# Communication Systems Project Report

## Design of FM Using Simulink


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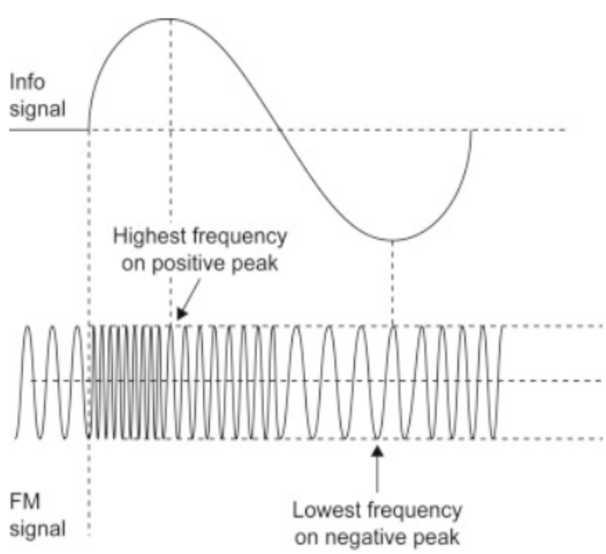
## Introduction:

### Frequency Modulation

- Frequency modulation (FM) is the encoding of information in a carrier wave by varying the instantaneous frequency of the wave. This technology is used in telecommunications, radio broadcasting, signal processing, and computing.

- In frequency modulation, the carrier amplitude remains constant, but its frequency is changed in accordance with the modulating signal. Specifically, the higher the amplitude of the information signal, the greater the frequency change. The actual carrier frequency deviates above and below the center carrier frequency as the information signal amplitude varies. Figure below shows frequency modulation with a sine wave information signal. Note that the carrier frequency gets higher on the positive peaks and lower on the negative peaks of the information signal.



- In analog frequency modulation of an audio signal representing voice or music, the instantaneous frequency deviation, i.e. the difference between the frequency of the carrier and its center frequency, has a functional relation to the modulating signal amplitude.

- There are two different types of frequency modulation used in telecommunications: analog frequency modulation and digital frequency modulation. In analog modulation, a continuously varying sine carrier wave modulates the data signal. The three defining properties of a carrier wave -- frequency, amplitude, and phase -- are used to create AM, PM, and Phase Modulation. Digital modulation, categorized as either Frequency Shift Key, Amplitude Shift Key, or Phase Shift Key, functions similarly to analog, however where analog modulation is typically used for AM, FM, and short-wave broadcasting, digital modulation involves transmission of binary signals (0 and 1).

**Advantages of FM:**

- The frequency of a radio wave is less vulnerable to noise than the amplitude, FM was originally introduced to reduce noise and improve the quality of radio reception. In order to accomplish this, FM radio signals have bandwidth several times that of AM signals. Bandwidths six times or larger are common.

- Also in AM if the amplitude of modulation is to be increased, the power must be increased proportionately. In FM the amplitude of the frequency modulation can be increased without increasing the power at all. In addition, since the amplitude of the FM signal remains constant, amplitude limiters can be set close to the FM signal amplitude and thus very effectively reduce impulse noise.

**Procedures for Generation of FM Signals:**

**Direct Method for generating FM signal**

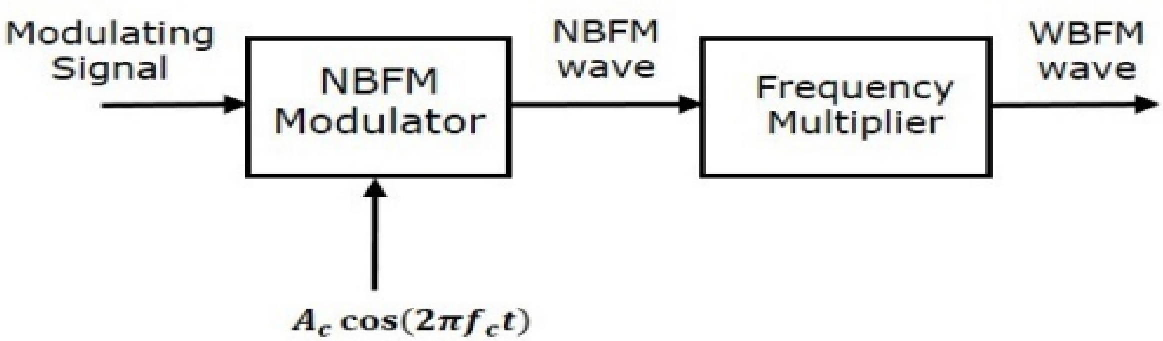
• In this method frequency modulation is done by using Voltage Controlled Oscillator (VCO).

