UNIVERSITY OF BAHRAIN
COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EENG 373: DIGITAL COMMUNICATIONS

EXPERIMENT NO. 5
BASEBAND MODULATION TECHIQUES

Objective

The main objectives of this experiment are:

1. To gain understanding about Baseband digital transmission
2. To learn how to simulate digital transmission system using MATLAB SIMULINK
3. To investigate the operation of these systems

Theory and Background

In mobile communication system, there are transmission or reception signal of baseband intermediate frequency band and radio frequency band depending on the frequency band of the signal. The base band is a frequency band occupied by the original information signal before modulation. Therefore base band is the frequency band of which the lowest frequency is near to 0 or containing a direct current component. The intermediate frequency band is a frequency band to which a base band frequency to be transmitted to outside of the station is increased by adding a local oscillator frequency in a frequency converter in a base station and ,opposite to this, to which a radio frequency received from outside of the station is decreased by subtracting the local oscillator frequency in the frequency converter. The radio frequency band is a frequency band for use in radio communications within an electromagnetic spectrum range from 10KHz to 300GHz.

A Base station transmission system in a mobile communication system comprises

- Modulating a received voice signal in to a base band signal containing I signal portions and Q signal portions and transmitting the base band signal in series
- Digital combining unit for combining the I and Q signals portion on a channel –by-channel basis for each of the sectors
- A digital /analog converting unit for converting the serial baseband signal output from the digital combining unit into a parallel signal ,and then converting the parallel signal into an analog signal and
- A base band signal processing unit for processing the baseband signal from the digital/analog converting unit to conform to a predetermined radio signal.

Application of different digital Modulation techniques in wireless communication are mainly based on the relative spectral efficiency

Phase Shift Keying (PSK)

One of the simplest forms of digital modulation is binary or Bi-Phase Shift Keying (BPSK).The phase of a constant amplitude carrier signal moves between zero and 180 degrees. On an I and diagram , the I state has two different values. There are two possible locations in the state diagram, so a binary one or zero can be sent. The symbol rate is one bit per symbol.
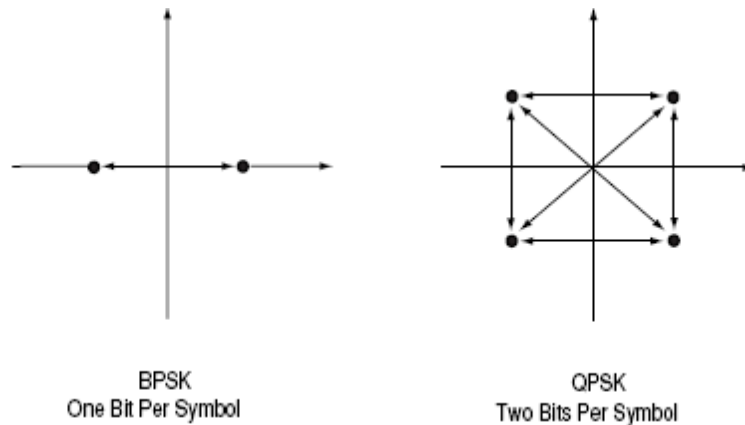

BPSK
One Bit Per Symbol

QPSK
Two Bits Per Symbol

Fig1.1: Phase Shift Keying

A more common type of phase modulation is Quadrature Phase Shift Keying(QPSK). Is used extensively in applications including CDMA cellular services, wireless local loop etc. Quadrature means that the signal shifts between phase states which are separated by 90 degrees. The signal shifts in increments of 90 degrees from 45 to 135,-45,or -135 degrees. These points are chosen as they can be easily implemented using an I/Q modulator .Only two I values and two Q values are needed and this gives two bits per symbol. There are four states because $2^2 = 4$.It is therefore a more bandwidth –efficient type of modulation than BPSK, potentially twice as efficient.

