Assignment 1

This assignment is an application on Simulink. It gives you the ability to simulate an Analog communication system that uses frequency modulation (FM). It discusses the bandwidth and the waveform of the message throughout baseband stage, modulation stage and reconstruction stage.

Simulink and Frequency Modulation (FM):

The objective of this section is to increase the students’ familiarity with both simulink and frequency modulation (FM) signals. Where we will do the following:

- Create an FM signal by modulating a message signal onto a carrier.
- Examine the spectrum of the modulated carrier.

Background:

Angle modulation is a process in which the angle of the modulating sinusoidal carrier wave is varied according to the baseband signal. In this method of modulation, the amplitude of the carrier wave is maintained constant. An important feature of angle modulation is that it can provide better discrimination against noise and interference than amplitude modulation. However, this improvement in performance is achieved at the expense of increased transmission bandwidth; that is, angle modulation provides us with a practical means of exchange channel bandwidth for improved noise performance. Such a trade off is not possible with amplitude modulation, regardless of its form.

The most commonly used methods to vary the angle of the carrier signal in accordance to the message are phase modulation (PM) and frequency modulation (FM). In our experiment we will consider FM. FM is that form of angle modulation in which the instantaneous frequency \( f_i(t) \) is varied linearly with the message signal \( m(t) \) as shown by: \( f_i(t) = f_c + k_f m(t) \), where \( k_f \) denotes a scaling factor, limiting the maximum frequency deviation of signal

\[
\Delta \omega = k_f \left| f(t) \right|_{max} \Rightarrow S(t) = A \cos(\omega_c t + k_f \int_0^t m(\tau)d\tau)
\]

As you know, from communications I class, the theoretical bandwidth of FM signals is infinity. Anyway, we can approximate the BW of the FM signal using Carson’s rule, which is defined as

\[
BW_{FM} = 2(\Delta f + BW_{m(t)})
\]

where \( \Delta f \) is the peak frequency deviation.
In this part you will benefit from the spectrum analyzer block in displaying the frequency contents of the modulated signal and thus to estimate the signal bandwidth.

**Assignment(1):**

**Design problem:**

We intend to build a communication system that has the following design specifications:

- **Modulation type:** Frequency modulation
- **Modulating signal:** sine wave
- **Modulating frequency:** 7.5 Hz
- **Carrier frequency:** 75 Hz
- **Amplitude of modulating signal:** 2Vpp
- **Amplitude of carrier signal:** 2Vpp

**Building Frequency Modulation (FM) Model**

1. Start Simulink by typing `simulink` in the Matlab workspace.
2. Open a new model window (File → New → Model).
3. Create the following FM model.

4. Set the parameters of the different blocks as follows:

**Signal generator**

- **Waveform:** Sine
- **Amplitude:** 1
- **Frequency:** 2.5
- **Units:** Hertz

Select checkbox (interpret vector parameter as 1-D)

**FM modulator passband**

- **Carrier frequency:** 75
- **Initial phase:** 0
- **Modulation constant:** 25
- **Symbol time:** 0.001
- **Symbol interval:** Inf

**FM demodulator Passband:**
Lowpass filter numerator: \[ [4.57 \quad 9.14 \quad 4.57] \times 0.01 \]
Lowpass filter denominator: \[ [1 \quad -1.3108 \quad 0.4936] \]

**Analog Filter design:**

Desired method: Butterworth    
Filter type: Lowpass
Filter order: 5    
Passband edge frequency: 350

**Spectrum Analyzer**

Number of sample points: 512    
Sample period: 0.001
Plotting period: 10

**Simulation parameters**

(Simulation \(\rightarrow\) simulation parameters), Select solver tab

a. Start time 0.0    
Stop time 10
b. Type: fixed step    
Ode5 (Dormand-price)
c. Fixed step size: 0.001    
Mode: Auto
5. Run the simulation and answer the following:

- Use the scope to display the input signal and the modulated signal.
- What is the purpose of the lowpass filter in our model?
- Is the reconstructed signal (the signal at the demodulator output) the same as the input signal?

Now if we change the input to a square wave, then the frequency of the carrier signal will change back and forward between two different frequencies. This is a type of digital modulation techniques called Binary Frequency Shift Keying (BFSK). In this method, the symbol 1 and 0 are distinguished from each other by the frequency of the carrier (modulated) signal. Here you are invited to simulate this system and don't worry about the details, later we will study such a system in depth.

6. Change the input message from a sine wave to a square wave

- Display the signal after the modulator stage in time domain.
- Is the reconstructed signal (the signal at the demodulator output) the same as the input signal?

**Important notes about FM modulator and demodulator blocks:**

Typically, an appropriate Carrier frequency value is much higher than the highest frequency of the input signal. To avoid having to use a high carrier frequency and consequently a high sampling rate, you can use baseband simulation (FM Modulator.
Baseband block) instead of passband simulation. By the Nyquist sampling theorem, the reciprocal of the Sample time parameter must exceed twice the Carrier frequency parameter.

In the course of demodulating, the block uses a filter whose transfer the lowpass filter numerator describes function and Lowpass filter denominator parameters, which are listed in order of descending powers of s.