Lab Handout # 1
Performance analysis of various digital modulation schemes over AWGN Channel

Design LAB II(Software)

Instructor: D. RAWAL, N. SHARMA

Dept. of ECE, The LNMIIT, Jaipur

Time : 3:00 Hour Maximum Marks : 10

Instructions and information for students

- This Lab Handout consists of 2 pages. Please check that you have a complete copy.
- Simulate in matlab or any other Software.

Objective:

1) Analyze and Simulate BER performance of BPSK/QPSK signal over AWGN channel.

1) **Introduction**
2) **BER performance over AWGN channel**
   a) A BPSK modulated signal with power $P = E_b$ is transmitted over (AWGN) Additive White Gaussian Channel is affected by various types of noise, like thermal noise. This noise is additive in nature, has flat spectrum(white - uncorrelated), has gaussian PDF(probability density function).
   $$Y = \sqrt{P} \cdot X + V$$
   where X is BPSK signal and V is gaussian noise $\mathbf{N}(\mu, \sigma^2)$.

   b) The PDF of **V** is given by
   $$P(V) = \frac{1}{2 \cdot pi \cdot \sigma^2} \cdot exp(\frac{v - \mu}{2 \cdot \sigma^2})$$
   c) The BER expression (from the figure) for BER over BPSK is given by
   $$Q(\sqrt{\frac{P}{\sigma^2}})$$

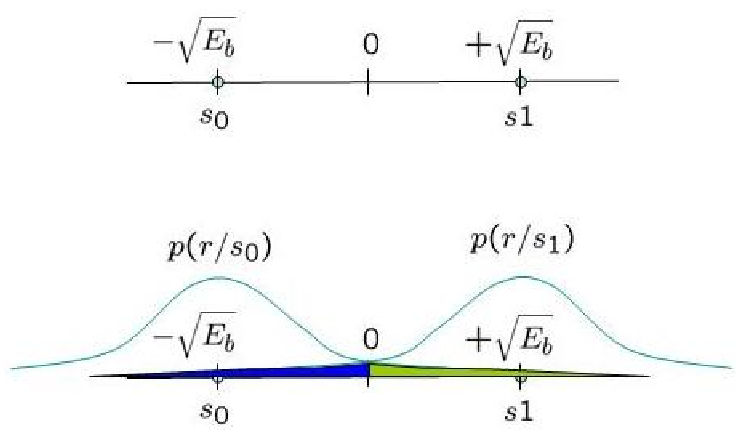

Fig. 1. BPSK over AWGN channel

1) **BER BPSK-AWGN**
   a) Generate a random binary sequence of 10000 values. Lets call it 'X' sequence.
   b) Generate Gaussian noise(randn function) and vary the snr(signal to noise ratio) from 0 to 24 in step of 4 db (or noise variance from 1 to 0.001), lets call it 'V' sequence. Use

   $$SNR_{dB} = 10 \cdot log10(SNR_{linear})$$

   c) Now Apply thresholding on 'V'.
   d) Recover sequence $\hat{X}$.
   e) Find out the total error 'e' between input 'X' and recovered sequence '$\hat{X}$'.
   f) Plot your conclusion.
   g) plot theroretical curve and verify.

2) **BER QPSK-AWGN**
   a) Generate QPSK signal from a pair of bits of a random binary sequence.
   b) Add AWGN Noise of variance '0.5' in real and imaginary part of QPSK symbol.
   c) Decode the real and imaginary part separately using thresholding.
   d) Plot BER for QPSK signalling.

3) **Observations and Results**.
   a) Plot BER Vs SNR for BSK over AWGN(m-file) [2]
   b) Verify above results with the theoretical expression of BPSK over AWGN [2]
   c) Make a simulink model of the above. [2]
   d) Plot BER Vs SNR for QPSK over AWGN(m-file) [2]
   e) Plot BER Vs SNR for QPSK over AWGN(Simulink: Call the simulink model in m-file using 'sim' function) [2]

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Lab Handout # 2
BER Performance over Wireless Channel

Design LAB II(Software)

Instructor: D. RAWAL, N. SHARMA

Dept. of ECE, The LNMIIT, Jaipur

Time : 3:00 Hour   Maximum Marks : 10

Instructions and information for students

- This Lab Handout consists of 2 pages. Please check that you have a complete copy.
- Simulate in matlab or any other Software.