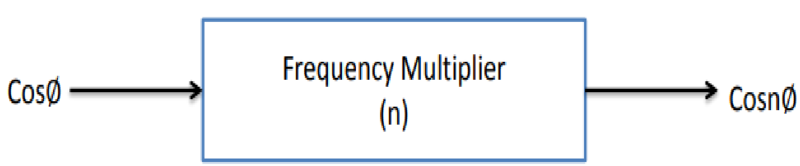
• VCO is an oscillator whose frequency can be controlled by external voltage.

• In a VCO, the oscillation voltage changes linearly with control/external voltage.

• Thus, in direct FM generation system, the instantaneous frequency of carrier wave is varied in accordance with the amplitude of baseband signal m(t) by using VCO

**Indirect method-Armstrong method**



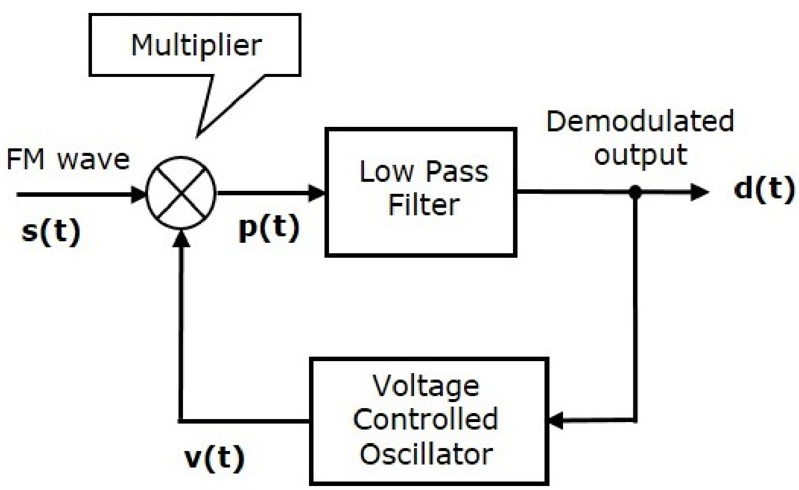




Here we can see from the above block diagram about what is happening
Here first about frequency multiplier. Frequency multiplier is a non-linear device, which produces an output signal whose frequency is ‘n’ times the input signal frequency. Where, ‘n’ is the multiplication factor.

Here the modulating signal is passed through a Narrow Band Frequency Modulator which converts it to a NBFM Wave. Then the NBFM Wave is passed through a frequency multiplier which at the end gives a WBFM Wave.

**We have tried 3 different methods of demodulation of FM signals.**
They are as follows:

**1) Phase Discrimination:** This block diagram consists of the multiplier, the low pass filter, and the Voltage Controlled Oscillator (VCO). VCO produces an output signal v(t), whose frequency is proportional to the input signal voltage d(t). Initially, when the signal d(t) is zero, adjust the VCO to produce an output signal v(t), having a carrier frequency and −90 phase shift with respect to the carrier signal. FM wave s(t) and the VCO output v(t) are applied as inputs of the multiplier. The multiplier produces an output, having a high frequency component and a low frequency component. Low pass filter eliminates the high frequency component and produces only the low frequency component as its output. This low frequency component contains only the term-related phase difference. Hence, we get the modulating signal m(t) from this output of the low pass filter.



**2) Envelope detection :**

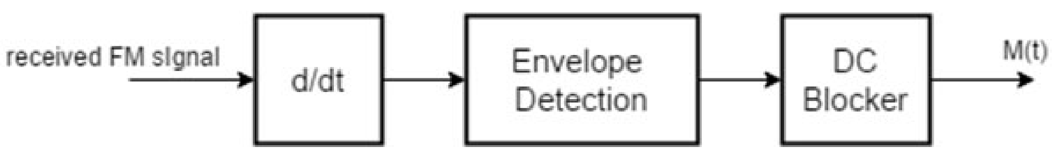
We know that the fm wave is -

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

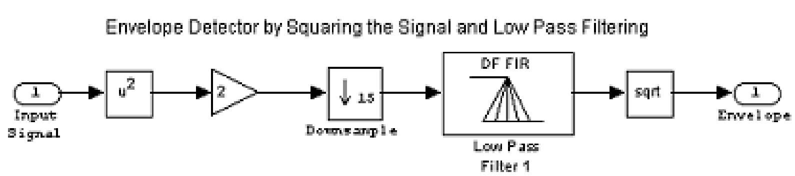
Differentiate the above equation with respect to 't'.