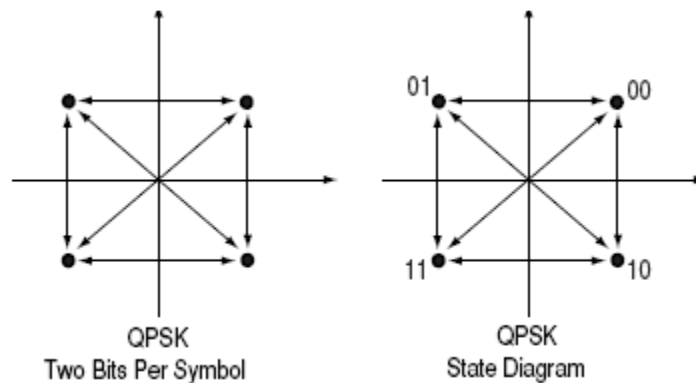The state diagram for QPSK signal is shown in Fig 1.2

QPSK
Two Bits Per Symbol

QPSK
State Diagram

If more bits can be sent with each symbol, then the same amount of data can be sent in a narrower spectrum .This is why modulation formats that are more complex and use a higher number of states can send the same information over a narrower piece of the RF spectrum.
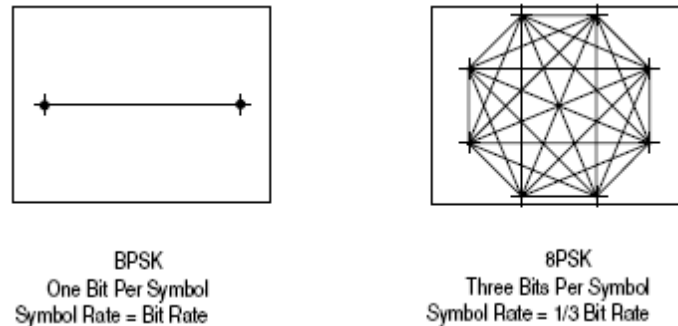

BPSK
One Bit Per Symbol
Symbol Rate = Bit Rate

8PSK
Three Bits Per Symbol
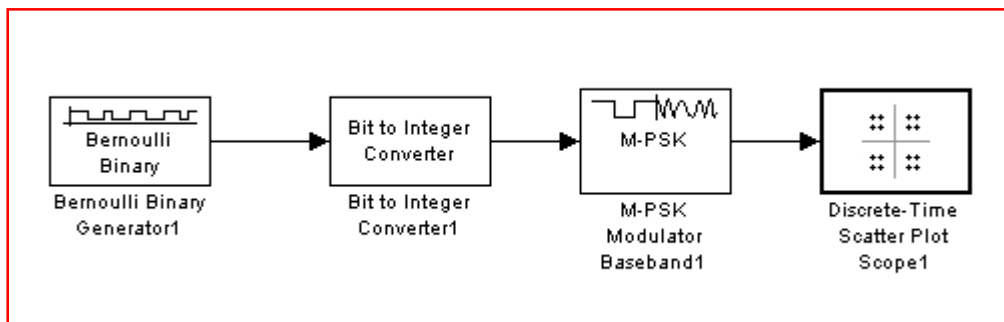Symbol Rate = 1/3 Bit Rate

