Lab Handout # 1
BER Performance over AWGN Channel

Simulation LAB-I

Instructor: D. RAWAL

Dept. of ECE, The LNMIIT, Jaipur

Time : 2:00 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) Generating Gaussian noise using CLT(Central limit theorem).
2) Analyze and Simulate BER performance of BPSK signal over AWGN channel.

1) **Introduction**
   a) **Central limit theorem**
      i) CLT is an important, but less accurate approach to generate Normal random numbers. The theorem states that, if X_1, X_2,...,X_n are independent distributed uniform random variables according to some common distribution function with mean μ and finite variance σ^2, then as the number of random variables increases indefinitely, the random variable,

$$Y = \sum_{i=1}^{n} \frac{X_i - n\mu}{n\sigma^2}$$

      which converges to $\mathbf{N}(\mu, \sigma^2)$.

      ii) **BER performance over AWGN channel**
         A) A BPSK modulated signal with power $P = \sqrt{E_b}$ 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).

$$Y = X + V$$

         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

$$Q(\sqrt{\frac{P}{\sigma^2}})$$

   b) **Tasks**
      i) **CLT**
         A) Generate 10 or more sequence of 10000 samples of uniform random numbers using rand/randi function, call it X_1, X_2 $\ldots$ sequences.

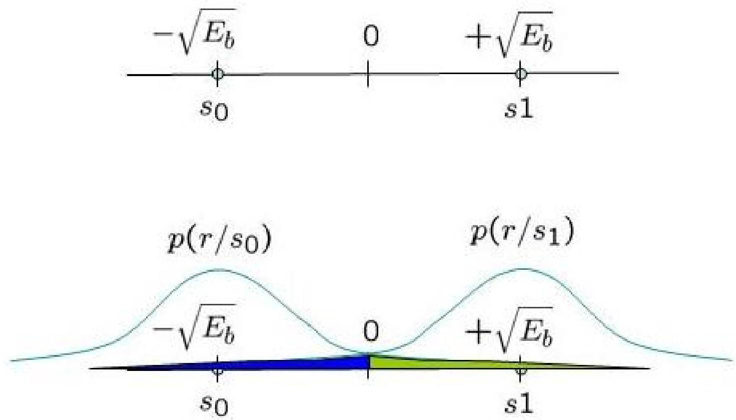

Fig. 1. BPSK over AWGN channel

B) Add these sequences respectively and find the mean value, call it sequence Y.
C) Divide the $R- > [0, 1]$ real line interval in 10 bins(10 blocks of 0.1 interval each).
D) Plot the histogram.
E) plot the PDF.

ii) **BER AWGN**

A) Generate a random binary sequence of 10000 values. Lets call it 'x' sequence.
B) Generate Gaussian noise 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 'z' sequence. Use

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

C) Now Apply thresholding on 'z'.
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.

iii) Extend the above problem for QPSK signal.

————————————————WELL, It's DONE————————————————-

Lab Handout # 2
BER Performance over Rayleigh Channel

Simulation LAB-I

Instructor: D. RAWAL

Dept. of ECE, The LNMIIT, Jaipur

Time : 2:00 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 signal over Rayleigh channel.

1) **Introduction**
   a) **BER performance over Rayleigh channel**
      i) A BPSK modulated signal with power $P = \sqrt{E_b}$ 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).

$$Y = h * X + V$$

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

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

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

      iii) The BER expression (from the figure) for BER over BPSK is given by

$$Q(\sqrt{|h|^2 \cdot \frac{P}{\sigma^2}})$$

The simplified expression is given by

$$\frac{1}{2} \cdot (1 - \sqrt{\frac{\frac{P}{\sigma^2}}{2 + \frac{P}{\sigma^2}}})$$

and the approximate BER expression is given by The simplified expression is given by

$$\frac{1}{2 \cdot \frac{P}{\sigma^2}}$$

   b) **Tasks**
      i) **BER Rayleigh**
         A) Generate a random binary sequence of 10000 values. Lets call it 'x' sequence.
         B) Generate Gaussian noise 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 'z' sequence. Use

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

C) Now divide z by h.
D) Now Apply thresholding on ’z’.
E) Recover sequence $\hat{x}$.
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.

ii) Extend the above problem for QPSK signal.