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

Now we can see that the message term is in the amplitude side due to differentiation. If we find the envelope of the differentiated signal, we can assume that to be the message signal.

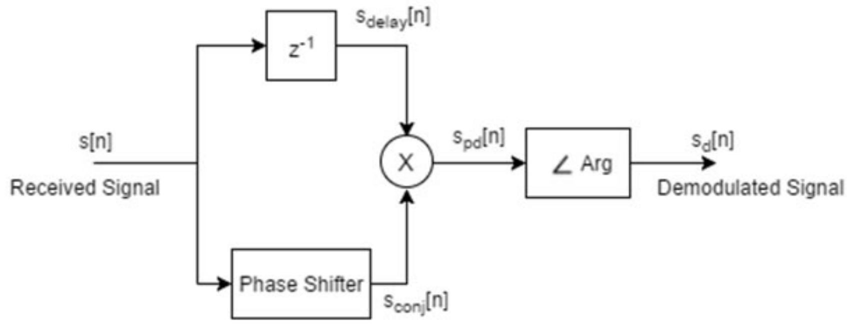



To find the envelope we use the squaring method.




We square the signal and square root it to get the magnitude of the signal. Magnitude is nothing but the message signal

**3) Non-coherent FM Demodulator(Complex Delay Line Frequency Demodulator) :**




We use the above block diagram for finding the demodulated signal.

The message signal can be written as-

$$s(t) = A_c e^{j(2\pi f_c t + \theta_F M(t))}$$

Now we find the conjugate and delay of our message signal.

$$s_{conj}(n) = A_c e^{-j(2\pi f_c t + \theta_F M(t))}$$

$$s_{delay}(t) = A_c e^{j(2\pi f_c (t-\tau) + \theta_{FM}(t-\tau))}$$

Now by multiplying these 2 signals, we got:

$$s_p d(t) = s_c onj(t) \times s_d elay(t) = A_c^2 e^{-j[(2\pi f_c t + \theta(t) - (2\pi f_c (t-\tau) + \theta_F M(t-\tau))]}$$

By finding the phase of the above signal:

$$S\angle s_{pd} = -(2\pi f_c t + \theta(t) - (2\pi f_c(t-\tau) + \theta_{FM}(t-\tau))$$

$$= -(2\pi f_c t - 2\pi f_c(t-\tau) + \theta_{FM}(t) - \theta_{FM}(t-\tau))$$

We get 2 terms; one is the message signal and the other one is the carrier signal frequency.

$$s_d = \angle s_{pd} = -\left[\frac{d}{dt}(2\pi f_c t) + \frac{d}{dt}\theta_{FM}(t)\right] = -\left[2\pi f_c t + 2\pi K_f m(t)\right]$$