Objective:

1) Analyze and Simulate BER performance of BPSK/QPSK signal over Wireless channel.

Itroduction:

1) **BER performance over Wireless channel**
   a) A BPSK modulated signal with power P is transmitted over wireless channel accompanied by AWGN noise.

$$Y = \sqrt{P} \cdot h \cdot X + V$$

   where X is BPSK signal and V is gaussian noise $\mathbf{N}(\mu, \sigma^2)$.

   b) The PDF of **V** is given by

$$P(V) = \frac{1}{2 \cdot pi \cdot \sigma^2} \cdot exp(\frac{v - \mu}{2 \cdot \sigma^2})$$

   c) The BER expression (from the figure) for BER of BPSK over Wireless channel is given by

$$\frac{1}{2}\left(1 - \sqrt{\frac{SNR}{2 + SNR}}\right)$$

   Where SNR_{linear} is signal to noise ration in linear scale.

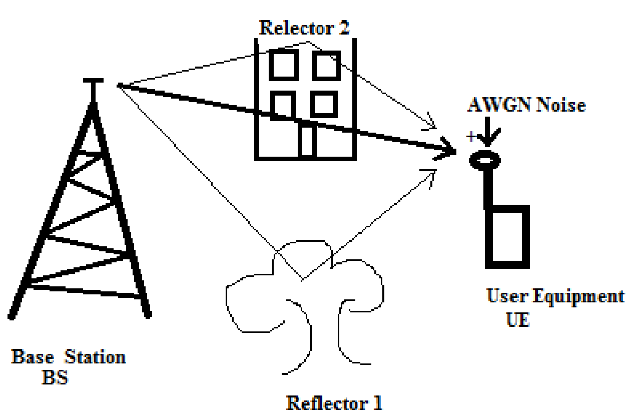

Fig. 1. Signal Transmission over Wireless channel

1) **Simulating BER of BPSK over Wireless channel**
   a) Generate a random binary sequence of 10000 values. Lets call it 'X' sequence.
   b) Transmit the above sequence over wireless channel, which is reperesented as an attenuation/amplification factor h.
   c) Generate Gaussian noise(randn function) and vary the snr(signal to noise ratio) from 0 to 24 in step of 4 dB (or noise variance from 1 to 0.001), lets call it 'V' sequence. Use

$$SNR_{dB} = 10 \cdot log10(SNR_{linear})$$

   d) The received sequence is represented as

$$Y = h \cdot X + V$$

   e) At the receiver, the signal can be decoded as
      i) Decode Method 1:
         - Divide the received signal by h, call it Dec_1.

$$Dec_1 = \frac{Y}{h} = \frac{h \cdot X + V}{h} = X + \frac{V}{h}$$

         - Apply thresholding(compare greaterthan/less than zero) on Dec_1 and Generate $\hat{X}$.

      ii) Decode Method 2:
         - Multiply the received signal by h^* and divide it by norm $|h|^2$, call it Dec_2.

$$Dec_2 = \frac{h^* \cdot Y}{|h|^2} = \frac{|h|^2 \cdot X + h^* \cdot V}{|h|^2} = X + \frac{V}{h}$$

         - Apply thresholding(compare greaterthan/less than zero) on Dec_2 and Generate $\hat{X}$.

   f) Find out the total error 'e' between input 'X' and recovered sequence '$\hat{X}$'.
   g) Plot your conclusion.
   h) plot theroretical curve and verify.

2) **BER of QPSK Over Wireless Channel**
   a) Repeat all the above steps for QPSK signal.
3) **Observations and Results**.
   a) Plot BER Vs SNR for BPSK over Wireless channel (m-file) [2]
   b) Verify above results with the theoretical expression of BPSK over Wireless channel. [2]
   c) Make a simulink model of the above. [2]
   d) Plot BER Vs SNR for QPSK over Wireless Channel(m-file). [2]
   e) Plot BER Vs SNR for QPSK over Wireless Channel.(Simulink: Call the simulink model in m-file using 'sim' function) [2]

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Lab Handout # 3
BER Performance over Multiple Receiving Antennas

Design LAB II(Software)

Instructor: D. RAWAL, N. SHARMA

Dept. of ECE, The LNMIIT, Jaipur

Time : 3:00 Hour | Maximum Marks : 10

Instructions and information for students

- This Lab Handout consists of 2 pages. Please check that you have a complete copy.
- Simulate in matlab or any other Software.