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Lab Handout # 3
Performance of M-QAM, M-QPSK over awgn Channel

Simulation LAB-I
Instructor: D. RAWAL
Dept. of ECE, The LNMIIT, Jaipur

Time : 2:00 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 various digital modulation over AWGN channel.

1) **Introduction**
   a) **BER performance over AWGN channel**
      i) A M-PSK modulated signal with power $P = \sqrt{E_b}$ 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).
$$Y = X + V$$
where X is M-PSK signal and V is gaussian noise $\mathbf{N}(\mu, \sigma^2)$.

      ii) The PDF of **V** is given by
$$P(V) = \frac{1}{2 \cdot pi \cdot \sigma^2} \cdot exp(\frac{v-\mu}{2 \cdot \sigma^2})$$

      iii) The BER expression for BER of M-PSK over AWGN is given by
$$P_e(M-PSK) = 2 \cdot Q(\sqrt{2 \cdot log_2 M \cdot sin^2(\frac{\pi}{M}) \cdot \frac{P}{\sigma^2}})$$

      iv) The BER expression for BER of M-QAM(Let's say 4-QAM) over AWGN is given by
$$P_e(M-QAM) = 4 \cdot Q(\sqrt{\frac{3 \cdot log_2 M}{M-1} \cdot \frac{P}{\sigma^2}})$$

   b) **Tasks**
      i) **BER for M-PSK, M-QAM**
         A) Generate a random binary sequence of 10000 values. Lets call it 'x1' sequence.
         B) Use various constellation to map the binary sequence in a digitally modulated discrete level M-QAM sequence.
         C) Generate Gaussian noise 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 'z' sequence. Use
$$SNR_{dB} = 10 \cdot log10(SNR_{linear})$$
         D) Now Apply thresholding on 'z' and demodulate M-QAM signal to bit stream.
         E) Recover sequence $\hat{x1}$.
         F) Find out the total error 'e' between input 'x1' and recovered sequence '$\hat{x1}$'.

G) Plot your conclusion.
H) plot theroretical curve and verify.

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Lab Handout # 4
Performance of M-QAM over rayleigh Channel

Simulation LAB-I

Instructor: D. RAWAL

Dept. of ECE, The LNMIIT, Jaipur

Time : 2:00 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 M-QAM digital modulation over Rayleigh channel.

1) **Introduction**
   a) **BER performance over Rayleigh channel**
      i) A M-PSK modulated signal with power P transmitted over Rayleigh Channel is affected by various types of noise, and fading. This noise is additive in nature, has flat spectrum(white - uncorrelated), has gaussian PDF(probability density function).

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

where h is complex flat dading rayleigh coefficient, X is M-QAM signal and V is gaussian noise $\mathbf{N}(\mu, \sigma^2)$.

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

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

      iii) The BER expression for BER of M-QAM(Let's say 4-QAM) over Rayleigh is given by

$$P_e(M-QAM) = 2\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right) \cdot \left(1 - \sqrt{\frac{1.5 \cdot \frac{P}{\sigma^2}}{M-1+1.5 \cdot \frac{P}{\sigma^2}}}\right)$$

$$-\left(\frac{\sqrt{M}-1}{\sqrt{M}}\right)^2 \cdot \left(1 - \sqrt{\frac{1.5 \cdot \frac{P}{\sigma^2}}{M-1+1.5 \cdot \frac{P}{\sigma^2}}}\left(\frac{4}{\pi} tan^{-1}\sqrt{\frac{M-1+1.5 \cdot \frac{P}{\sigma^2}}{1.5 \cdot \frac{P}{\sigma^2}}}\right)\right)$$

   b) **Tasks**
      i) **BER for M-QAM**
         A) Generate a random binary sequence of 10000 values. Lets call it 'x1' sequence.
         B) Use various M-QAM constellation to map the binary sequence in a digitally modulated discrete level M-QAM sequence.
         C) Generate a complex random rayleigh coefficient h, multiply/convolve(since single co-efficent so multiplication and convolution are same) the input sequence x1 with this rayleigh coefficient.
         D) Generate Gaussian noise 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 'z' sequence. Use

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

E) Divide/Deconvolve the sequence z with rayleigh coefficient h call it z1.
F) Now Apply thresholding on 'z1' and demodulate M-QAM signal to bit stream.
G) Recover sequence $\hat{x1}$.
H) Find out the mean square error 'e' between input 'x1' and recovered sequence '$\hat{x1}$'.
I) Plot your conclusion.
J) plot theroretical curve and verify.

