Lab 1: Transmission Fundamentals

Course Name: Wireless Data Networks

Course Code: CPIT-375

Objectifs:

Review the signal properties and transmission fundamentals

Learn how to use Matlab/Simulink to model signals

What is Simulink?

Simulink is an icon-driven dynamic simulation package that allows the user to represent a system or a process by a block diagram. Once the representation is completed, Simulink may be used to digitally simulate the behavior of the continuous or discrete-time system. Simulink inputs can be Matlab variables from the workspace, or waveforms or sequences generated by Simulink itself. These Simulink-generated inputs can represent continuoustime or discrete-time sources.

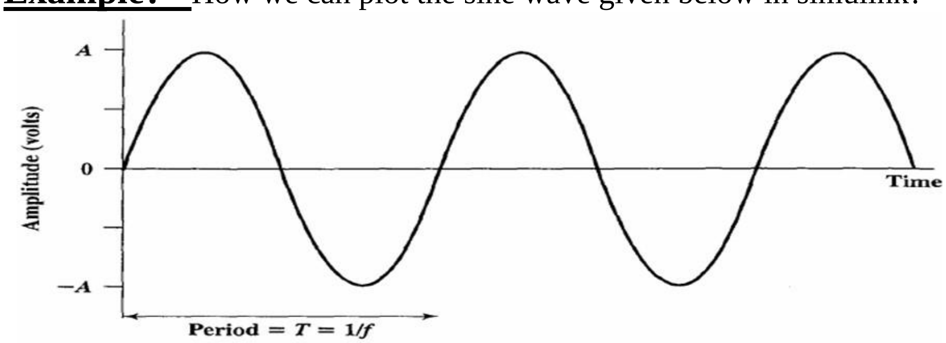
First time with Matlab/Simulink ?

1. Start Matlab from start menu
2. In the command menu write simulink

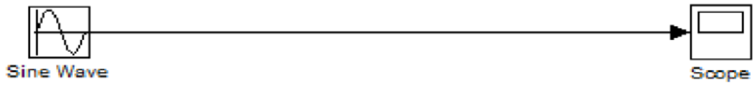
   The simulink tool will be started; it consists of a main window that has many tools.
3. Go to file from the menu select new then select model

   Now, we can add components of the circuit to the model. We will use gates from four main categories (Source; Sink; Logical and bit operators; Math Operators)
4. Click and drag the gate to the model window
5. Connect the block as the Diagram needed
6. Test the block/diagram by press on start button

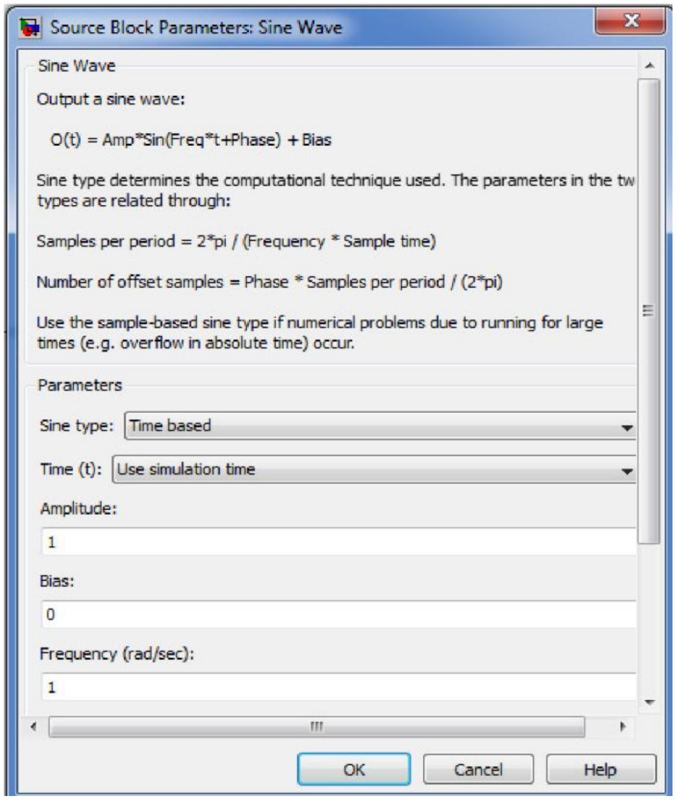
Example? How we can plot the sine wave given below in simulink?