Objective:

1) Analyze and Simulate BER performance of BPSK/QPSK signal over Multiple receiving antenna system.

Itroduction:

1) **BER performance over Wireless channel using Multiple receiving antenna.**
   a) A BPSK modulated signal with power P is transmitted over wireless channel accompanied by AWGN noise. The user equipment is equipped with multiple receiving antennas let's say L (Here L =2). The received signal at respective antenna is given by

$$Y_1 = \sqrt{P} \cdot h_1 \cdot X + n_1$$
$$Y_2 = \sqrt{P} \cdot h_2 \cdot X + n_2$$

   where X is BPSK signal and n_1 and n_2 are gaussian noise $\mathbf{N}(\mu, \sigma^2)$.

   b) The BER performance expression(Asymptotic or tangential) of multiple receiving antenna system for BPSK transmitted signal over Wireless channel is given by

$$\binom{2L-1}{L}\left(\frac{1}{2SNR}\right)^L$$

   Where SNR_{linear} is signal to noise ration in linear scale.

1) **Simulating Multiple Rx. antenna system**
   a) Generate a random binary sequence of 10000 values. Lets call it 'X' sequence.
   b) Transmit the above sequence over wireless channel links, which are reperesented as an attenuation/amplification factors h_1, h_2.
   c) Generate Gaussian noise(randn function) and vary the snr(signal to noise ratio) from 0 to 24 in step of 4 dB (or noise variance from 1 to 0.001), lets call it n_1 and n_2 noise sequences. Use

$$SNR_{dB} = 10 \cdot log10(SNR_{linear})$$

   d) The received signal at user equipment (UE) is given by (for ease of understanding let's take $P = 1$)

$$Y_1 = h_1 \cdot X + n_1$$
$$Y_2 = h_2 \cdot X + n_2$$

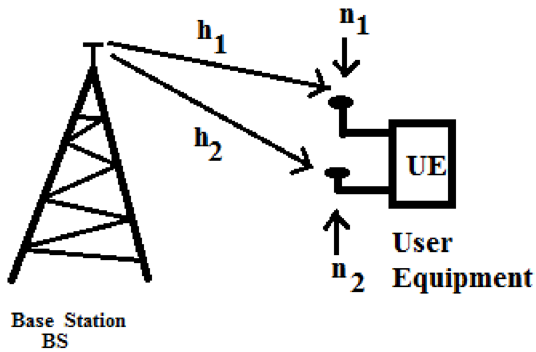

Fig. 1. Signal Reception using multiple Receive antennas

Which can be represented in vecor form as

$$\bar{Y} = \bar{h}X + \bar{n}$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_1 \\ h_2 \end{bmatrix} X + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

e) At the receiver, the signal can be decoded as
   - Multiply the received signal by a vector$[\frac{h_1^*}{|\bar{h}|^2}, \frac{h_2^*}{|\bar{h}|^2}]$ and divide it by norm $|h|^2$, call it Dec_1.

$$\begin{bmatrix} \frac{h_1^*}{|\bar{h}|^2} & , & \frac{h_2^*}{|\bar{h}|^2} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \frac{h_1^*}{|\bar{h}|^2} & , & \frac{h_2^*}{|\bar{h}|^2} \end{bmatrix} \begin{bmatrix} h_1 \\ h_2 \end{bmatrix} X + \begin{bmatrix} \frac{h_1^*}{|\bar{h}|^2} & , & \frac{h_2^*}{|\bar{h}|^2} \end{bmatrix} \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

$$Dec_1 = X + \frac{h_1^* \cdot n_1 + h_2^* \cdot n_2}{|h|^2}$$

   - Apply thresholding(compare greaterthan/less than zero) on Dec_1 and Generate $\hat{X}$.

f) Find out the total error 'e' between input 'X' and recovered sequence '$\hat{X}$'.
g) Plot your conclusion.
h) plot theroretical expression curve and verify.