## <u>Problem Statement:</u>

### Design of FM using MATLAB Simulink:

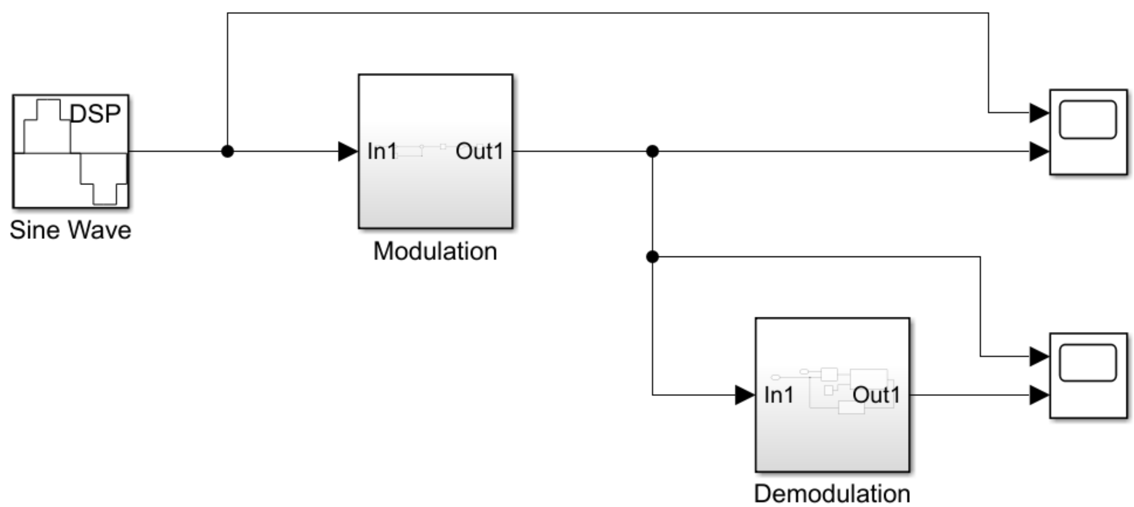
We have to use the simulink package in matlab to simulate the FM modulation and demodulation and test it with inputs. Our goal is to create a FM model which can take a speech signal as input and demodulate the same speech signal in the receiving part. We simulated 3 models with different inputs.

**Results:**

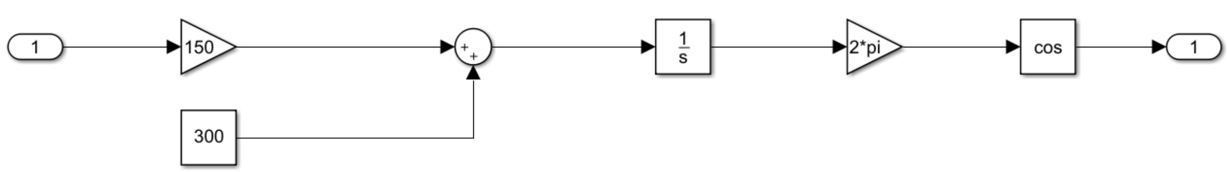
By implementing these 3 methods of demodulation in matlab simulink we got the following simulations and results:

1) **Phase discrimination**

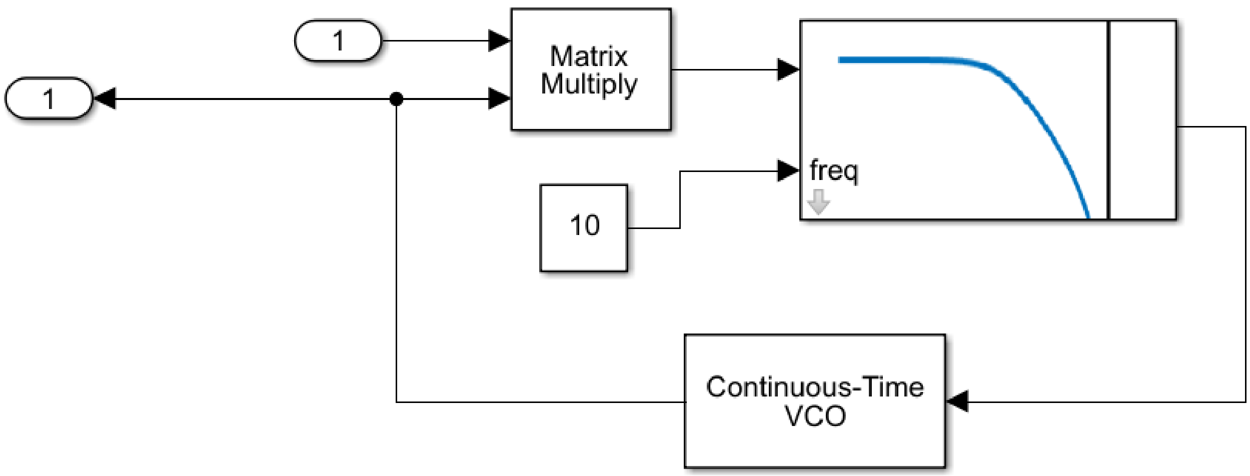
**The Simulink model :** Here we are sending a sin wave of 10Hz as an input and the carrier frequency is 300 Hz. the whole modulation happens in the modulation block.