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Lab Handout # 5
Capacity over AWGN and Rayleigh channel

Simulation LAB-I

Instructor: D. RAWAL

Dept. of ECE, The LNMIIT, Jaipur

Time : 2:00 Hour Maximum Marks : 10

Instructions and information for students

- This Lab Handout consists of 1 page. Please check that you have a complete copy.
- Simulate in matlab or any other Software.

Objective:

1) Find the channel capacity over AWGN and Rayleigh channel.

1) **Introduction**
   a) **Channel capacity over AWGN and Rayleigh channel**
      i) The channel capcity over an AWGN channel is given by

$$C = B \cdot log_2 \left(1 + \frac{S}{N}\right)$$

      ii) The channel capcity over a Rayleigh channel is given by

$$C = E\left[B \cdot log_2 \left(1 + |h|^2 \cdot \frac{S}{N}\right)\right]$$

Where E represents expectation operation. where h is complex flat dading rayleigh coefficient, S is BPSK signal power and N is gaussian noise with $\mathbf{N}(\mu = 0, \sigma^2)$. Also, $|h|^2 \cdot \frac{S}{N}$ is the instantaneous received power at the output of rayleigh channel. So instantaneous capacity is directly proportional to instantaneous power.

   b) **Tasks**
      i) **Capacity over AWGN and rayleigh channel**
         A) Generate a random binary sequence of 10000 values. Lets call it 'x1' sequence.
         B) Use BPSK constellation to map the binary sequence in a digitally modulated sequence.
         C) Plot Snr Vs C showing AWGN capacity.
         D) Repeat first two steps and then generate a complex random rayleigh coefficient h, multiply/convolve(since single coefficent so multiplication and convolution are same) the input sequence x1 with this rayleigh coefficient.
         E) Plot Snr Vs average channel Capacity showing Rayleigh channel capacity.
         F) Use M-QAM constellation to map the binary sequence in a digitally modulated M-QAM sequence.
         G) Plot Snr Vs average channel Capacity.
         H) Use retransmission of the same block in both channel scenarios.
         I) Plot Snr Vs channel capacity.
         J) Conclude your remarks for all the above plots.

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PG LAB-6
Performance analysis of BPSK over Rician Channel

Prepared By: Divyang Rawal
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1) **BER performance of BPSK signal over Rice channel**
   a) i) A BPSK modulated signal with power P transmitted over Rice Channel is affected by AWGN noise. The received signal is given by

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

where X is BPSK signal and V is gaussian noise $\mathbf{N}(\mu, \sigma^2)$. Also h is Rice channel coefficient.
The rice channel can be modeled as a multipath channel with strong LOS component. The rice channel is defined by two parameters.

A) The Rice factor K defined as

$$K = \frac{Power\ \ in\ \ LOS}{Power\ \ in\ \ NLOS}$$

and can very from 1,2 ,3....10 ......
For Rice factor K = 0.0001(small values) it approaches Rayleigh channel. Thus the mean of the Rice channel is given by

$$m = \sqrt{\frac{K}{K+1}{\sigma_h}^2}$$

Where ${\sigma_h}^2$ is the Channel variance.

B) The variance σ^2 is defined as

$$\sigma^2 = \frac{{\sigma_h}^2}{2(K+1)}$$

Where ${\sigma_h}^2$ is the Channel variance.

ii) **Simulation**

A) Generate a random binary sequence of 10000 values. Let's call it X sequence.
B) Generate complex Gaussian noise sequence $V(0, \sigma^2)$ and add to the X sequence, call it Y sequence.
C) Generate Rice channel using the K factor and standard variance for various values of K and P_T.
D) Receive sequence $Y_c h = h \cdot X + n$, recover sequence $Y = Y_c h/h$.
E) Now Apply thresholding on Y, Call it recovered sequence $\hat{X}$.
F) Find out the total error 'e' between input X and recovered sequence $\hat{X}$.
G) Now, vary the snr(signal to noise ratio) from 0 to 24 in step of 4 dB (or noise variance from 1 to 0.001). Use

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

and repeat above steps.
H) Plot 'e' Vs SNR.

