



# *Study of Frequency Modulation and Demodulation using Simulink*

*Lab Report 7*

*Data Communication [D]*

*Submitted by:*

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## **Title: Study of Frequency Modulation and Demodulation using Simulink 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:

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

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

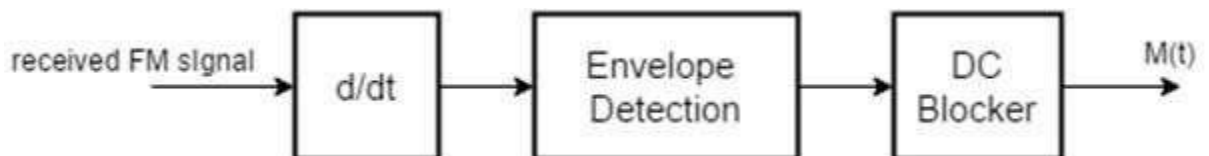
#### a. Demodulation using Differentiation:

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

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

The differentiated signal is both amplitude and frequency modulated, the envelope is  $A_c [2\pi f_c + K_f m(t)]$  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 modulated signal  $s(t)$  is:

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.

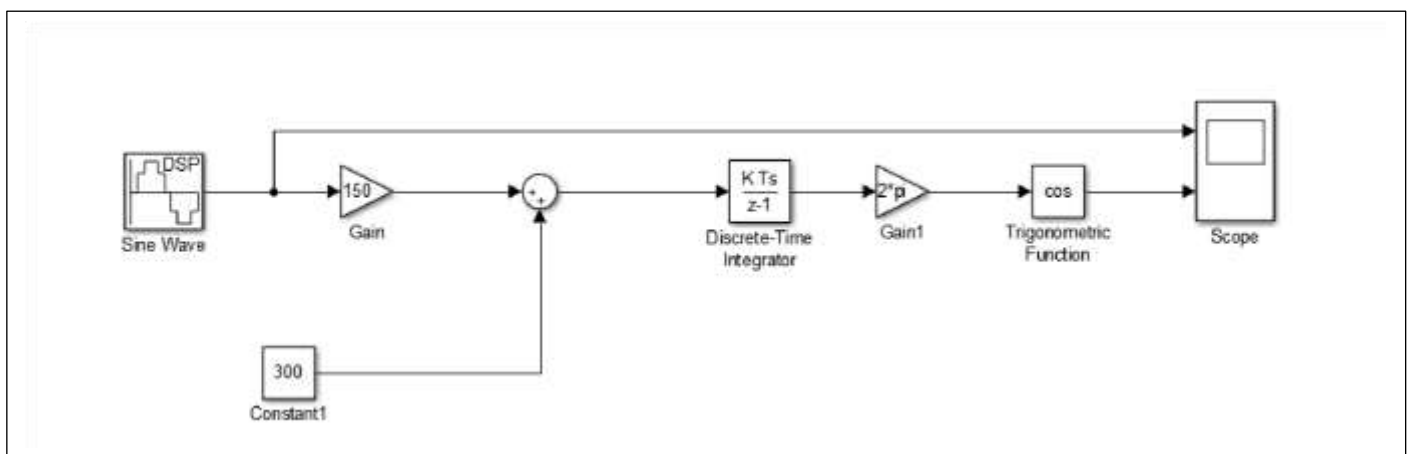
## **Building Simulink Model of Frequency Modulation and Demodulation:**

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.