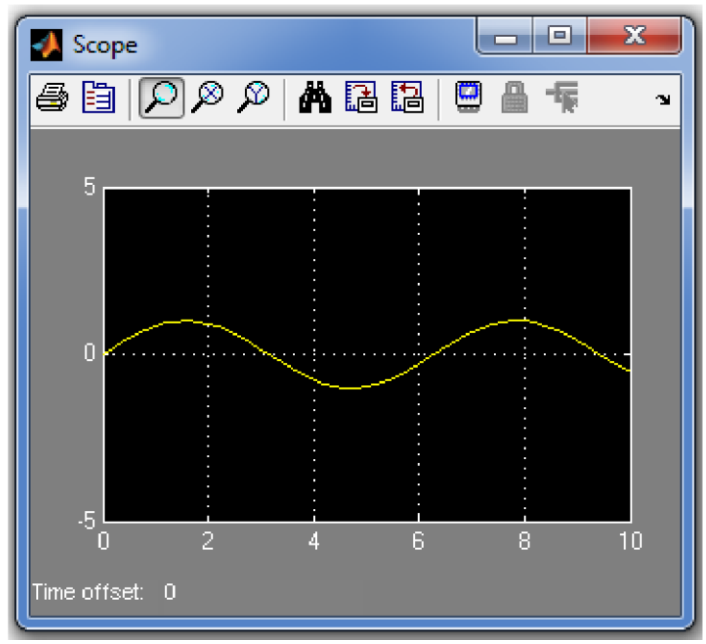


a) We will use Sign wave from sources and Scope from sinks.



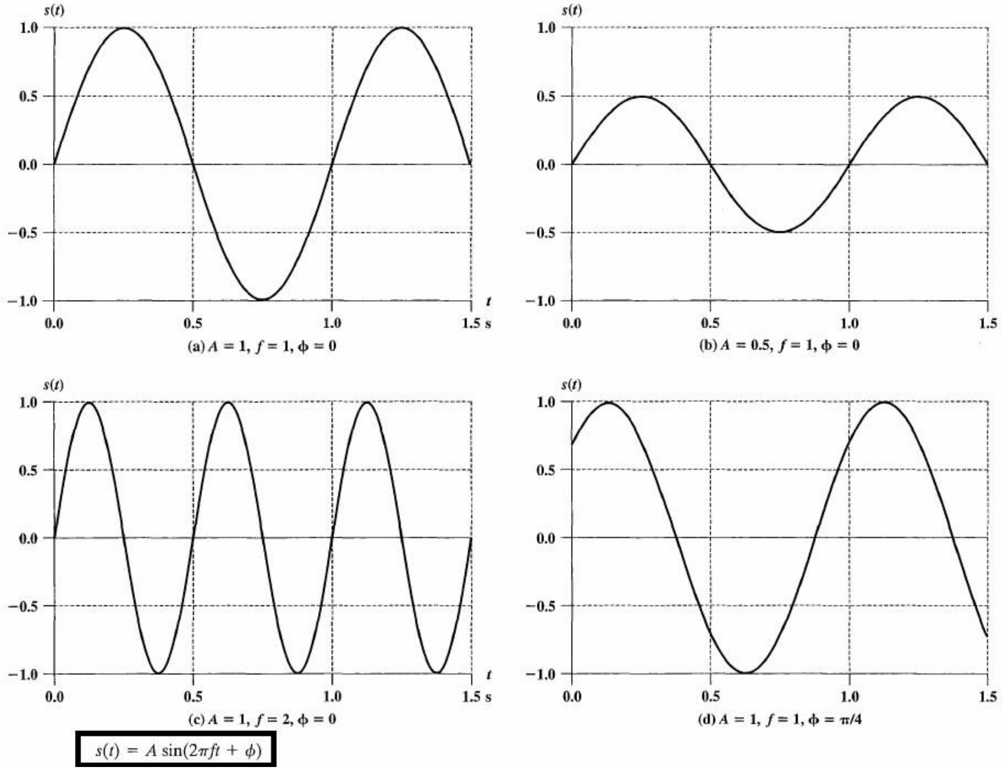
By clicking the Sign wave block, parameters can be configured (such as Frequency, Time and amplitude of the signal) and we can visualize the signal by clicking the Scope block.