2) **BER of QPSK Over Multiple receiving antennna system**
   a) Repeat all the above steps for QPSK signal.
3) **Observations and Results**.
   a) Plot BER Vs SNR for BPSK over $L = 2$ receiving antenna system.(m-file) [2]
   b) Make a generalized code for any number of receiving antenna. [2]
   c) Match tangential theoretical expression with above BER result. [2]
   d) Plot BER Vs SNR for QPSK over Wireless Channel(m-file). [2]
   e) Make a generalised simulink model of the above. [2]

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Lab Handout # 4
CPP based based Simulation of M-QAM modulation over wired/wireless system

Design LAB II(Software)

Instructor: D. RAWAL, N. SHARMA

Dept. of ECE, The LNMIIT, Jaipur

Time : 3:00 Hour | Maximum Marks : 10

Instructions and information for students

- This Lab Handout consists of 2 pages. Please check that you have a complete copy.
- Simulate in matlab or any other Software.

Objective:

1) Simulate M-QAM modulator and Demodulator.

Itroduction:

1) $C++$ **based Qam modulator Demodulator.**

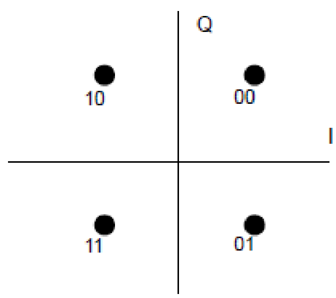

Figure - QPSK constellation

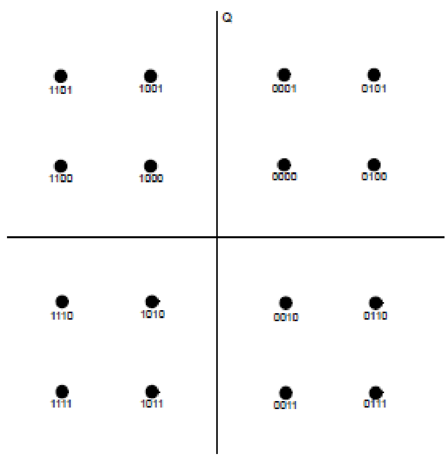

Table - QPSK bits to symbol mapping

B(1)	B(2)	I	Q
0	0	1	1
0	1	1	–1
1	0	–1	1
1	1	–1	–1

B(1)	B(2)	B(3)	B(4)	I	Q
0	1	0	1	3	3
0	1	0	0	3	1
0	1	1	0	3	–1
0	1	1	1	3	–3
0	0	0	1	1	3
0	0	0	0	1	1
0	0	1	0	1	–1
0	0	1	1	1	–3
1	0	0	1	–1	3
1	0	0	0	–1	1
1	0	1	0	–1	–1
1	0	1	1	–1	–3
1	1	0	1	–3	3
1	1	0	0	–3	1
1	1	1	0	–3	–1
1	1	1	1	–3	–3

Fig. 1. Modulator

a) **Simulating M-Qam modulator using C++:**
   i) Generate a random binary sequence of 100-10000 values using rand function. Lets call it 'X' sequence.
   ii) Map it to various QAM modulator given in the figure. For ex. for 16 QAM use combination of 1 and 3 to genrate constellation points.
   iii) Use Normalization factor $\frac{1}{\sqrt{2}}$ for QPSK and $\frac{1}{\sqrt{10}}$ for 16-QAM.
   iv) Use $DevC++$ to generate $C++$ code for the above modulator.
   v) For comparison of simulated results use
   i) Theoretical BER of QPSK:

$$QPSK_{BER} = erfc\left(\sqrt{\frac{snr}{2}}\right)$$

   and
   ii) Theoretical BER of 16-QAM:

$$16QAM_{BER} = 1.5erfc(\sqrt{snr/10})$$

2) **Observations and Results**.
   a) Generate QPSK modulator in Dev C++ and using S-function Builder. [2]
   b) Generate QPSK demodulator in Dev C++ and using S-function Builder. [2]
   c) Generate Gaussian noise with mean zero and variance 1. [2]
   d) Make an end-to-end simulink model for wired channel QPSK Transceiver. Plot Simulated BER. (Tuesday batch) [4]
   e) Make an end-to-end simulink model for wired channel 16-QAM Transceiver. Plot Simulated BER. (Wednesday batch) [4]

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Lab Handout # 5
Image Transceiver Using QAM (Dev c++ and ZedBoard-SOC).

Design LAB II(Software)

Instructor: D. RAWAL, N. SHARMA, A. Gupta

Dept. of ECE, The LNMIIT, Jaipur

Time : 3:00 Hour | Maximum Marks : 10

Instructions and information for students

- This Lab Handout consists of 1 page.
- Simulate in Dev C/C++.