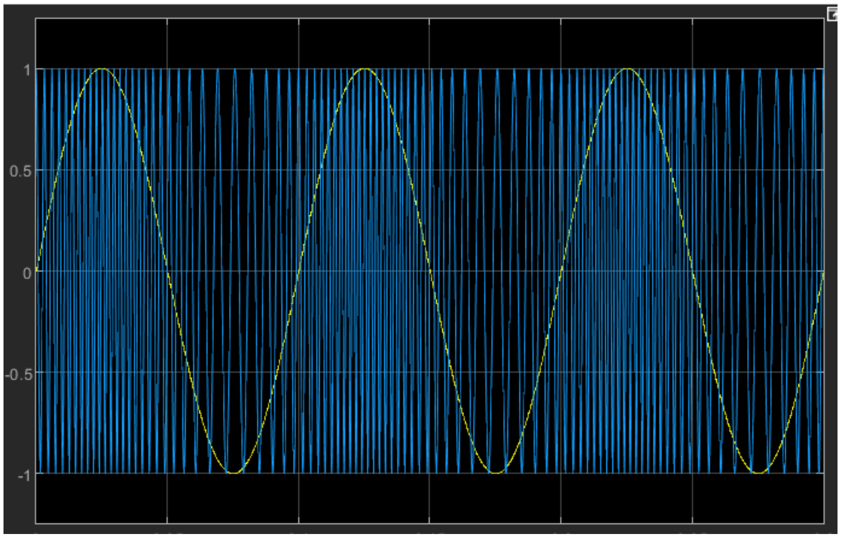

**Modulation block:**



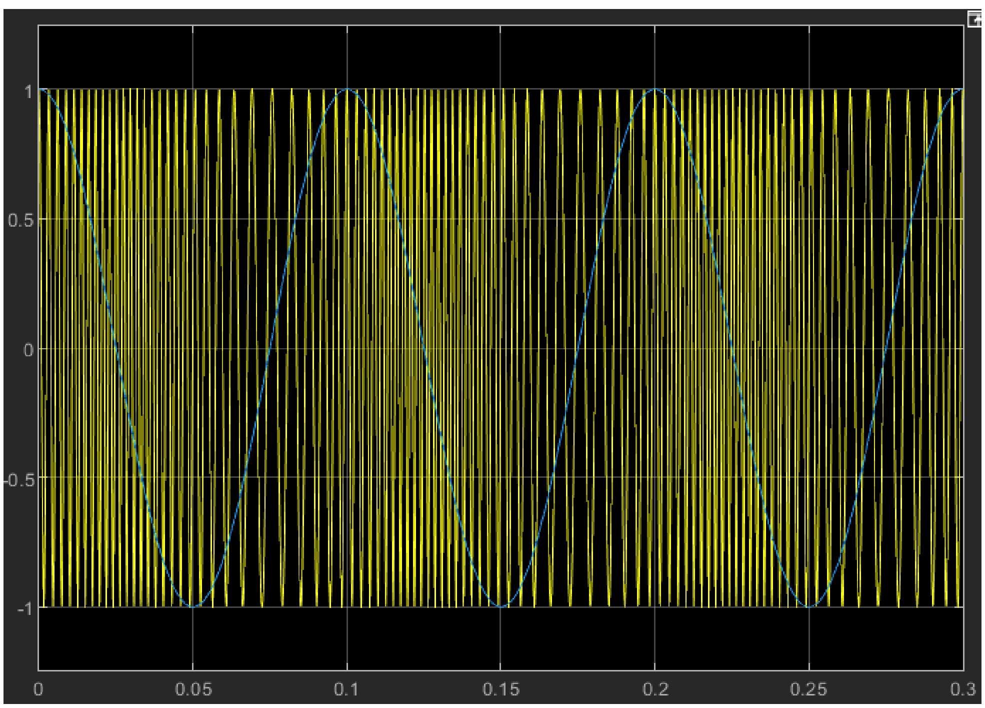
**Demodulation block:**



**Results:**



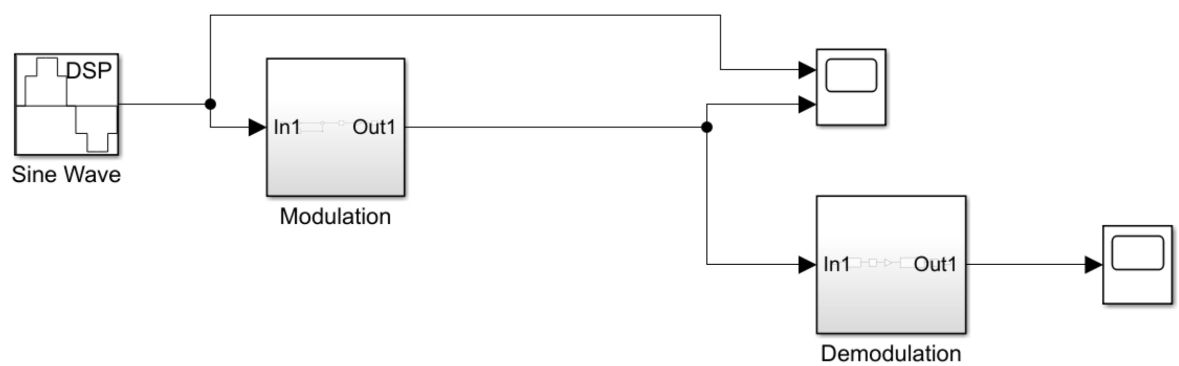

This is the input of the simulink model: yellow graph represents a sin wave, blue signal represents the FM modulated sine signal



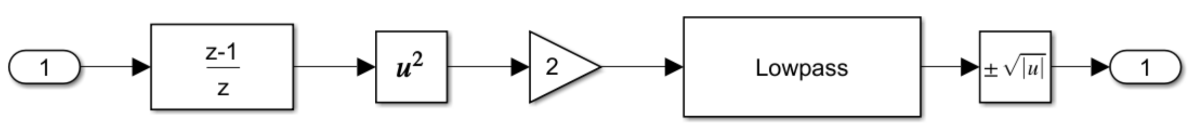

This is the output of the simulink model: blue graph represents a sin wave , yellow signal represents the FM modulated sine signal

## 2)Envelope Detection

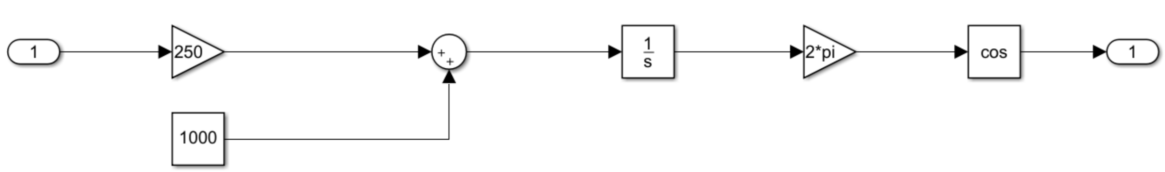
**The Simulink Model :** Here we are sending a sin wave of 10Hz as an input and the carrier frequency is 300 Hz. the whole modulation happens in the modulation block.