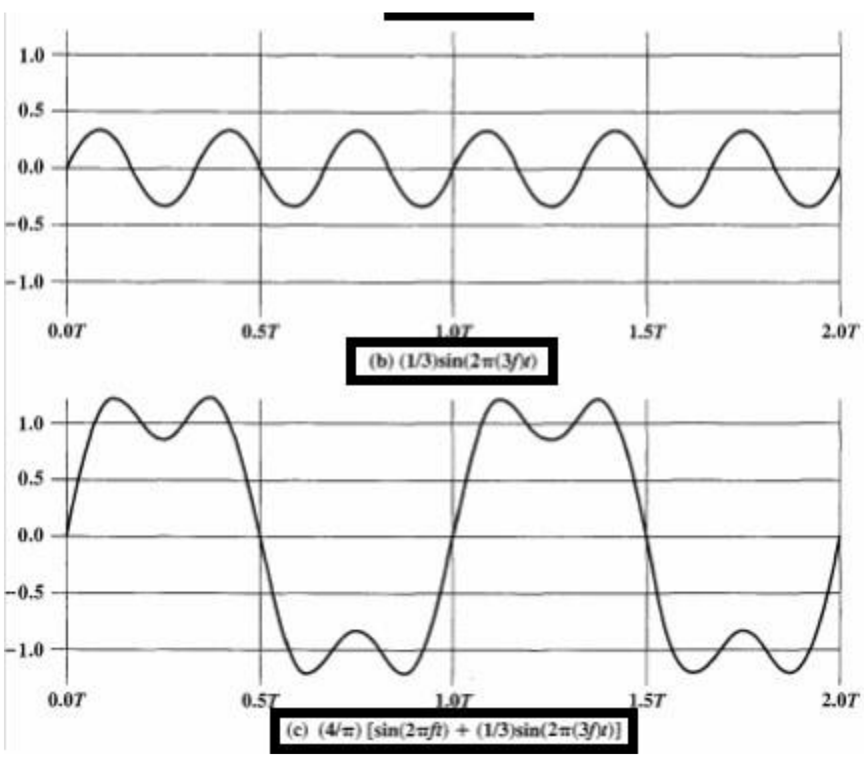


Labs activities:

1) Using the same diagram, draw the plots of sine wave given below in the simulink; vary the parameters of the signal as given in figure.



2) Draw the Plots of sine wave given below in the simulink; vary the parameters of the signal as given in figure.



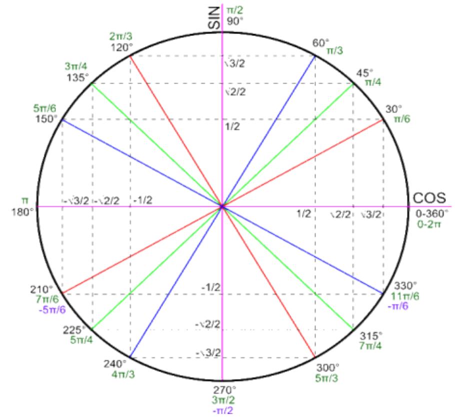
3) Using Matlab script, represent the frequency spectrum of the signal below.
   s(t)= 30sin(2***10⁶***pi*t)+ 5sin(2***5*10⁶***pi*t)+ 10sin(2***10*10⁶***pi*t)

Exercices:

1) A signal has a fundamental frequency of 1000 Hz. What is its period?

The period (T) of a signal is the reciprocal of its frequency (f). Therefore, the period of a signal with a frequency of 1000 Hz is 1/1000 seconds or T = 0.001 s

2) Based on the trigonometric circle, find the phase of each signal: $s_1(0)=A$, $s_2(0)=A*\sqrt{2}/2$, $s_3(0)=A*\sqrt{3}/2$, $s_4(0)=A/2$, $s_5(0)=0$



- s1(0) = A
  s1 starts at amplitude A on the trigonometric circle. This corresponds to a phase of 0 degrees.
- s2(0) = A * sqrt(2) / 2
  s2 starts at amplitude A/sqrt(2), which is 45 degrees on the trig circle. So s2 has a phase of 45 degrees.
- s3(0) = A * sqrt(3) / 2
  s3 starts at amplitude A/sqrt(3), which corresponds to 60 degrees phase.
- s4(0) = A/2
  s4 starts at half of amplitude A. This is at 90 degrees on the trig circle, so s4 has a phase of 90 degrees.
- s5(0) = 0
  s5 starts at zero amplitude, which is at 270 degrees phase on the trigonometric circle.

3) Assume that a periodic signal of period T is traveling with a velocity *v*. What is its wavelength λ **(**the distance occupied by a single cycle**)**?

Period (T) is the time it takes to complete one cycle of the periodic signal

Velocity (v) is the rate at which the signal travels distance per time

Wavelength (λ) is the distance occupied by a single cycle of the periodic signal

The relationship between period, velocity, and wavelength is:

$\lambda = vT$

Where:
λ = Wavelength
v = Velocity
T = Period

So if we know the period T and velocity v of the signal, we can calculate the wavelength λ as:

$\lambda = vT$

Therefore, for a periodic signal with period T traveling at velocity v, the wavelength λ is simply the product of v and T.