Objective:

1) Image Transmission and Reception using QAM.

Itroduction:

1) Procedure: $C++$ **based Image Transmission**
   a) Open and Read Image file using file open and read function respectively.
   b) Store the above readed data into character array.
   c) Convert the character data into decimal/AscII by adding 128 value.
   d) Convert the above data into binary value(by writing code for decimal to binary function) and store it in single dimensional array.
   e) Use QAM Mapper to modulate data into QPSK and 16-QAM.
   f) Write the above generated QAM mapped data into '*.txt' file.(This file is used by ZedBoard-SOC to transmit over wired/wireless channel as will be provided in InLab Demo).
   g) Do the all steps in reverse to Generate the Image file.

2) **Inlab Demo: InLab Demo on ZedBoard SOC**
   a) This Demo uses Zed-Board(An Evaluation Board having Xilinx 702 Archtecture).
   b) This evaluation board can be configured into (System On Chip)SOC/FPGA using approvpriate connection of the five Jumpers(J05 J08).
   c) Once Configured as an SOC, the Evaluation ZedBoard-SOC (Which runs on Linux/Ubuntu platform) uses inuilt G++ compiler to compile C/C++ codes.
   d) The C code of the above 'Image Transmitter using QAM code' generates 'Qamdata.txt' or other supported files like '*.txt, *.mat, *.csv' etc.
   e) This files are used for transmision using the AD-FMCOMM 'AD9361- RF transceiver' to other ZedBoard-SOC acting as receiver.

3) **Observations and Results(using Dev C++)**.
   a) Read the image file using file operation . [2]
   b) Generate QPSK modulated data file for above image. [2]
   c) Generate 16-QAM modulated data file for above image. [2]
   d) Regenerate/ Recreate image file from the above generated QAM modulated files. [4]

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Lab Handout # 6
BER Performance over OSTBC/ Alamouti Code.

Design LAB II(Software)

Instructor: D. RAWAL, N. SHARMA, A. Gupta

Dept. of ECE, The LNMIIT, Jaipur

Time : 3:00 Hour | Maximum Marks : 10

Instructions and information for students

- This Lab Handout consists of 3 pages. Please check that you have a complete copy.
- Simulate in matlab or any other Software.

Objective:

1) Analyze and Simulate BER performance of BPSK/QPSK signal over wireless OSTBC/ Alamouti coded system.

Itroduction:

1) **BER performance over Wireless channel using Alamouti Code.**
   a) In Alamouti code, transmission is done over two time slots.
   i) In time slot 1, A BPSK modulated data Block $X = [X_1, X_2]^T$ with total power $P_1 + P_2 = \frac{P}{2} + \frac{P}{2} = P$ is transmitted with let's say L (Here L =2) antennas over wireless channel links h_1, h_2. The user equipment/ Rx. is equipped with single receiving antenna. The received signal over time slot 1, Y_1 is flat faded transmitted signal accompanied by AWGN noise.

   ii) In time slot 2, BPSK modulated data Block $X = [-X_2^*, X_1^*]^T$ with total power $P_1 + P_2 = \frac{P}{2} + \frac{P}{2} = P$ is transmitted with let's say L (Here L =2) antennas over wireless channel links h_1, h_2. The received signal over time slot 2, Y_2 is flat faded transmitted signal accompanied by AWGN noise. The received signal over two consequtive time slots are given by

$$Y_1 = \sqrt{\frac{P}{2}} \cdot h_1 \cdot X_1 + \sqrt{\frac{P}{2}} \cdot h_2 \cdot X_2 + n_1$$
$$Y_2 = \sqrt{\frac{P}{2}} \cdot h_1 \cdot (-X_2^*) + \sqrt{\frac{P}{2}} \cdot h_2 \cdot X_1^* + n_2$$

   where n_1 and n_2 are complex gaussian noise $\mathbf{N}(\mu, \sigma^2)$.

   b) The BER performance expression(Asymptotic or tangential) of Alamouti coded system for BPSK transmitted signal over Wireless channel is given by

$$P_e = \binom{2L-1}{L} \left(\frac{1}{SNR_{linear}}\right)^L$$

   Where $L = 2$ and SNR_{linear} is signal to noise ration in linear scale.