Fig 1.3: Spectrum Requirement

An example of how symbol rate influence spectrum requirements can be seen in eight-state Phase Shift Keying(8PSK).It is a variation of PSK. There are eight possible states that the signal can transition to at any time. The phase of the signal can take any of eight values at any symbol time. Since $2^3 = 8$,there are three bits per symbol .This means the symbol rate is one third of the bit rate. This is relatively easy to decode.
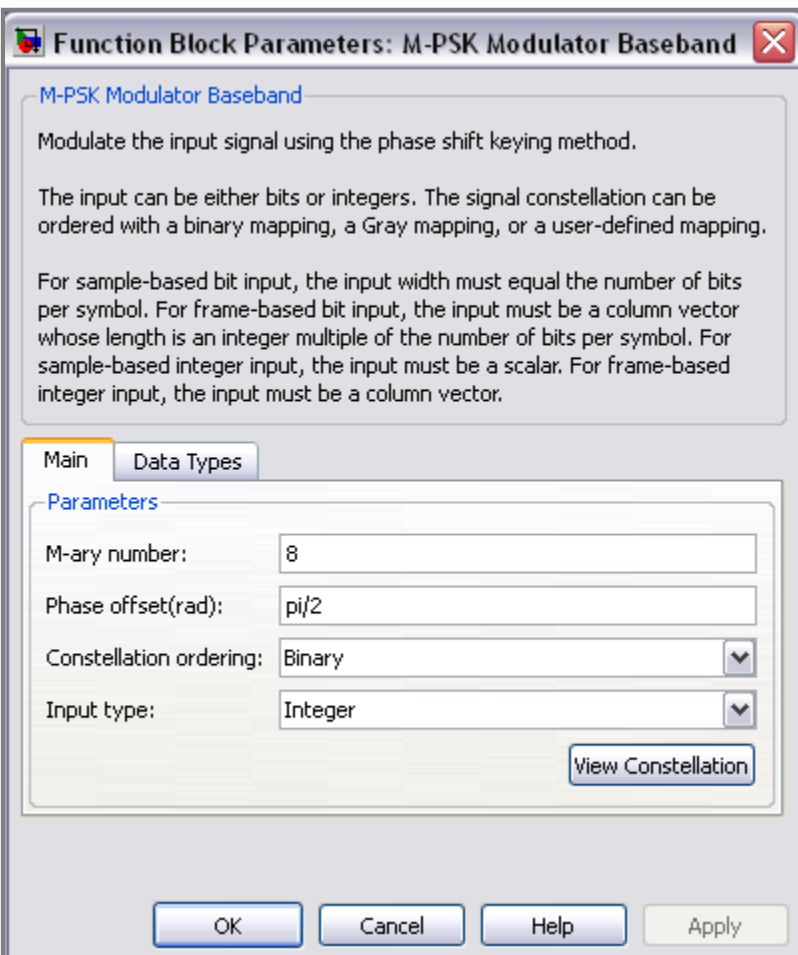
Frequency Shift Keying (FSK)

Frequency modulation and phase modulation are closely related. A static frequency shift of +1Hz means that the phase is constantly advancing at the rate of 360 degree per second(2π rad/sec), relative to the phase of the unshifted signal. FSK (Frequency Shift Keying) is used in many applications including cordless and paging systems. In FSK, the frequency of the carrier is changed a function of the modulating signal(data) being transmitted. Amplitude remains unchanged. In binary FSK (BFSK or 2FSK) ,a "1" is represented by one frequency and a '0' is represented by another frequency.

Laboratory Procedure

I. Simulation of Baseband M-PSK (M=2 and 4)

Source Block Parameters: Bernoulli Binary Generator

Bernoulli Binary Generator

Generate a Bernoulli random binary number.
To generate a vector output, specify the probability as a vector.

Parameters

Probability of a zero: `0.5`

Initial seed: `61`

Sample time: `0.01`

☑ Frame-based outputs

Samples per frame: `3`

Output data type: `double` ▾
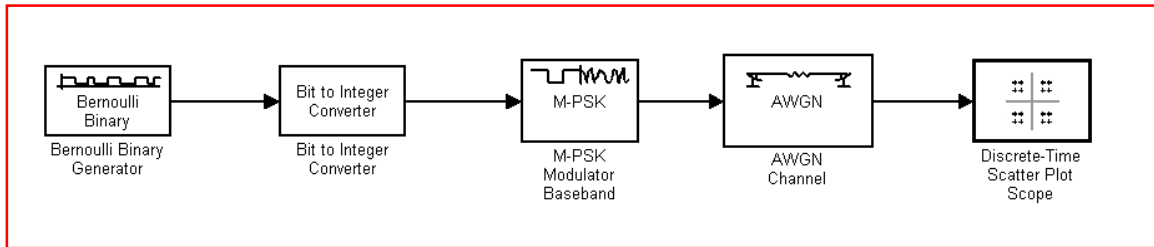
[OK] [Cancel] [Help]

Function Block Parameters: Bit to Integer Converter

Bit to Integer Converter (mask) (link)

Map a vector of bits to a corresponding vector of integer values. The 'Number of bits per integer' parameter defines how many bits are mapped for each output.

This block is single-rate and single-channel. The input can be either a scalar, a sample-based vector, or a frame-based column vector. For sample-based inputs, the input length must equal the 'Number of bits per integer'. For frame-based inputs, the input length must be an integer multiple of the 'Number of bits per integer'. The output is always a column vector with a length equal to 'Number of bits per integer' times smaller than the input signal length.