4) Consider two periodic functions A(t) and h(t), with periods T1 and T2, respectively. Is it always the case that the function f(t) = A(t) + h(t) is periodic? If not, under what conditions is f(t) periodic?

The function f(t) = A(t) + h(t) is periodic if and only if the periods T1 and T2 are multiples of each other or have a common multiple. In other words, the ratio of T1 to T2 should be a rational number. If the ratio is irrational, the resulting function f(t) will not be periodic.

5) Assume that $s(t) = (4/\pi)\,[\sin(2\pi ft) + 1/3 \sin(2\pi(7f)t)]$ and $f=10^3$(Hz). What is its bandwidth and data rate? What if $f=10^6$(Hz)?

The signal s(t) contains two sinusoidal components: one at frequency f and one at frequency 7f.

The bandwidth is the difference between the highest and lowest frequencies.

Here the lowest frequency is f = 10^3 Hz.

The highest frequency is 7f = 710^3 = 710^3 Hz.

Therefore, the bandwidth is 7*10^3 - 10^3 = 6000 Hz. (Bmax – Bmin)

The data rate is 2 times the highest frequency (Nyquist rate).

Here the highest frequency is 7*10^3 Hz.

Therefore, the data rate is 2710^3 = 14,000 samples/sec.

If f = 10^6 Hz:

Bandwidth = 710^6 - 10^6 = 610^6 Hz

Data rate = 2710^6 = 14*10^6 samples/sec

So, for f = 10^3 Hz, bandwidth is 6000 Hz and data rate are 14,000 samples/sec.

For f = 10^6 Hz, bandwidth is 6 MHz and data rate are 14 MS/s.

6) Define the Signal-to-noise ratio. Give the formula in dB.

The Signal-to-noise ratio (SNR) is a measure of the quality of a signal relative to the background noise. It is defined as the ratio of the power of the signal to the power of the noise. The formula to calculate SNR in decibels (dB) is:

SNR_dB = 10 * log10(SNR) or SNR_dB = 10 * log10(signal power / noise power).

7) What is the channel capacity for a teleprinter channel with a 300-Hz bandwidth and a signal-to-noise ratio of 3 dB?

The channel capacity for a teleprinter channel with a 300-Hz bandwidth and a signal-to-noise ratio of 3 dB can be calculated using the formula:

C = B * log2(1 + SNR)

where C is the channel capacity, B is the bandwidth, and SNR is the signal-to-noise ratio.

Plugging in the values:

$C = 300 * \log_2(1 + 10^{(3/10)})$

$C \approx 300 * \log_2(2.995)$

$C \approx 300 * 1.58$

$C \approx 474$ bits per second (bps)

8) Under which condition Nyquist establishes the capacity formula? Give the Nyquist capacity formula for binary signal and multi-level signal.

Nyquist's formula for channel capacity states that the maximum data rate (C) of a channel is equal to 2 times the bandwidth (B) multiplied by the logarithm of the number of different signal levels (M). The formula for binary signals (M = 2) is:

$C = 2B$

For multi-level signals, the formula is:

$C = 2B * \log_2(M)$

9) Given a channel with an intended capacity of 20 Mbps, the bandwidth of the channel is 3 MHz. What signal-to-noise ratio is required to achieve this capacity?

- The channel capacity formula is:
  $C = B \log_2(1 + SNR)$

  Where:
  C = Channel capacity (bps)
  B = Channel bandwidth (Hz)
  SNR = Signal-to-noise ratio
- We are given:
  C = 20 Mbps = 20,000,000 bps
  B = 3 MHz = 3,000,000 Hz
- Find the required SNR.
- Plugging the values into the formula:

  $20,000,000 = 3,000,000 \log_2(1 + SNR)$
- Now solve this:
  $SNR = 10^7 - 1$
  $SNR \approx 9.965$
- Converting to dB:
  $SNR (dB) = 10 \log_{10}(SNR)$
  ≈ 20 dB

Therefore, to achieve a 20 Mbps capacity on a 3 MHz channel, a signal-to-noise ratio of 20 dB is required.

10) An amplifier has an output of 20 W. What is its output in dBW?

To convert the output power of an amplifier from watts (W) to decibel-watts (dBW), you can use the following formula:

Power (dBW) = 10 * log10(Power (W))

where Power (W) is the power in watts.

For example, if the output power of an amplifier is 20 W:

Power (dBW) = 10 * log10(20) ≈ 13 dBW

So, the output power of the amplifier is approximately 13 dBW.