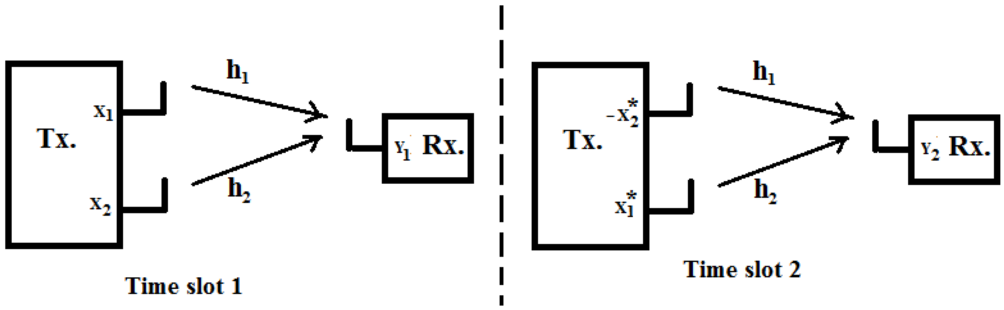

Fig. 1. Signal Reception over Two Time slots

1) **Simulating Alamouti code system**
   a) Generate two random binary sequences of 10000 values. Lets call it 'X_1, X_2' sequences.
   b) Transmit the above sequences over wireless channel links, which are reperesented as an attenuation/amplification factors h_1, h_2.
   c) Generate complex Gaussian noise(using randn function) and vary the snr(signal to noise ratio) from 0 to 24 in step of 4 dB (or noise variance from 1 to 0.001), lets call it n_1 and n_2 noise sequences. Use

$$SNR_{dB} = 10 \cdot log10(SNR_{linear})$$

   d) The received signal at user equipment (UE) is given by (for ease of understanding let's take $P = 1$)

$$Y_1 = h_1 \cdot X_1 + h_2 \cdot X_2 + n_1$$
$$Y_2 = h_1 \cdot (-X_2^*) + h_2 \cdot X_1^* + n_2$$

   For simplicity taking conjugate of Y_2 and arranging in vector form

$$Y_2^* = h_1^* \cdot (-X_2) + h_2^* \cdot X_1 + n_2^*$$

$$\bar{Y} = H \cdot X + \bar{n}$$

$$\begin{bmatrix} Y_1 \\ Y_2^* \end{bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix}$$

   e) The columns of matrix H are given by

$$C_1 = \begin{bmatrix} h_1 \\ h_2^* \end{bmatrix}, \qquad C_2 = \begin{bmatrix} h_2 \\ -h_1^* \end{bmatrix}$$

   .
   Than $C_1^H C_2 = (h_1^* h_2) - (h_2 h_1^*) = 0$ confirms orthogonality of the code transmitted over space and time slots.
   f) At the receiver, the signal can be decoded as
      - Multiply the received signal by $[C_1^H]$ and divide it by norm $|C_1|^2$, call it Dec_1.

$$\begin{bmatrix} \frac{C_1^H}{|C_1|^2} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} \frac{h_1^*}{|{h_1}^2 + {h_2}^2|} & , & \frac{h_2}{|{h_1}^2 + {h_2}^2|} \end{bmatrix} \begin{bmatrix} h_1 \\ h_2^* \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} \frac{h_1^*}{|{h_1}^2 + {h_2}^2|} & , & \frac{h_2}{|{h_1}^2 + {h_2}^2|} \end{bmatrix} \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix}$$

$$Dec_1 = X_1 + \frac{h_1^* \cdot n_1 + h_2^* \cdot n_2}{|h|^2}$$

- Apply thresholding(compare greaterthan/less than zero) on Dec_1 and Generate $\hat{X}_1$. Similarly with use of C_2 value of $\hat{X}_2$ is determined.

g) Find out the total error 'e' between input block 'X' and recovered sequence '$\hat{X}$'.
h) Plot your conclusion.
i) plot theroretical expression curve and verify.

