American International University- Bangladesh
Department of Computer Engineering
COE 3201: Data Communication Laboratory

Title: Study of Frequency Modulation and Demodulation using Simulink (MATLAB)

Abstract:

This experiment is designed to-

1.To understand the use of Simulink for solving communication engineering problems.
2.To develop understanding of Frequency Modulation and Demodulation using Simulink.

Theoretical Background:

Amplitude modulation was the first modulation type to be considered in analog communication systems. Amplitude modulation has the obvious advantage of being simple and relatively bandwidth efficient. The disadvantages of amplitude modulation are [1]:

- Since the message is embedded in the amplitude of the carrier signal, the cost, performance, and the size of the linear amplifiers are difficult to accomplish for obtaining fair performance in AM systems.
- When the message goes through a quiet period in Double Side Band (DSB) or Single Side Band (SSB) systems, very small carrier signals are transmitted. The absence of the signal tends to accentuate the noise.
- The passband bandwidth is small compared to the other modulation schemes, i.e. FM, cellular, Wi-Fi etc.

Angle Modulation

In the first experiment, we analyzed the effect of varying the amplitude of a sinusoidal carrier in compliance with the baseband (information) signal. A major improvement in performance in the transmission is achieved with *angle modulation*. In this type of modulation, the amplitude of the carrier is kept constant. Angle modulation provides the improved noise performance.

Phase Modulation and Frequency Modulation are both the modulation techniques analyzed in angle modulation. In this second experiment, we will examine the most common modulation scheme in daily life, namely, the Frequency Modulation, or FM.

Frequency Modulation

The angle modulated signal described in time domain:

$$s(t) = A_c \cos[2\pi f_c t + \theta(t)] = Re\{A * \exp(j\phi(t))\}$$

Where A_c is the amplitude, then

The instantaneous phase is:

$$\phi_i = 2\pi f_c t + \theta(t)$$

The instantaneous frequency of the modulated signal is:

$$f_i(t) = \frac{1}{2\pi}\frac{d}{dt}[2\pi f_c t + \theta(t)] = f_c + \frac{1}{2\pi}\frac{d[\theta(t)]}{dt}$$

Where $\frac{d[\theta(t)]}{dt}$ is called phase deviation.

The phase deviation of the carrier, $\phi(t)$ is related to the baseband message $m(t)$. Then,

$$\frac{d[\theta(t)]}{dt} = K_f m(t)$$

Where K_f is frequency deviation constant

$$\phi(t) = K_f \int_{-\infty}^{t} m(\lambda)d\lambda$$

Finally, the frequency modulated signal is expressed as in time domain:

$$s(t) = A_c \cos[2\pi f_c t + K_f \int_{-\infty}^{t} m(\lambda)d\lambda]$$

Carson's rule is used to determine the bandwidth of the FM wave. According to the Carson's rule, the bandwidth is given by:

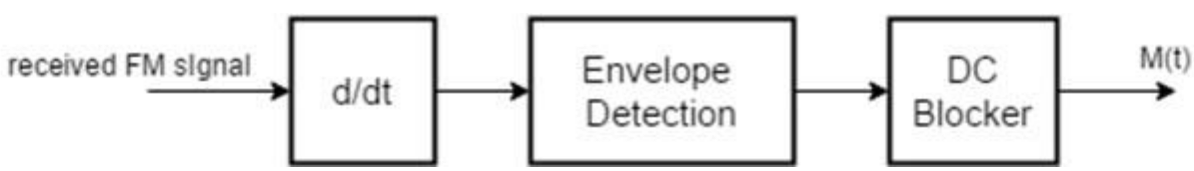
$B_t = 2W(1 + D)$, where W is the bandwidth of the information signal, and D is the frequency deviation which is defined as for FM:

$$D = \frac{K_f}{2\pi W}\max|m(t)|$$

Frequency Demodulation

a. Demodulation using Differentiation:

A frequency discriminator theoretically extracts the message from the received FM signal.



