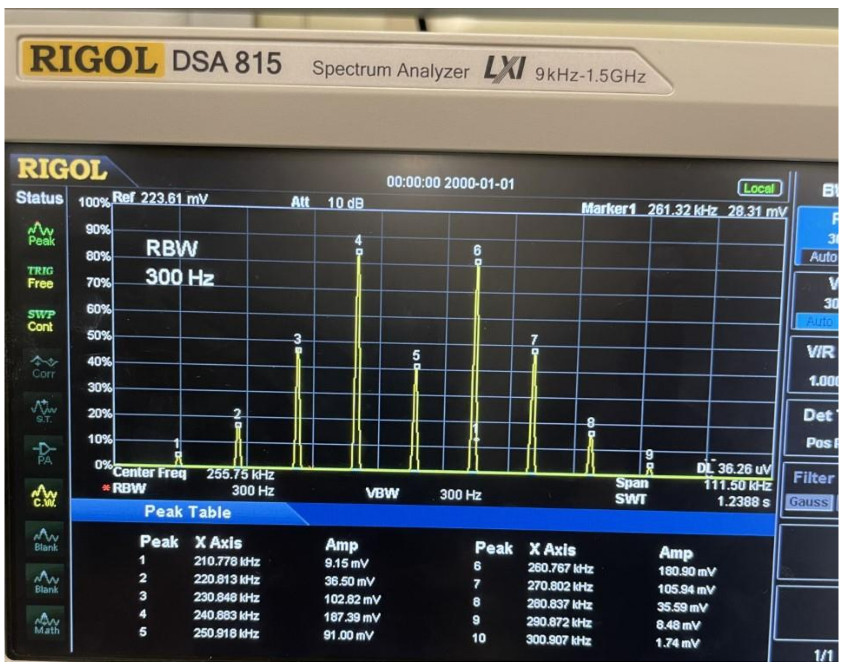
2. Calculate what the amplitude of the input message should be for prelab part 1(a), 1(b), and 1(c) using the equation:

$$A_m = \frac{\beta * f_m}{f_d}$$

where β is the desired maximum phase deviation constant (from the prelab), f_m is the frequency of the message signal (10 kHz in this case), and f_d is the frequency deviation constant that you calculated in part 1 of this lab. Obtain data and print the frequency spectrums for all three parts. Use one of the function generators to obtain the message waveform.