2) **Observations and Results**.
  a) Plot BER Vs SNR for BPSK over $L = 2$ receiving antenna system.(m-file) [2]
  b) Match tangential theoretical expression with above BER result. [4]
  c) Make a generalised simulink model of the above. [4]

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The LNM Institute of Information Technology
DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Project List
Simulation and Prototype on ZedBoard/ZyBo board

Instructor: D. RAWAL, N. SHARMA

Dept. of ECE, The LNMIIT, Jaipur

Instructions and information

- This List consists of 33 projects. Every project will be evaluated with 4 different components as mentioned below.
  - Write M file code for the given project.
  - Make a Simulink model for the given project.
  - Clarification regarding the objective of the projects will be given in the upcoming lab sessions.
  - For C based simulation either use Dev++/S-Function to simulate the project. For VHDL based project write VHDL/Verilog script for the same. For VHDL help, one can take reference from DSP lab(convolution on ZYBO board).
  - Verification of above C/VHDL code using zedboard/ZyBO board for given Image/Audio/Video signal.
  - Everybody is advised to submit their all the working files and verify with respective TA's Three days prior to the project evaluation day.
  - On project presentation day, Everybody has to make 5 slides mentioning Title of the project, System/Circuit diagram, Project Desscription, small video containing application and Result verifying the project.
  - Everybody needs to take small size different images for their projects.(No common images for two groups)

[P.T.O.]

Projects List:

1) Receive diversity, MRC QPSK(ZedBoard,C, Image→ QPSK.txt and viseversa)
2) Receive diversity, MRC 16-QAM(ZedBoard,C, Image→ QAM.txt and viseversa)
3) Receive diversity, MRC 64-QAM(ZedBoard,C, Image→ QAM.txt and viseversa)
4) Decode and forward system, BPSK(ZedBoard,C, Image→ BPSK.txt and viseversa)
5) Decode and forward system, QPSK(ZedBoard,C, Image→ QPSK.txt and viseversa)
6) Decode and forward system, 16-QAM(ZedBoard,C, Image→ 16QAM.txt and viseversa)
7) Selective Decode and forward system, BPSK(ZedBoard,C, Image→ BPSK.txt and viseversa)
8) Selective Decode and forward system, QPSK(ZedBoard,C, Image→ QPSK.txt and viseversa)
9) Selective Decode and forward system, 16-QAM(ZedBoard,C, Image→ QAM.txt and viseversa)
10) Image transmission over Wired channel 64-QAM using Zedboard.
11) Image transmission over Wireless channel 64-QAM using Zedboard.
12) Audio transmission over Wired channel 16-QAM using Dev C++.
13) Audio transmission over Wireless channel 16-QAM using Dev C++.
14) Fixed point decoder for Receive diversity, MRC QPSK(ZedBoard,C, Image→ QPSK.txt and viseversa)
15) Fixed point decoder for Receive diversity, MRC 16-QAM(ZedBoard,C, Image→ QAM.txt and viseversa)
16) Fixed point decoder for Receive diversity, MRC 64-QAM(ZedBoard,C, Image→ QAM.txt and viseversa)
17) Fixed point decoder for Decode and forward system, BPSK(ZedBoard,C, Image→ BPSK.txt and viseversa)
18) Fixed point decoder for Decode and forward system, QPSK(ZedBoard,C, Image→ QPSK.txt and viseversa)
19) Fixed point decoder for Decode and forward system, 16-QAM(ZedBoard,C, Image→ QAM.txt and viseversa)
20) Fixed point decoder for Selective Decode and forward system, BPSK(ZedBoard,C, Image→ BPSK.txt and viseversa)
21) Fixed point Wired system: Noise removal from audio (ZedBoard,C, Audio→ QPSK.txt and viseversa)
22) Fixed point Wired system: Noise removal from Image (ZedBoard,C, Audio→ QPSK.txt and viseversa)
23) Fixed point Image transmission over Wired channel 64-QAM using Zedboard.
24) Fixed point Image transmission over Wireless channel 64-QAM using Zedboard.
25) Audio transmission over Wired channel 64-QAM using Dev C++.
26) Audio transmission over Wireless channel 64-QAM using Dev C++.
27) Psuedo Noise Sequence Generator. (ZYBO, VHDL)
28) Cyclic code Generation.(ZYBO, VHDL)
29) Cyclic code Decoding.(ZYBO, VHDL)
30) Data stream Interleaver.(ZYBO, VHDL)
31) Data stream De-Interleaver.(ZYBO, VHDL)
32) Repetition code encoder.(ZYBO,VHDL)
33) Repetition code Decoder.(ZYBO,VHDL)

——————————————WELL DONE——————————————-