The modulated signal $s(t)$ is:

$$\frac{ds(t)}{dt} = -A_c[2\pi f_c + K_f m(t)]sin(2\pi f_c t + 2\pi K_f \int_{-\infty}^{t} m(\lambda)d\lambda)$$

The differentiated signal is both amplitude and frequency modulated, the envelope $A_c[2\pi f_c + K_f m(t)]$ is linearly related to message signal (amplitude component) and $sin(2\pi f_c t + 2\pi K_f \int_{-\infty}^{t} m(\lambda)d\lambda)$ is high frequency component. Therefore, $m(t)$ can be recovered by an envelope detection of $\frac{ds(t)}{dt}$.

b. PLL Demodulation:

The PLL demodulates the FM signal using feedback force a Voltage-Controlled-Oscillator (VCO) to remain in phase with the carrier of the incoming signal. The message is recovered as the control input of the VCO [2]. In the simulation experiment (section-2), we used the VCO to demodulate the information signal.

<u>Building Simulink Model of Frequency Modulation and Demodulation:</u>

The frequency modulator and demodulator structures are as explained below. In the first model, you are provided a FM structure that is very similar to the theoretical background of this experiment. In the second model, you will observe the frequency variations with respect to the input signal's waveform. In this case, you will use the modulator and demodulator blocks provided by Simulink.

Model-1

<u>Frequency Modulation:</u>

The Simulink model for FM modulator is:

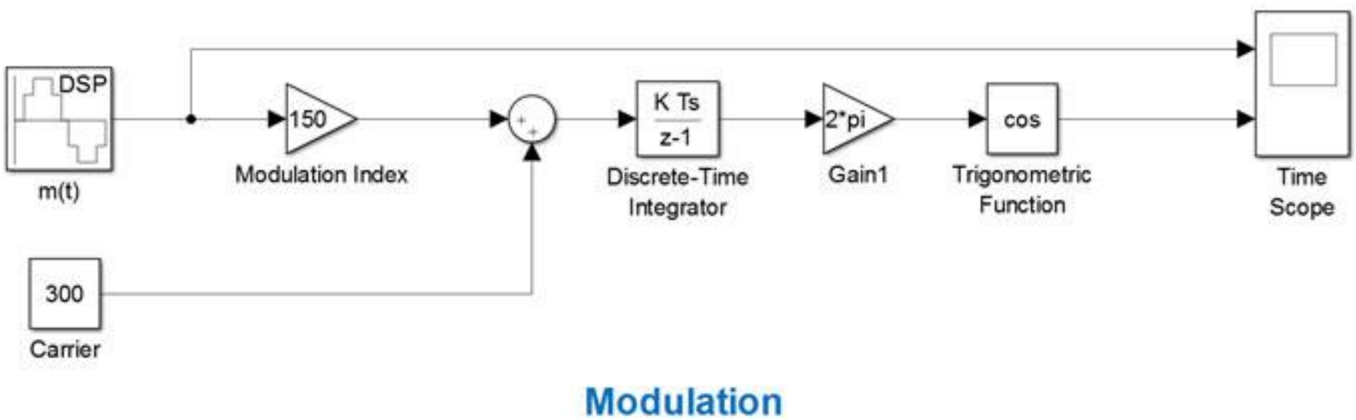


Figure 1: Block Diagrams for the FM Modulator

The blocks' parameters are as described below:

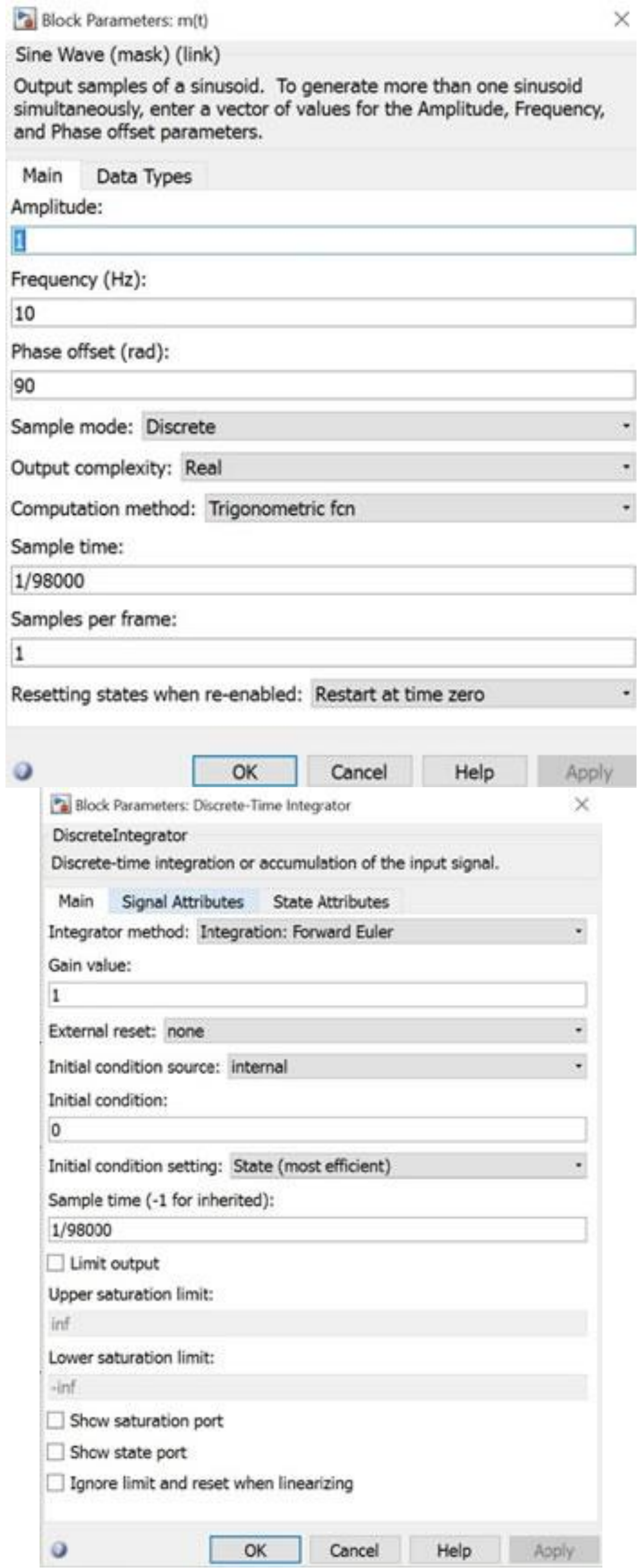


Figure 2: Blocks' Parameters for FM Modulator

Adjust the simulation time about 0.2 sec to observe the waveforms precisely.

The result in time scope will be

:

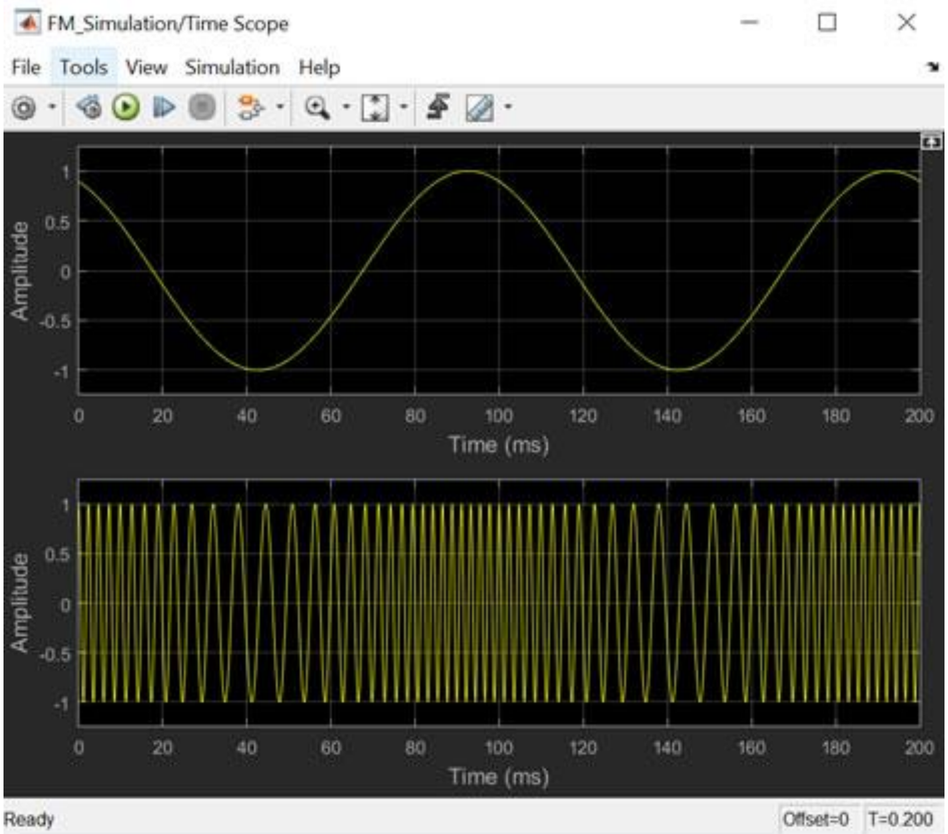


Figure 3: Time Scope

Frequency Modulator and Demodulator:

The Simulink model of the complete FM modulator and demodulator is shown next:

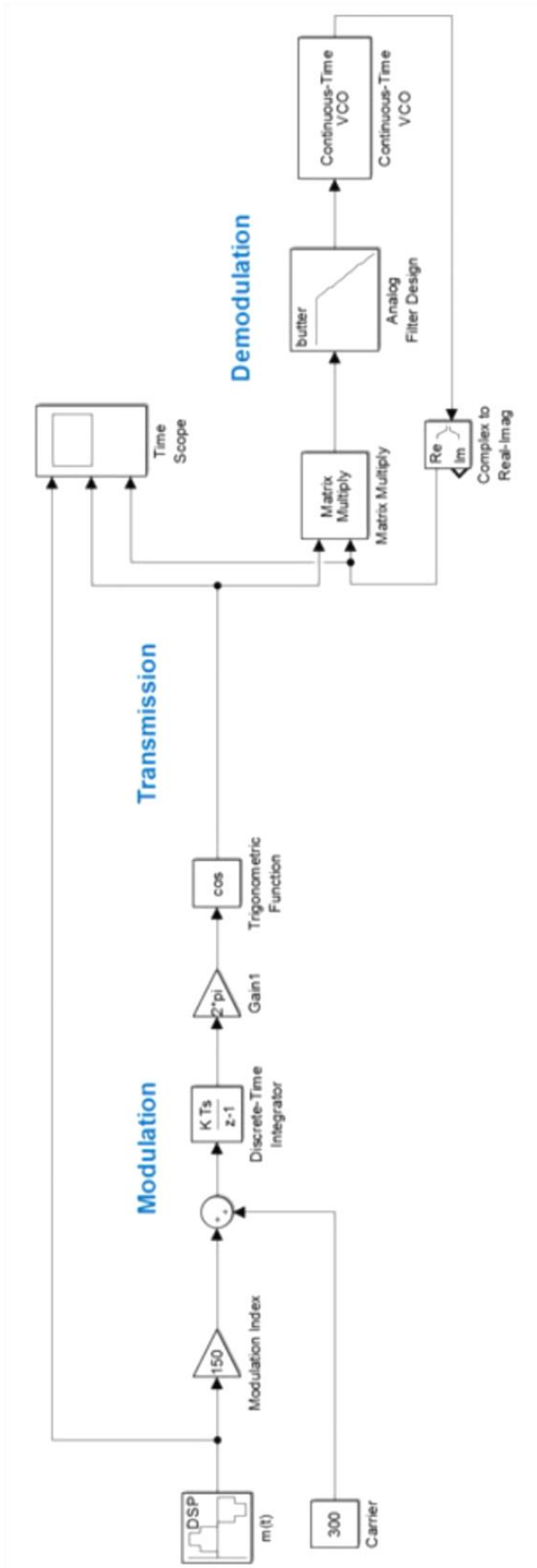


Figure 4: FM Modulator and Demodulator

You need to modify the filter and the VCO parameters as shown in the screenshots:

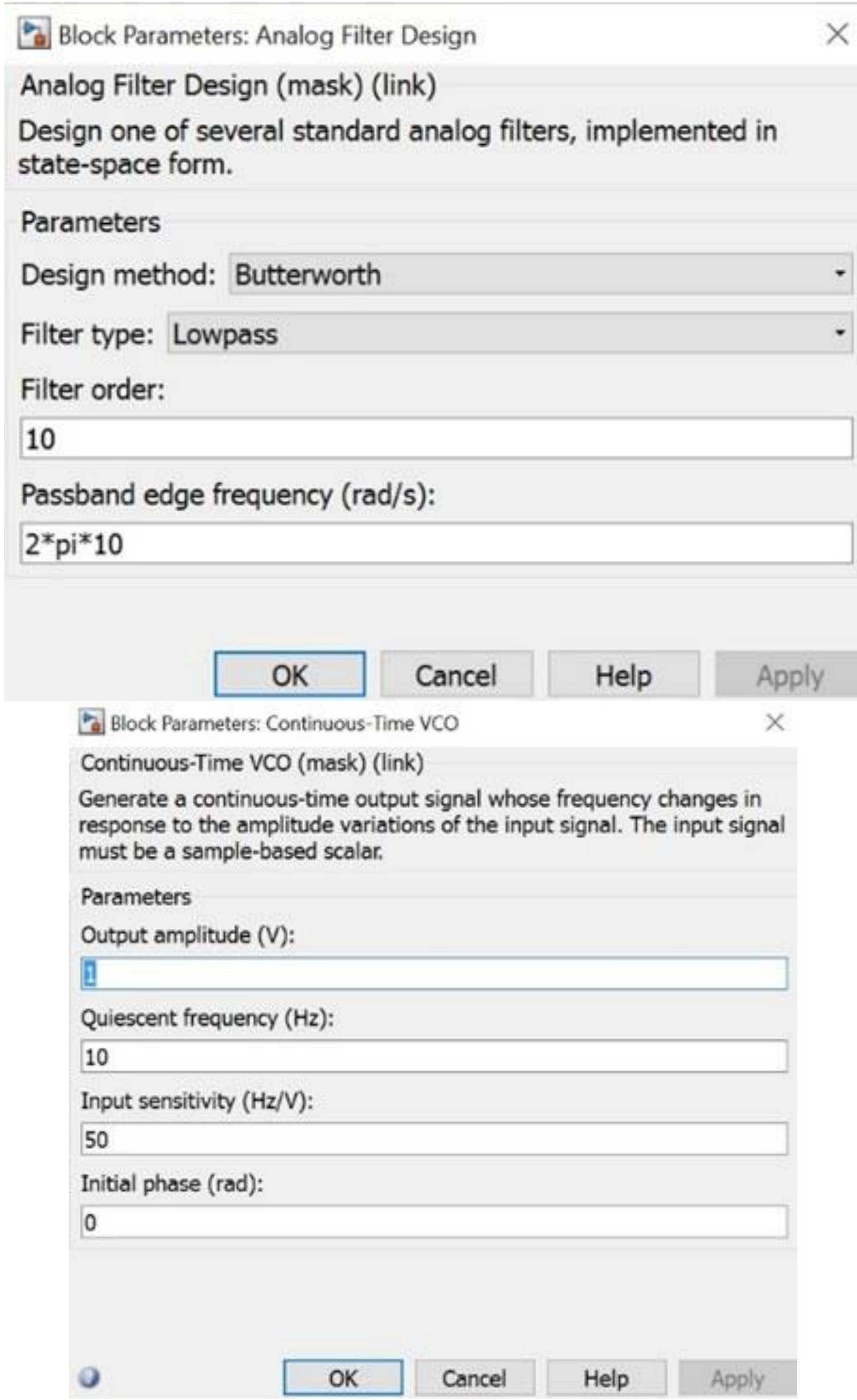


Figure 5:Block Parameters

Run your simulation and observe the signals in the time scope:

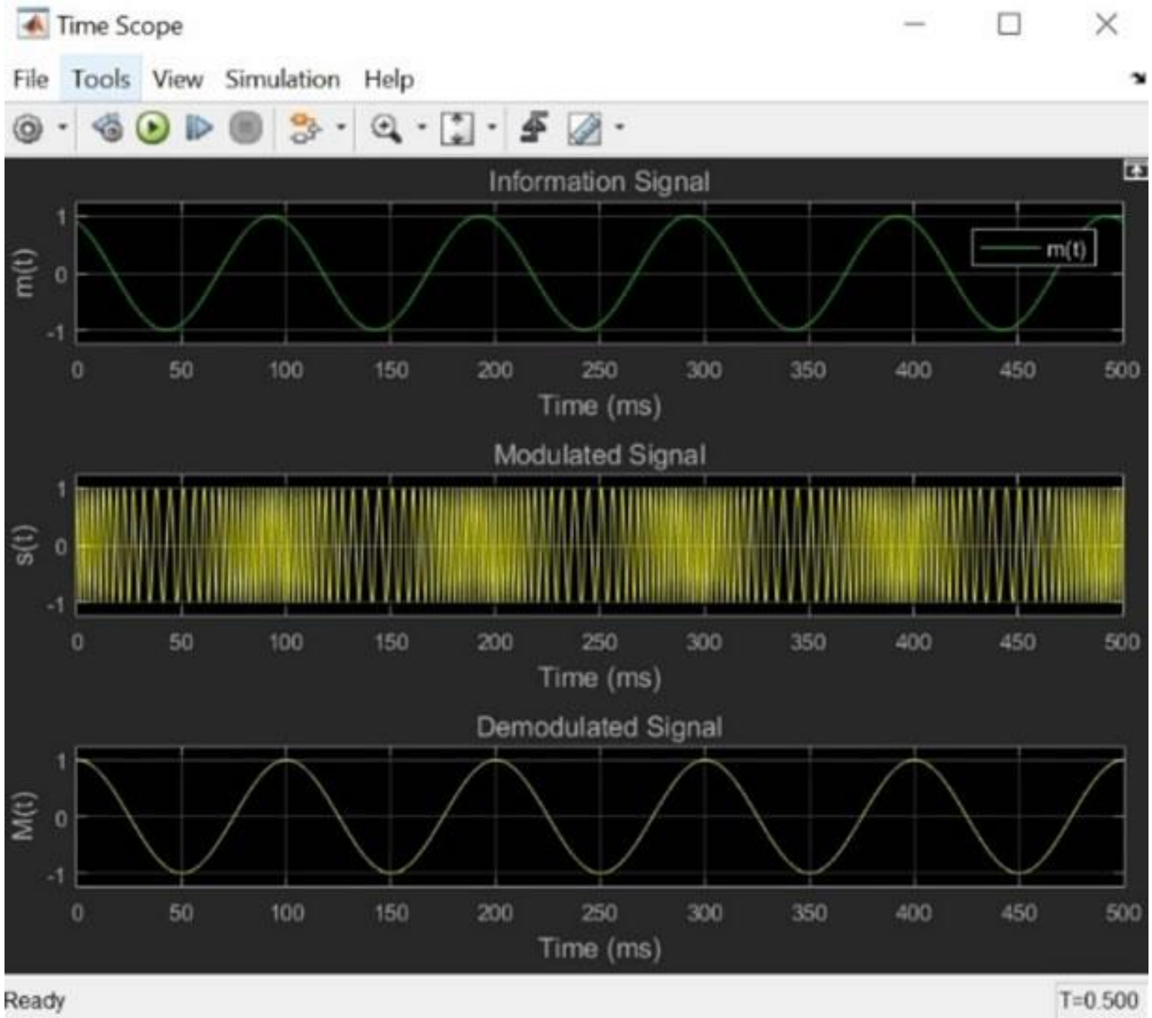


Figure 6: Time Scope for Model-1

As you can see, the FM modulated sinusoid is recovered in demodulation.

Model-2

In model-1, you have already learnt the theoretical foundations for FM. In the second model, instead of using complex modulator and demodulator structure, we will implement an FM system using direct modulator and demodulator blocks defined in Simulink. The input, in this case, has three different forms: sine wave, rectangular pulse train and triangular waves. Therefore, we will be able to observe the frequency variations using variety of inputs. The model-2 is expressed as:

