School of Engineering Science, Simon Fraser University
ENSC-327
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Lab #3 — FM Modulation and Demodulation using Simulink

Simulink Assignment:

Before starting your simulation, read the instructions in full, including the details of the simulation given at the end of this document.

IMPORTANT NOTATIONS

- k_f is the frequency sensitivity factor of the modulator (in units of Hz/volt).
- $\Delta f = k_f A_m$ indicates the frequency deviation (or maximum deviation) of the signal from the carrier frequency.
- $\beta = \Delta f \div f_m$ is the modulation index of single-tone FM waves.

1. FM Modulation

In this section, you will use a voltage-controlled oscillator (VCO) as an FM modulator. The VCO's input voltage, V_{in} , determines the VCO's output signal frequency as:

$$f_{out} = f_{center} + k_f V_{in}$$

We study the impact of the amplitude and frequency of the message signal on FM signals. The Schematic for the FM modulator is illustrated in Figure 1. Using the appropriate Simulink blocks build an FM-modulated signal with the following parameters:

- Message signal: A 2V p-p, 2 kHz sinusoidal signal
- FM frequency sensitivity = 2.5 KHz/Volt
- VCO Center Frequency= f_c =10 kHz

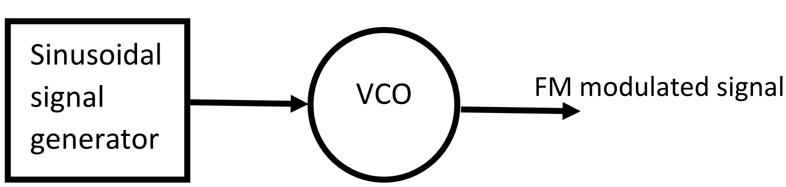

Figure 1: FM Modulator using VCO

A. Add a screenshot of the Simulink model you have implemented to your report.

B. Observe the output of the VCO on the Scope and the Spectrum Analyzer. Adjust the Spectrum Analyzer so that you can see the peaks clearly. Zoom in the Scope window so that you can observe only about 10 periods of the input signal, i.e., about 5 (ms). Take screenshots from both Scope and Spectrum Analyzer and attach them to your report.

C. Measure the bandwidth of the FM signal, ignoring frequency components that are 30dB or more below the highest component. Now, use Carson's rule to theoretically estimate the bandwidth and compare it with the measured bandwidth.

D. Calculate the theoretical power of the center band (f_c) and the 3rd band ($f_c + 3\ f_m$) and compare with the results you see on the Spectrum Analyzer. Do the Simulink results match the theory? Make sure you are using the same units for theory and practice (Simulink), e.g. dBm.

E. Change the message signal to a 4V p-p sinusoidal signal and repeat the previous steps.
F. Now change the frequency sensitivity factor of the FM modulator to 4.5 KHz/volt. Repeat steps B, C, D, and E for the new frequency sensitivity factor.

2. FM Demodulation

One of the methods that can be used to demodulate the FM signal, is to use a phase-locked loop (PLL). In this experiment, you will construct a PLL and use it for FM demodulation. For this experiment, you first need to construct an FM signal with the following properties:

- VCO center frequency =10 KHz
- FM frequency sensitivity=2.5 KHz/volt
- Message signal=2 KHz sinusoidal signal

The PLL is shown in Figure 2.

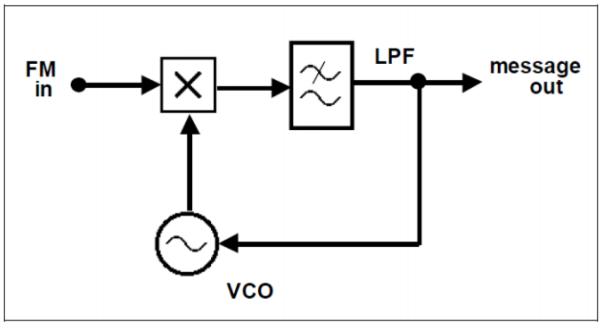

Figure 2: Phase Lock Loop (PLL)

A. Add a screenshot of the Simulink model you have implemented to your report.
B. Observe the demodulated signal on the Oscilloscope along with the message signal in one window (Use two channels of the same oscilloscope to show the original message and the demodulated signal.) **How long does it take for the PLL to lock and Why?**

C. Take 2 different screenshots from Scope with different zoom and includes them in your report (one screenshot without zoom to show the PLL locking time, one with zoom to show ~10 periods of the demodulated signal).
D. Observe the demodulated signal on the Spectrum Analyzer. Adjust the Spectrum Analyzer so that you can see the peak clearly. Take screenshots from both Scope and Spectrum Analyzer and attach them to your report.

In your report include the following:

1- Your system layout. 2- Figures showing the message signal, the modulated signal, and the demodulated signal on the scope (You need to zoom in to show the proper signal). 3- Figures showing the 3 mentioned signals on Spectrum Analyzer 4- Answers to questions in each section.

Tips:

1. The center frequency of VCO in PLL should be the same as the carrier frequency.
2. It takes time for PLL to lock. Therefore, the simulation time should be long enough. (~100ms with 100KHz sampling frequency)

Simulink Components

The following building boxes are required for this assignment:

- From the Simulink/Sources sublibrary: Sine Wave.
- From the Simulink/Math Operations sublibrary: Matrix multiplier.
- From the Simulink/Sinks sublibrary: Scope.
- From the DSP (meaning Digital Signal Processing) Blockset, Sinks sublibrary: Spectrum Analyzer.
- From Communications library: Discrete-Time VCO, Lowpass Filter

You can use the tutorial provided in assignment 2 for building your design in Simulink. Below are some of the parameters for your simulation.

Sample frequency: Set the sampling frequency to 100 KHz for all components.

Spectrum Analyzer:

Set the “window length” of Spectrum Analyzer to 8192 or 16384 or even higher.

VCO parameters:

Double-click on the VCO block to open its block parameters. You can adjust its parameters as follows:

- Quiescent Frequency: VCO Center Frequency
- Input Sensitivity: Frequency Sensitivity
- Initial phase: set to zero

Lowpass filter parameters:

- Filter Type: FIR
- Passband Edge Frequency: Slightly larger than the frequency of the message
- Stopband edge frequency: a little bit greater than Passband Edge Frequency
- Maximum passband ripple: between 0.1~1
- Minimum stopband attenuation: more than 80
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You can click on “View Filter Response” to see the frequency response of the designed filter.