Parameters

Number of bits per integer:

`3`

Input bit order: `MSB first` ▾

After bit packing, treat resulting integer values as: `Unsigned` ▾

Output data type: `Inherit via internal rule` ▾

[OK] [Cancel] [Help] [Apply]

Function Block Parameters: M-PSK Modulator Baseband

M-PSK Modulator Baseband

Modulate the input signal using the phase shift keying method.

The input can be either bits or integers. The signal constellation can be ordered with a binary mapping, a Gray mapping, or a user-defined mapping.

For sample-based bit input, the input width must equal the number of bits per symbol. For frame-based bit input, the input must be a column vector whose length is an integer multiple of the number of bits per symbol. For sample-based integer input, the input must be a scalar. For frame-based integer input, the input must be a column vector.

Main | Data Types

Parameters

M-ary number: `8`

Phase offset(rad): `pi/2`

Constellation ordering: `Binary` ▾

Input type: `Integer` ▾

[View Constellation]

[OK] [Cancel] [Help] [Apply]

II. Simulation of Baseband M-PSK with Noise

III. Simulation of Baseband 2-FSK

Source Block Parameters: Bernoulli Binary Ge...

Bernoulli Binary Generator

Generate a Bernoulli random binary number.
To generate a vector output, specify the probability as a

Parameters

Probability of a zero: 0.5

Initial seed: 61

Sample time: 1/100

☐ Frame-based outputs

☐ Interpret vector parameters as 1-D

Output data type: double

[OK] [Cancel]

Function Block Parameters: M-FSK Modulator Baseband

M-FSK Modulator Baseband (mask) (link)

Modulate the input signal using the frequency shift keying method.

The input can be either bits or integers. In case of sample-based bit input, the input width must equal the number of bits per symbol. In case of frame-based bit input, the input width must be an integer multiple of the number of bits per symbol.

For sample-based integer input, the input must be a scalar. For frame-based integer input, the input must be a column vector.

The inputs can be either binary-mapped or Gray-mapped into symbols.

In case of frame-based input, the width of the output frame equals the product of the number of symbols and the Samples per symbol value.

In case of sample-based input, the output sample time equals the symbol period divided by the Samples per symbol value.

Parameters

M-ary number:

2

Input type: Bit

Symbol set ordering: Binary

Frequency separation (Hz):

700

Phase continuity: Continuous

Samples per symbol:

100

Output data type: double

[OK] [Cancel] [Help] [Apply]
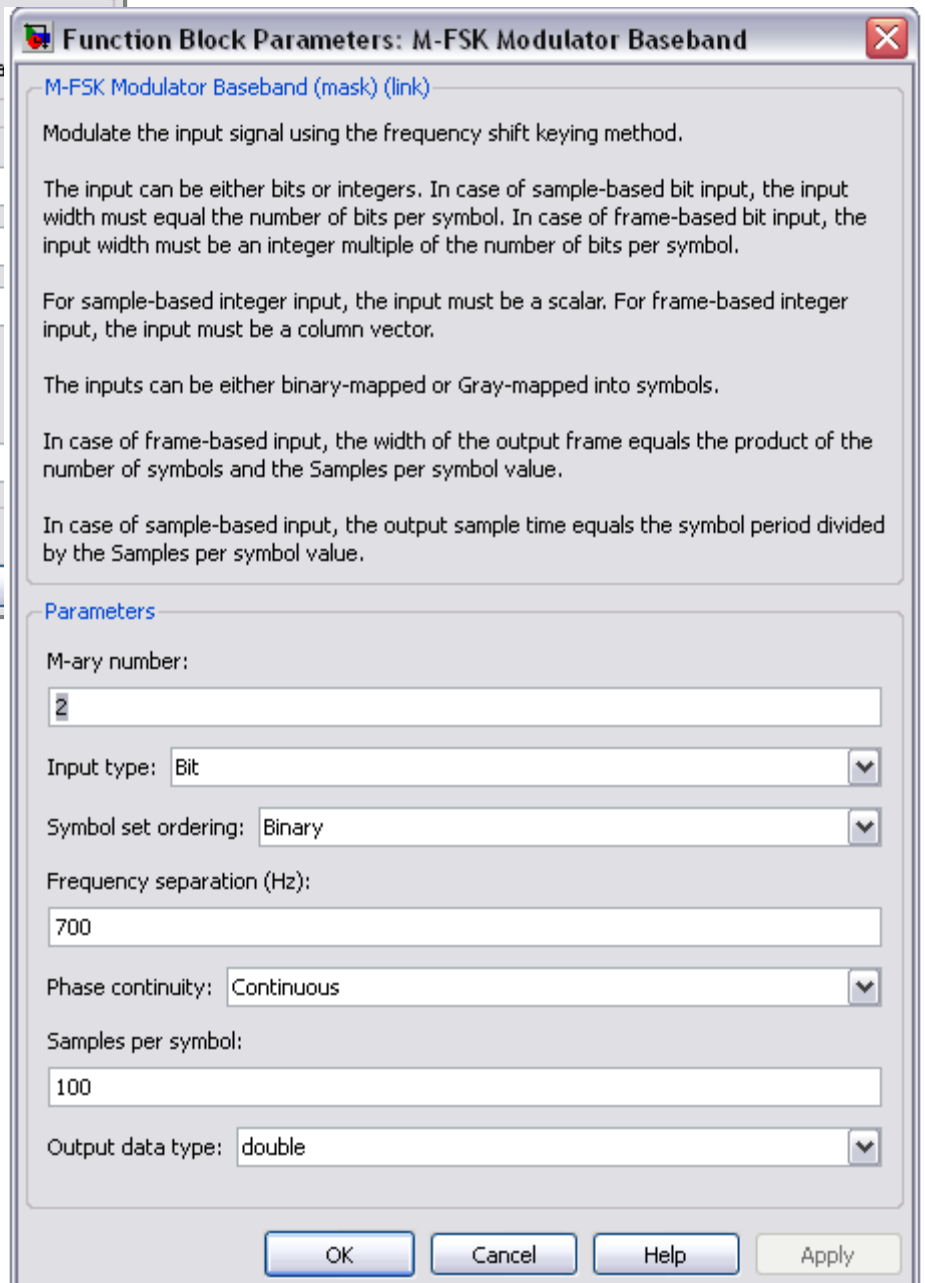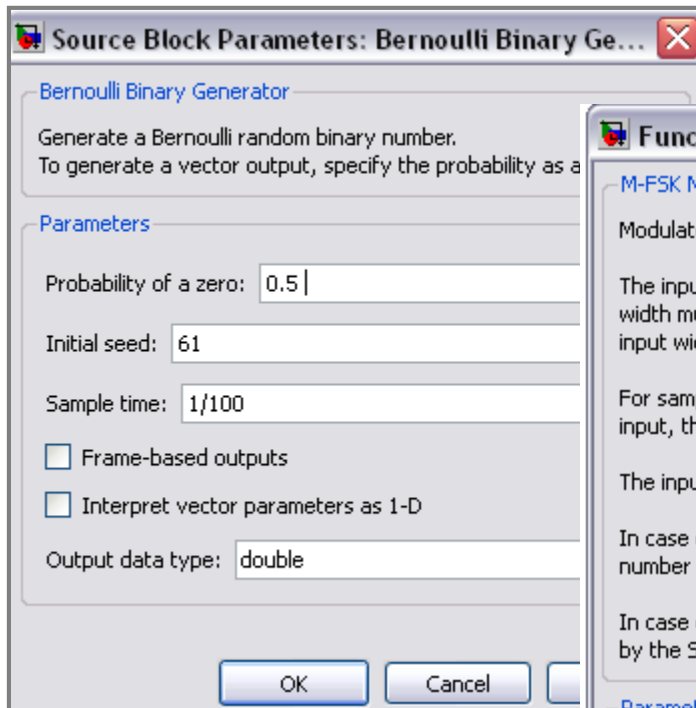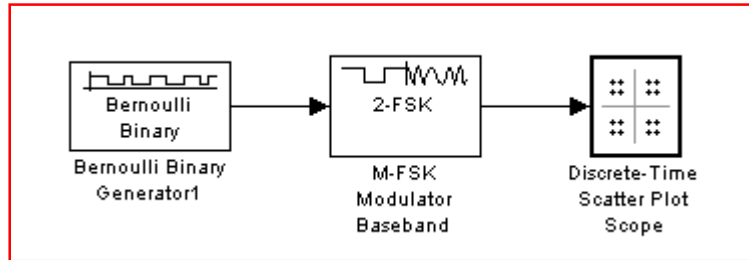
IV. Simulation of Baseband M-QAM (M=4,8, and 16)
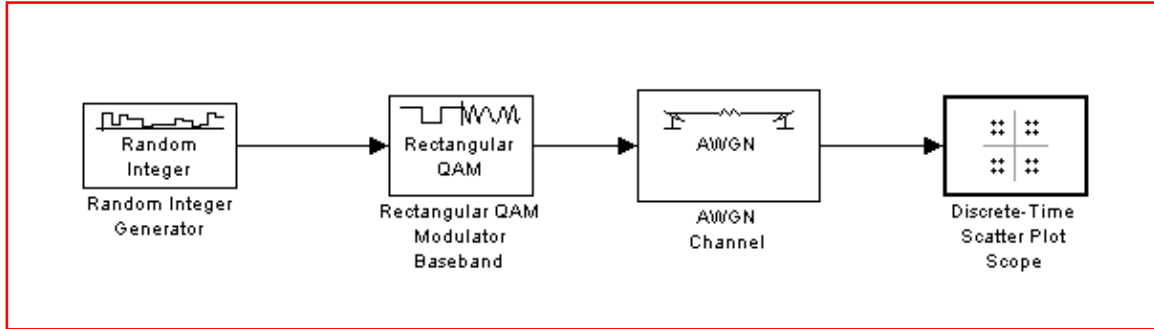
Random Integer Generator