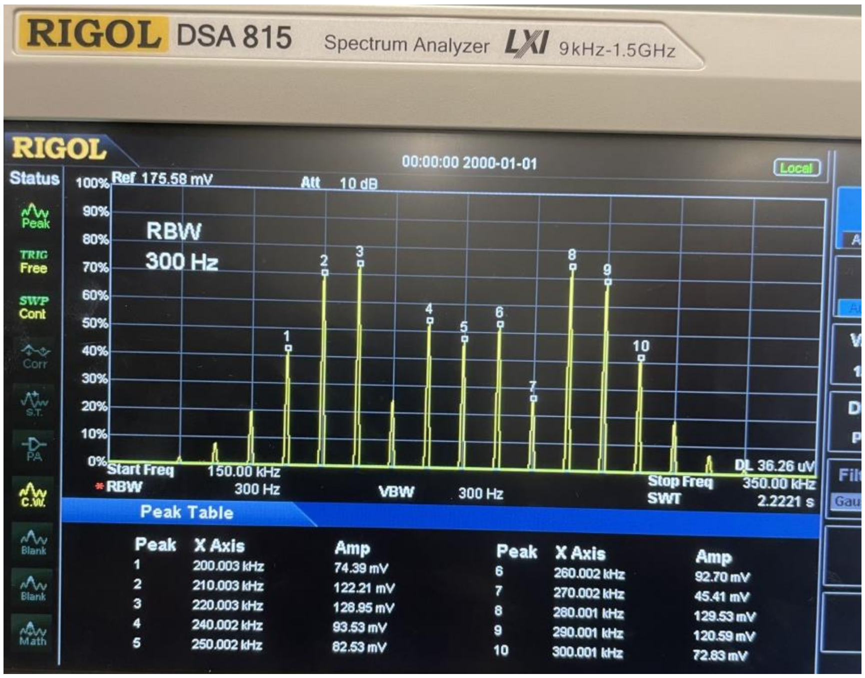
(a) For $\beta = 2$

$$A_m = \frac{2 * 10000}{138260}$$
$$A_m = 0.145$$



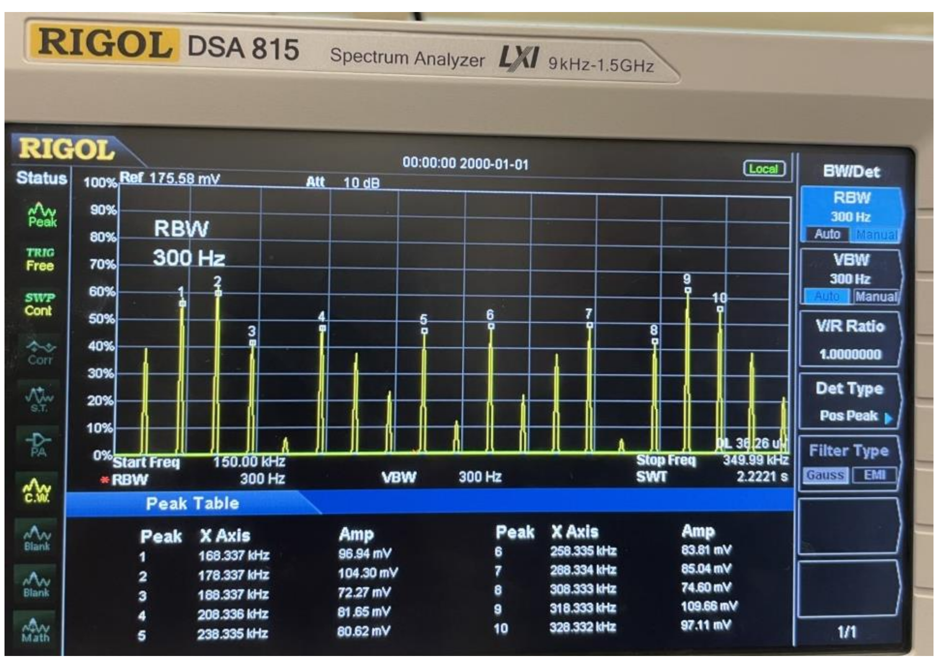
(b) $\beta = 5$

$$A_m = \frac{5 * 10000}{138260}$$
$$A_m = 0.362$$

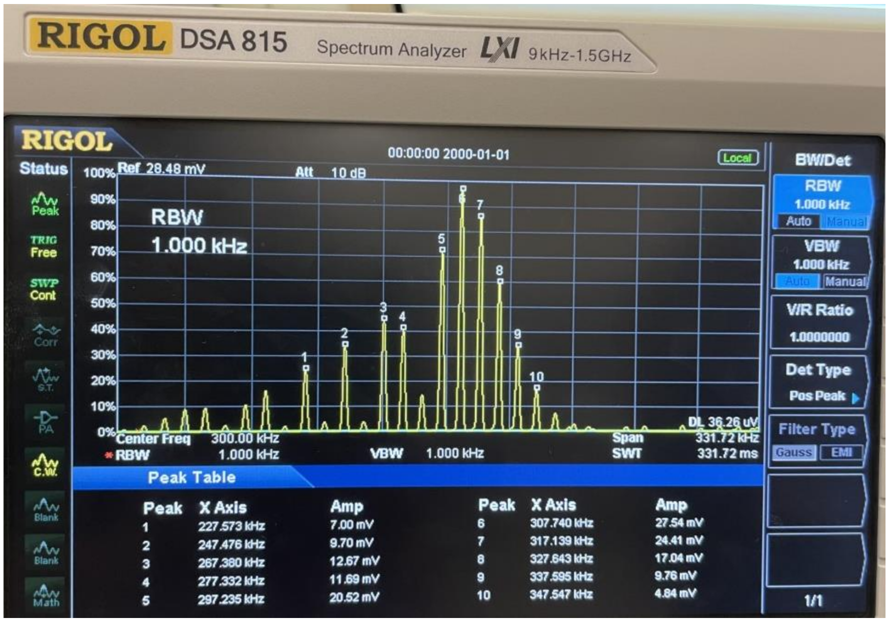


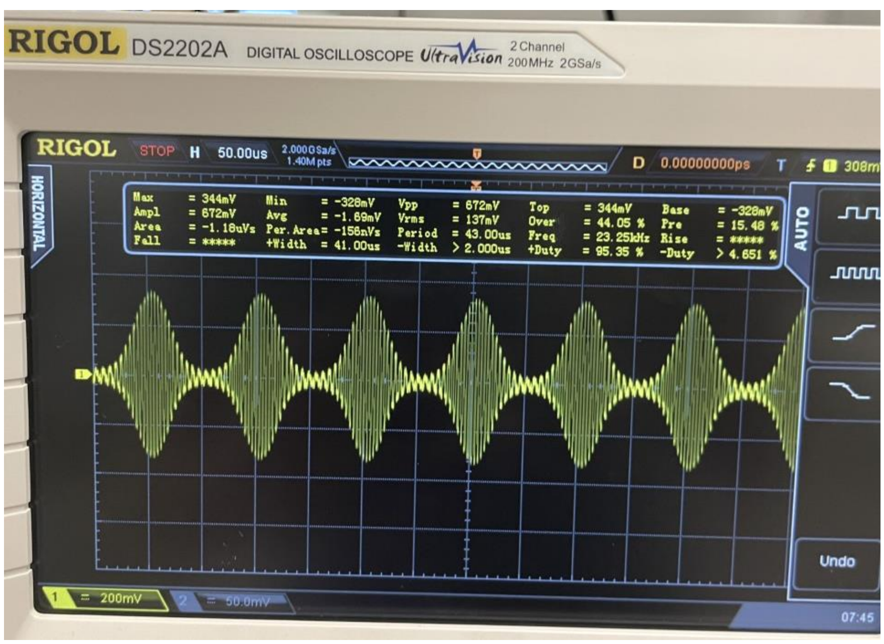
(c) $\beta = 10$

$$A_m = \frac{10 * 10000}{138260}$$
$$A_m = 0.723$$



3. Print the detected outputs of part 2 from the oscilloscope using your designed detector. You do not have to demodulate the signal completely, just show the original signal's envelope (use the Krohn Hite filter in highpass mode to do FM to AM conversion.)





Using the data from envelope detector displayed in the oscilloscope we can calculate the percent error from the calculated message amplitude in part 2 of the lab. The oscilloscope reads 672 mV and we calculated an amplitude of 0.723V, therefore we have,

$$\% \, Error = \frac{|V_{actual} - V_{calc}|}{V_{actual}} * 100$$

$$\% \, Error = 7.59 \, \%$$

CONCLUSION

In this lab we were tasked to produce the spectrum of a modulated signal at different beta values, then recover a message signal from a modulated signal. By running the modulated signal through a makeshift envelope detector, we are able to produce the envelope, which essentially follows the outline of the message signal. After calculating the frequency deviation of our voltage controlled oscilloscope, the spectrum of the modulated signal for different beta values were produced, and they matched the expected shape from part 1 of the prelab. Following this part of the lab, we filtered the spectrum of the modulated signal to recover the envelope of the modulated signal, which contains the shape of the demodulated message signal we are trying to obtain. We expected to see a shape similar to a cosine graph with an amplitude of that which we calculated using the given equation for the amplitude at $\beta = 10$ and the calculated frequency deviation. As seen by the images of the oscilloscope provided, we were able to recover the envelope of the message and the amplitude was within 10% error of the calculated value.