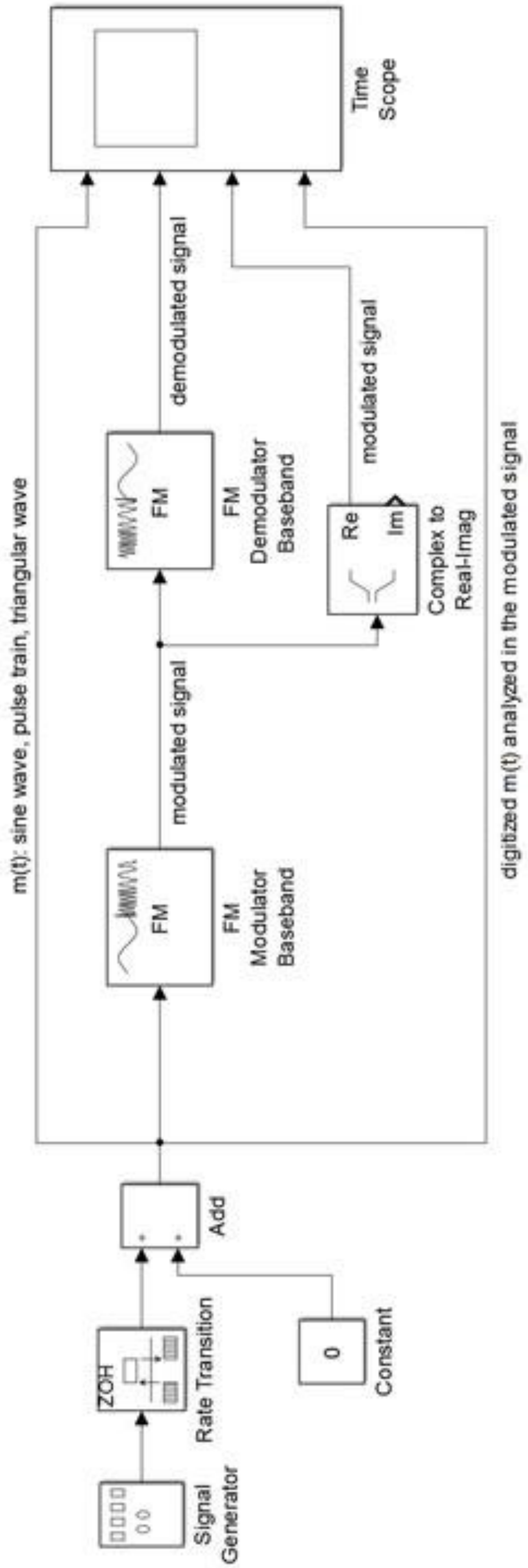


Figure 7: FM Model-2

The signal generator block is simply an analog input. In order to use this block as an input of the FM Modulator, we need to digitalize it. The rate transition block (zero-order-hold, or ZOH) will sample the analog information by the sampling period (please see the Review Manual for the sampling process). in this case, T_STS equals to $1/100e3$1/100e3.

Take the input signal's frequency as 5 Hz (use sine wave), and set the frequency deviation for the modulator and demodulator as 100 Hz, respectively. Also, adjust the time scope as three vertical layouts in order to analyze the $m(t)$m(t) vs. the modulated $m(t)$m(t).

The resulting time scope will be:

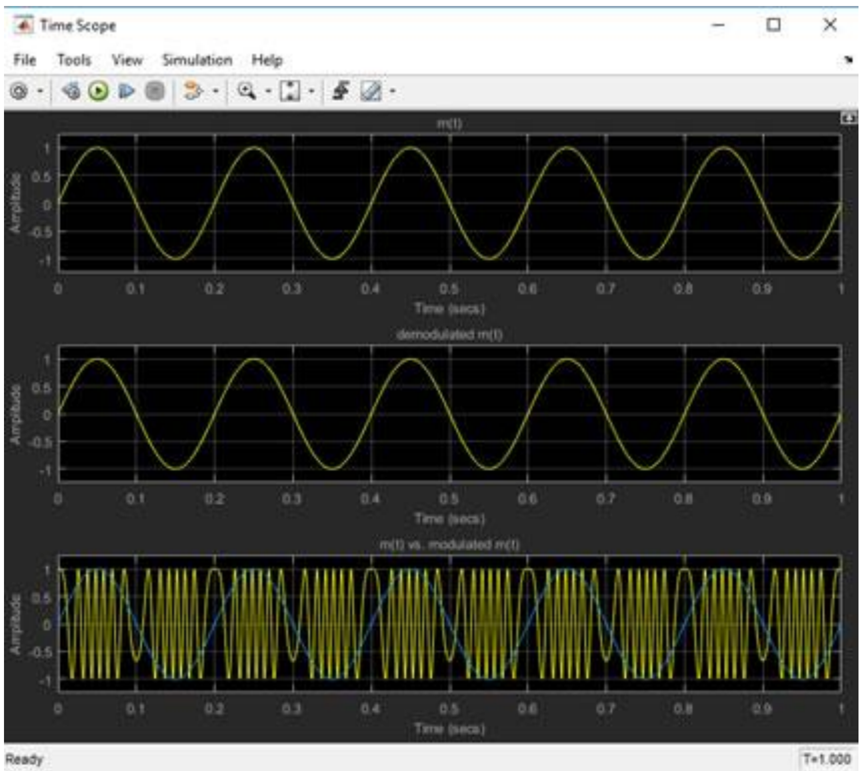


Figure 8: Time Scope for Model-2

Similarly, $m(t)$ is fully recovered.

References:

[1] M. P. Fitz, Fundamentals of Communications Systems, pp. 7.1-7.7, 2007, McGraw-Hill

[2] MathWorks®, Voltage Controlled Oscillator.