- Set M-ary number to 16.
- Set Initial seed to any positive integer scalar, preferably the output of the randseed function.
- Set the Sample time to 1.

Rectangle QAM Modulator Baseband

- Set Normalization method to Peak Power.

AWGN Channel

- Set Eb/No to 40.
- Set Number of bits per symbol to 4.
- Set Symbol period to 1.

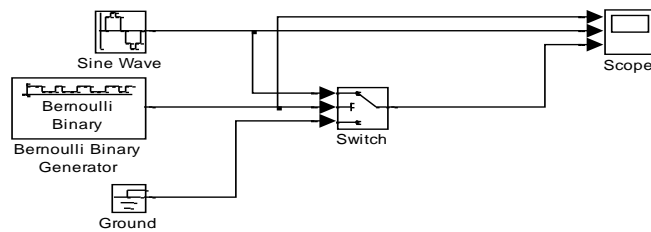## Discrete-Time Scatter Plot Scope

- Set Points displayed to 160.
- Set New points per display to 80.

On the Figure Properties panel, set Scope position to figposition([2.5 55 35 35]); On the same panel, Set Figure name to QAM Scatter Plot.

V. Simulation of Baseband M-PAM (M=4 and 8)
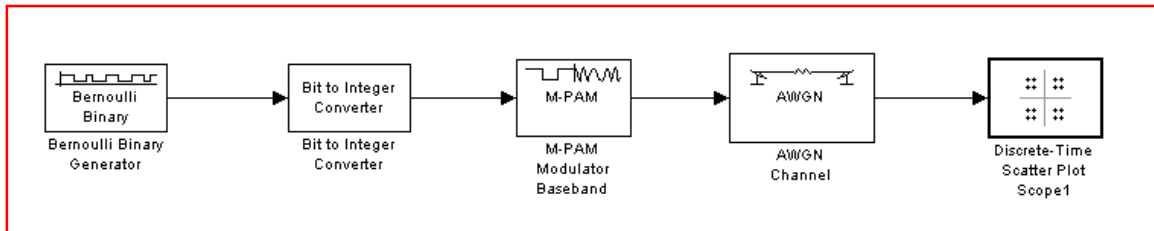
VI. ASK Transmission (ON-OFF Keying)

The circuit is built according to the schematic Shown below

The functions of different modules are explained below:

The Sine Wave block provides a sinusoid. The block operate on time-based mode with frequency set to 4000 Hz and sample time 1/100.