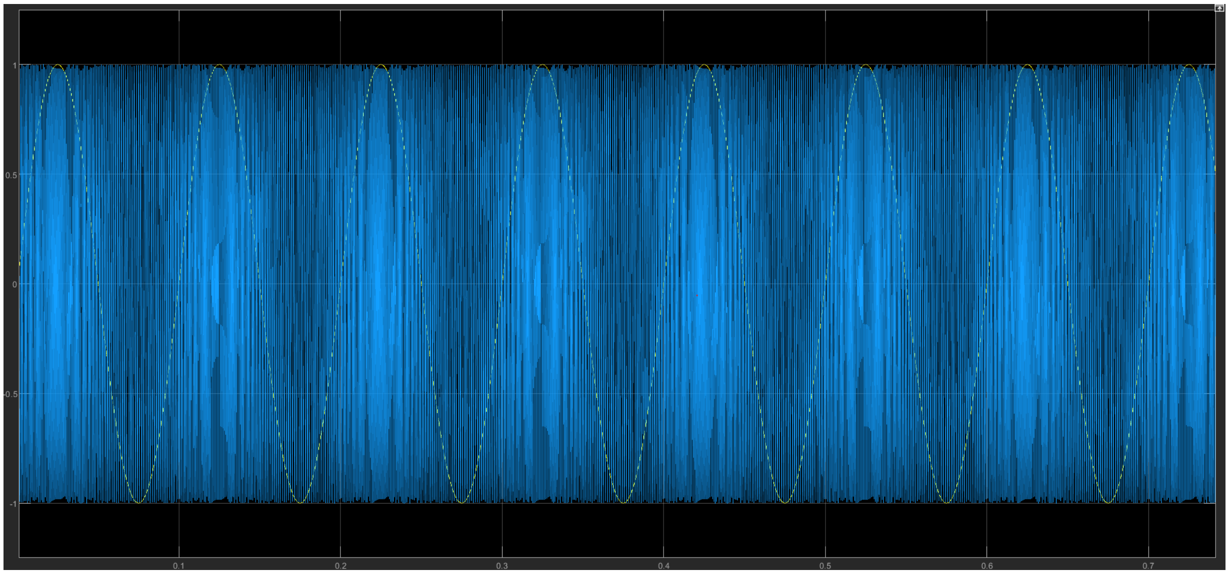

**Modulation block:**




**Demodulation block:**

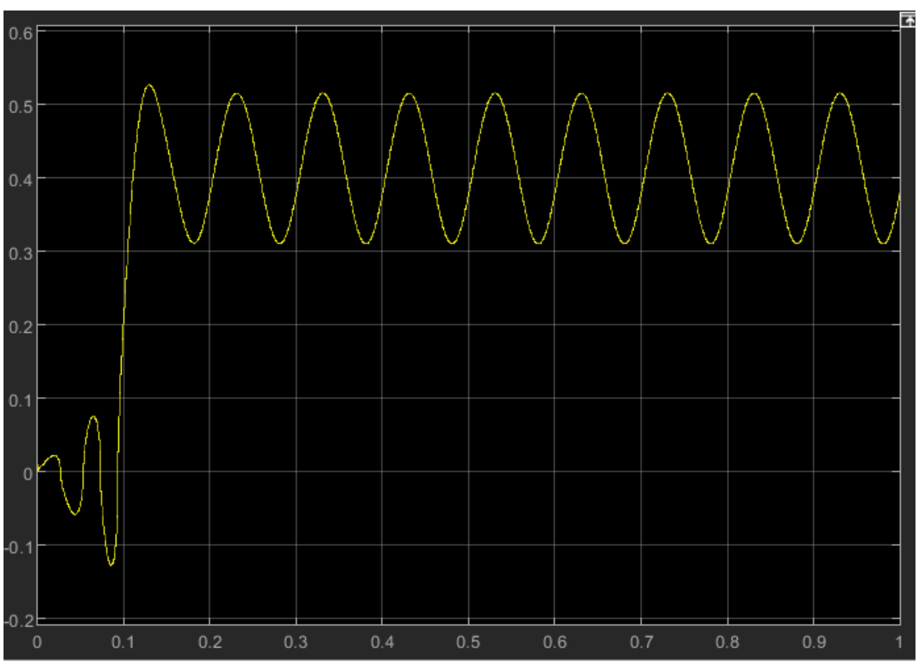


**Results:**



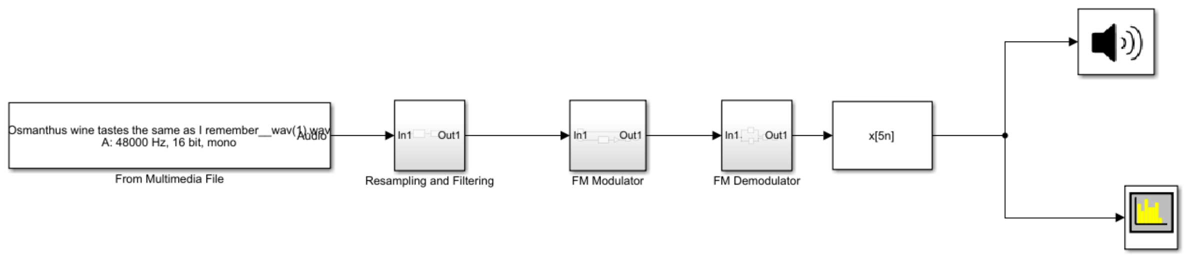
The yellow graph represents the sine wave and the blue graph represents the modulated sine wave. We can faintly make out the sine wave from the above input signal.

The output is as follows.