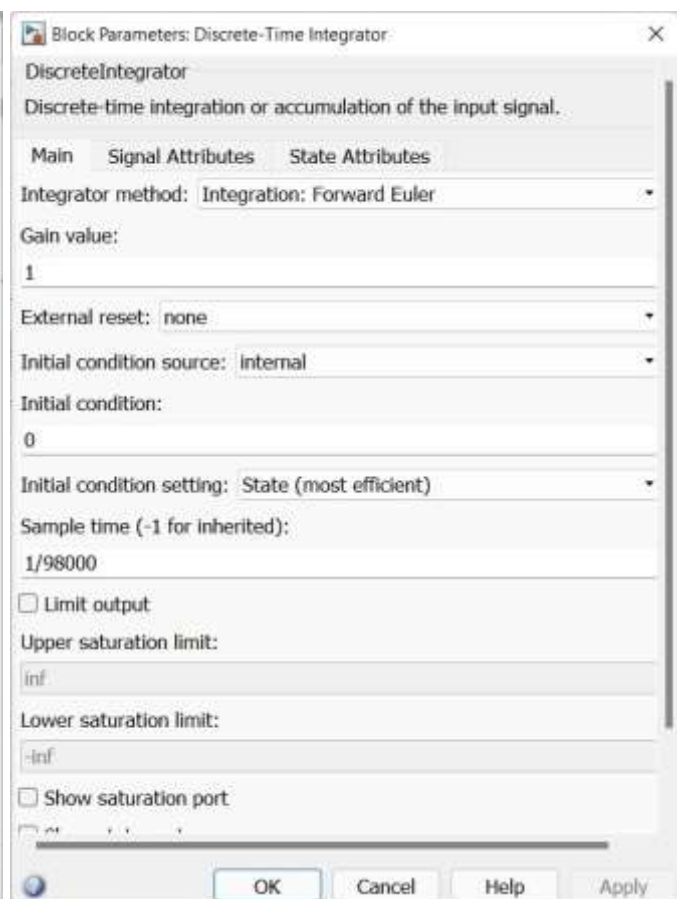
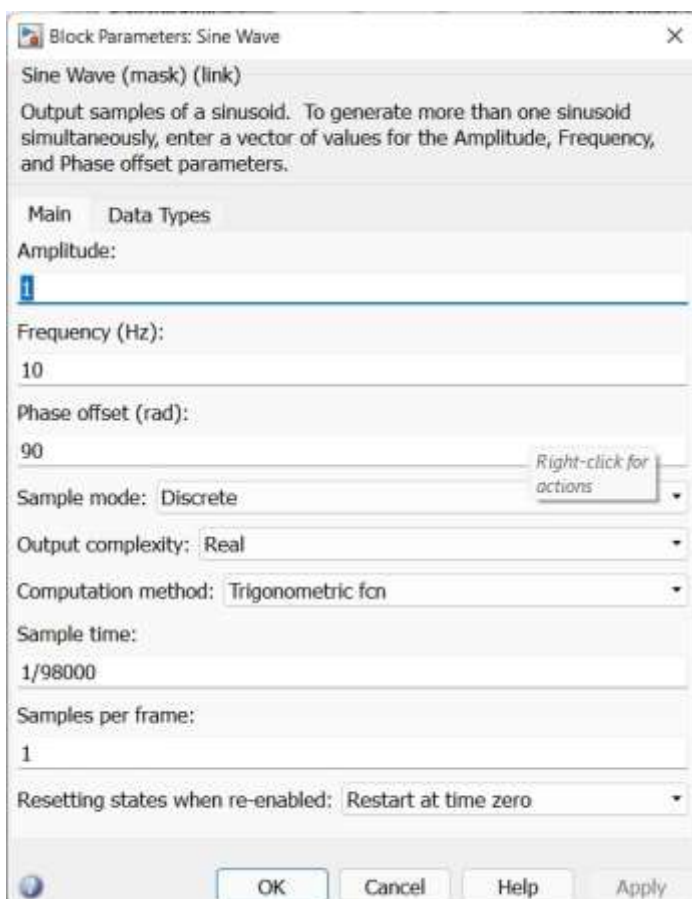
### **Model-1**

Frequency Modulation:

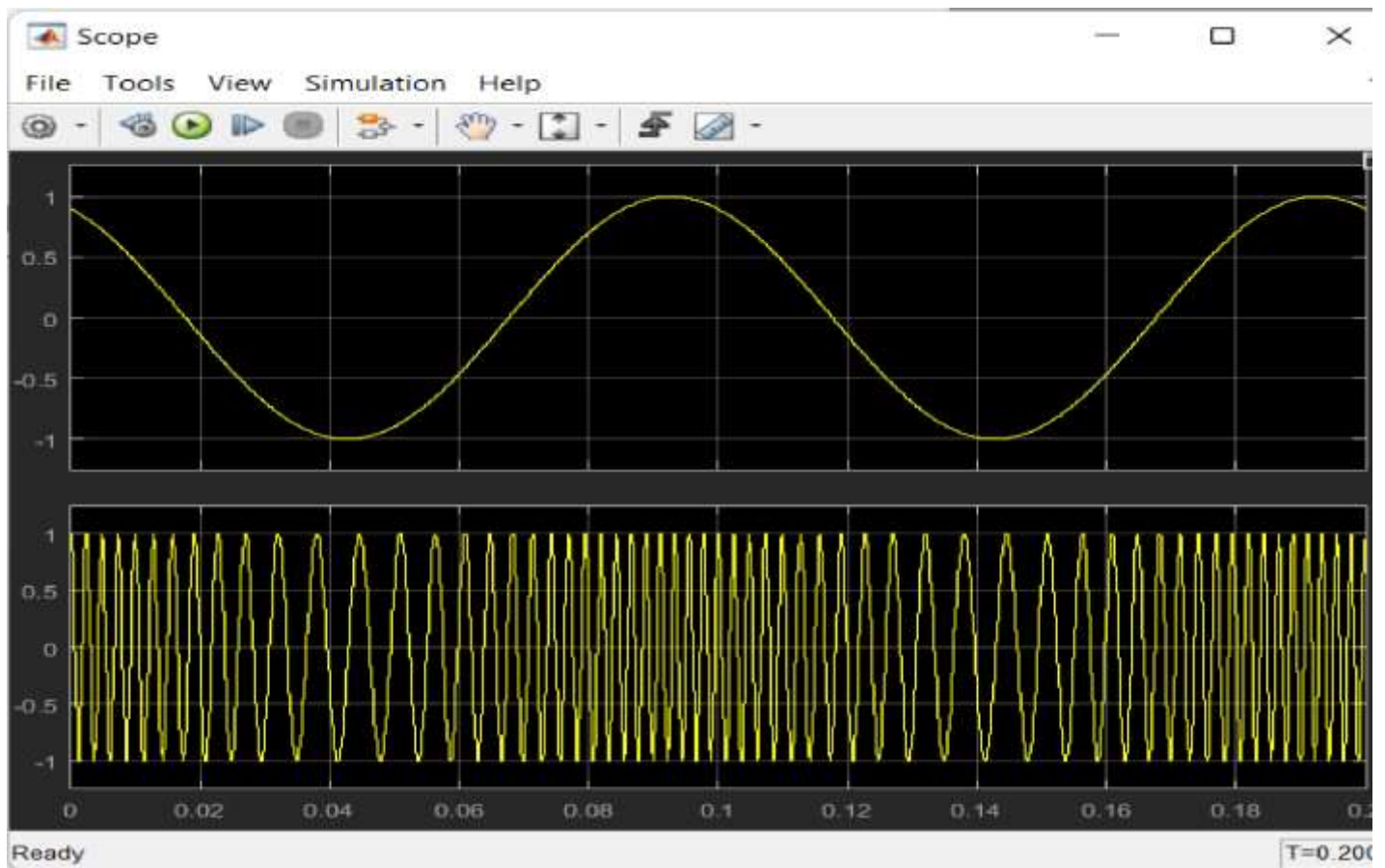
The Simulink model for FM modulator is:



The blocks' parameters are as described below:



Adjusting the simulation time about 0.2 sec to observe the waveforms precisely. The result in time scope will be