Source Block Parameters: Sine Wave

Sine Wave

Output a sine wave:

O(t) = Amp*Sin(Freq*t+Phase) + Bias

Sine type determines the computational technique used. The parameters in the two types are related through:

Samples per period = 2*pi / (Frequency * Sample time)

Number of offset samples = Phase * Samples per period / (2*pi)

Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.

Parameters

Sine type: Time based

Time (t): Use simulation time

Amplitude:
1

Bias:
0

Frequency (rad/sec):
4000/(2*pi)

Phase (rad):
0

Sample time:
1/100

☑ Interpret vector parameters as 1-D

[OK] [Cancel] [Help]

Source Block Parameters: Bernoulli Binary Gen...

Bernoulli Binary Generator (mask) (link)

Generate a Bernoulli random binary number.
To generate a vector output, specify the probability as a vector.

Parameters

Probability of a zero:
0.5

Initial seed:
61

Sample time:
1

☐ Frame-based outputs

Samples per frame:
1

☐ Interpret vector parameters as 1-D

Output data type: double

[OK] [Cancel] [Help]

VII. Generating BER Curve (BPSK and QPSK)

1. Using Simulink simulation tool connect the blocks as shown in the below figure and set the parameter of each block as instructed

2. Plot the curve of average bit error rate(BER) against average energy per bit to noise ratio(Eb/No)

3. Compare the above curve obtained by simulation with theoretical one. They should be closed.

4. Repeat the above steps for QPSK modulation scheme.
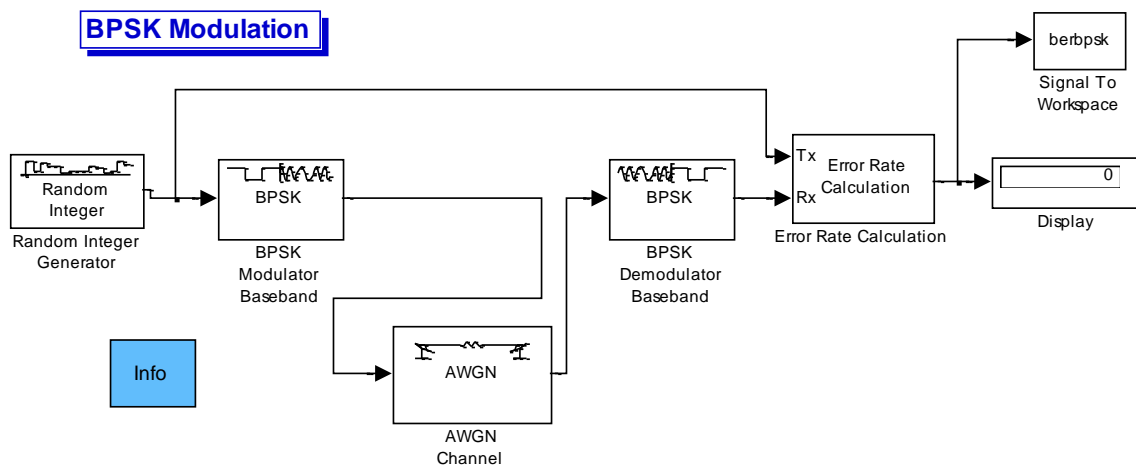
M-file

```
SNR = 0:1:10;
Eb_No_dB=[];Pte=[];Psim=[];
%Simulated probability of error
for i=1:length(SNR);
   Eb_No_dB=SNR(i);
   sim('bpskdoc');
   Psim(i)=berbpsk(1,2)/berbpsk(1,3);
end;
%Theoritical probability of error
for ii=1:length(SNR)
    snr=10^(SNR(ii)/10);
    Pte(ii)=qfunc(sqrt(2*snr));
end
semilogy(SNR,Psim,' :*',SNR,Pte,'-o');
legend('Simulated BER ','Theoritical BER');
xlabel('Eb/No (dB)');
ylabel('Error Probability');
title('BPSK system performance in AWGN channel')
```

Questions

Q1. Simulate M-ary Baseband PSK using the following parameters

- Eb/No= 20dB and 50dB

  - M=8
  - M=16
  - M=64
  - M=128

Q2. Simulate 64-ary Baseband QAM with Eb/No= 50dB

Q3. Simulate 16-ary Baseband PAM with Eb/No= 30dB