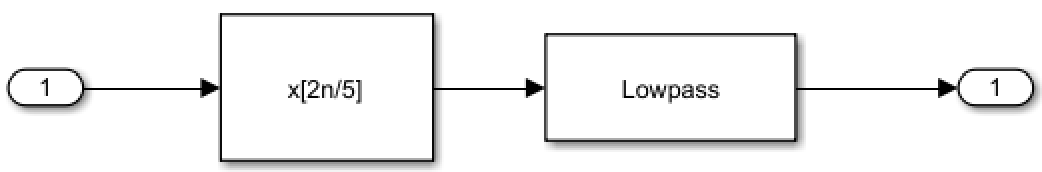


### 3)Non-coherent FM Demodulator(Complex Delay Line Frequency Demodulator)

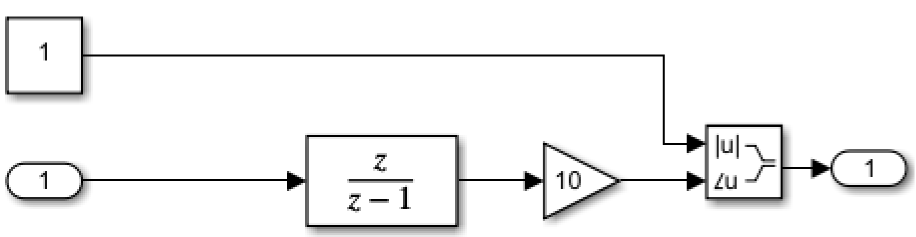
**The Simulink Model :** Here we are sending a speech signal at 48kHz sampling rate as an input.



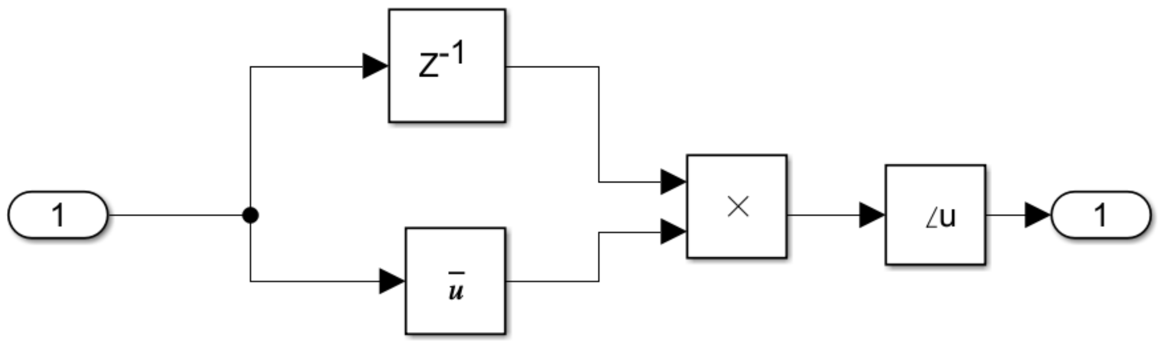

**Resampling and filtering block:** we first bring down the sampling rate by using FIR rate conversion block.




**Modulation block:**



**Demodulation block:**




**P.S:** The output here is an audio file. We have put in the matlab zip file along with the codes.Please look into it

## Discussions:

### Shortcomings of FM

- One of the minor disadvantages of frequency modulation is that the demodulator is a little more complicated, and hence slightly more expensive than the very simple diode detectors used for AM. However this is much less of an issue these days because many radio integrated circuits incorporate a built in frequency demodulator .

- Like AM, FM also produces sidebands. But unlike AM, which produces a single pair of sidebands for each frequency in the modulating signal, the FM process produces an infinite number of pairs of sidebands for each frequency in the information signal. As a result, the bandwidth occupied by an FM signal is enormous. Luckily, the number of sidebands produced can be controlled by properly selecting the amount of deviation permitted in the carrier. Small deviations result in fewer sidebands. Further, some of the higher-order sidebands are extremely low in amplitude and, therefore, contribute little to the FM signal. But while the bandwidth of an FM signal can be controlled and established to fit a desired frequency range, it does nevertheless usually take more room in the spectrum than an AM signal

## Conclusions:

- We got the same sine wave as an output in Phase discrimination method.
- Whereas in envelope detection the output is also a sine signal but it's not upto the scale and its shifted version of input.
- In the non-coherent FM demodulation model we are sending a speech signal as input and the output is the same. Since we are using low pass filters in sampling and filtering blocks, the output is somewhat distorted.