### Frequency Modulator and Demodulator:

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

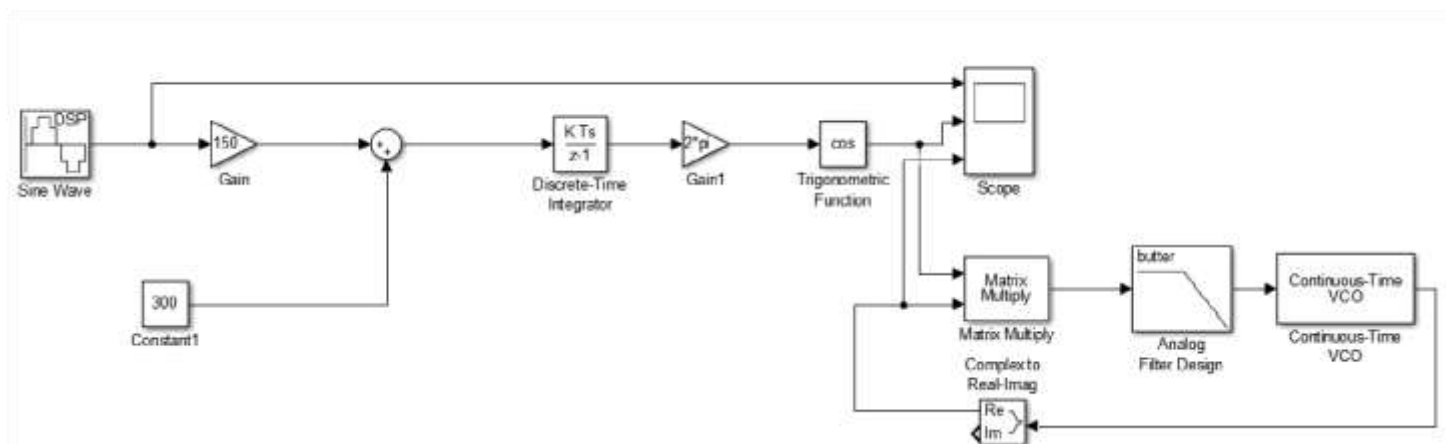
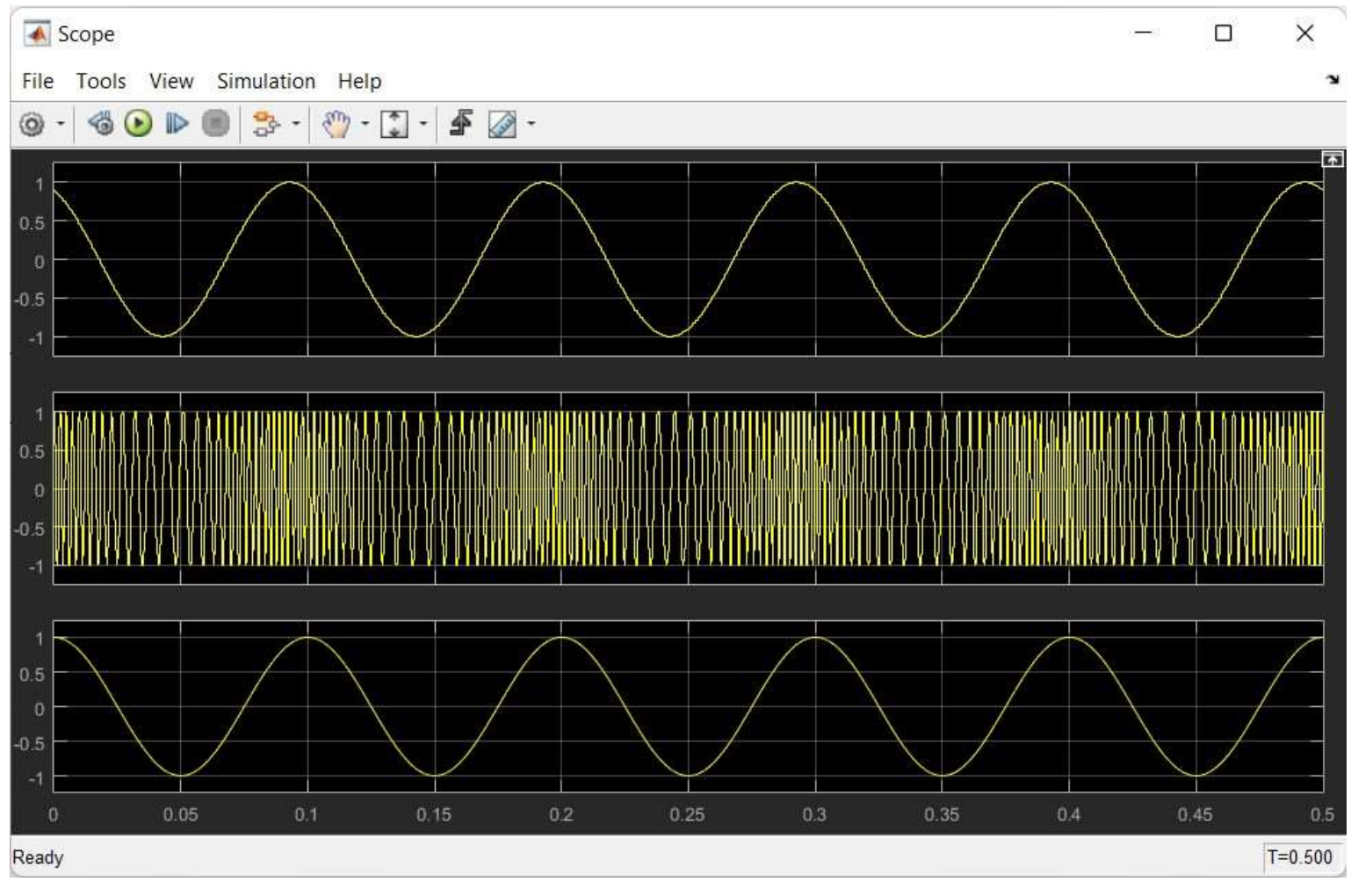


Figure 4: FM Modulator and Demodulator



**Block Parameters: Analog Filter Design**

Analog Filter Design (mask) (link)

Design one of several standard analog filters, implemented in state-space form.

Parameters

Design method: **Butterworth**

Filter type: **Lowpass**

Filter order: **10**

Passband edge frequency (rad/s):  **$2\pi \cdot 10$**

OK Cancel Help Apply

**Block Parameters: Continuous-Time VCO**

Continuous-Time VCO (mask) (link)

Generate a continuous-time output signal whose frequency changes in response to the amplitude variations of the input signal. The input signal must be a sample-based scalar.

Parameters

Output amplitude (V): **1**

Quiescent frequency (Hz): **10**

Input sensitivity (Hz/V): **50**

Initial phase (rad): **0**

OK Cancel Help Apply

**DISCUSSION:** A frequency demodulator, also called frequency discriminator, is a circuit, which converts instantaneous frequency variations to linear voltage changes. There are many types of circuits used in communication systems such as FM to AM conversion, phase-shift discriminators and phase locked loop (PLL) frequency demodulator. In this experiment we will introduce the operations of phase discrimination method as demodulation.

#### References:

- [1] M. P. Fitz, Fundamentals of Communications Systems, pp. 7.1-7.7, 2007, McGraw-Hill
- [2] MathWorks®, Voltage Controlled Oscillator