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Lab Handout # 7
Information Thoery & Coding - Channel Encoder

Prepared By: Divyang Rawal
Simulation LAB-I
Dept. of ECE, The LNMIIT, Jaipur

Instructions and information for students

- This Lab Handout consists of 1 pages. Please check that you have a complete copy.
- Simulate in matlab or any other Software.

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1) **What is Coding Gain. Lets find out:**
   a) Case 1
      i) Take a binary sequence of any length (for ex. 1000).
      ii) Add white Gaussian noise using randn function.
      iii) Receive y sequence at receiver and take binary decision (if received noisy bit > 0 then 1, else 0).
      iv) Find out total $error_1$ between y and x.
      v) Find error rate.

$$error_{rate} = \frac{number\ \ error}{total\ \ bits\ \ transmitted}$$

   b) Case 2
      i) Take a binary sequence of any length (for ex.100).
      ii) Transmit every bit if 0 as $-1, -1, -1$ and if 1 as $1, 1, 1$
      iii) Add white Gaussian noise using randn function to generated 3000 length sequence.
      iv) Receive y sequence at receiver and take binary decision from average of 3 bits at a time(if received noisy bit > 0 then 1, else 0).
      v) Find out total $error_2$ between y and x.
      vi) Find error rate.

   c) Which error is greater $error_1$ or $error_2$ and Why?
   d) Repeat the experiment for different noise variances $\sigma^2 = [1, 0.5, 0.25, 0.125]$ or $SNR(dB) = [0, 2, 4, 6, 8..20]$. using $SNR(dB) = 10log_{10}(\frac{S}{\sigma^2})$. Take $S = 1$ in one case and take $\sigma^2 = 1$ in other case.
   e) Plot logarithmic graph (use semilogy matlab function) for variance (on X-axis) Vs $error_{rate}$.
   f) Mention the advantage and disadvantage of above experiment.
   g) Make a generalize program where each bit can be coded as any arbitrary length. Like 0 can be 0000 or 00000 and similar for bit 1.
   h) Conclude what is coding gain.

——————————————- WELL, It's DONE ——————————————-

Lab Handout # 8
BER simulation for Linear (n, k) Block Code

Prepared By: Divyang Rawal
Simulation LAB-I
Dept. of ECE, The LNMIIT, Jaipur

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.
- For more details, please refer the class notes.

Objective:

1) Simulation of Linear (n, k) block code.

1) **Do as following.**
   a) **Linear $(6, 3)$ block code**
      i) Lets take a binary bit stream of 999 bits.
      ii) Divide the whole binary bit stream into an array with 333×3 dimension. Lets call it matrix A having dimension 333×3.
      iii) Take 3 bits or first row, call it message bits m. Multiply these $m = 3$ bits with the G Code Generator matrix (take modulo 2 multiplication and modulo-2 addition) given below.

$$G = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

      iv) The above step will give you Received 3 bits called r, where $r = mG$. In these 6 bits, first three bits are message bits if r is received without error.
      v) The above Received bits r again gets multiplied with Decoding matrix HT , where H is given by

$$H = \begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

      vi) The above step provides syndrome $S1 = rH^T$.
      vii) Check out the above syndrome from the syndrome table, which can be generated by multiplying error matrix e with H^T .

$$e = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

      viii) Multiplication gives $S2 = eH^T$.

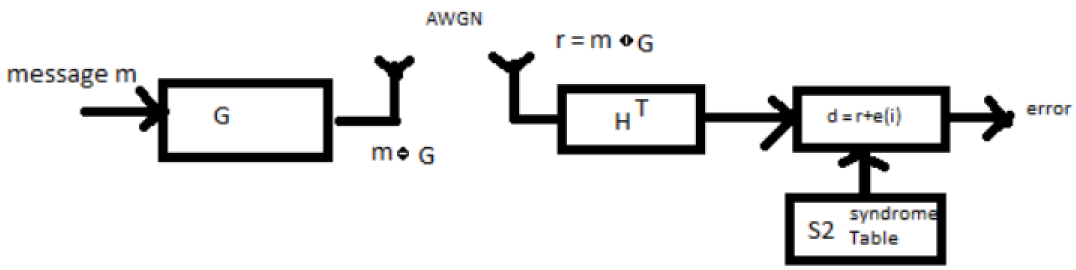

Fig. 1. block code

ix) Match the value of S1 with the corresponding row of S2.

x) Add the corresponding error vector row of e matrix to the received word r. Call it decoded bits $d = r + e(i)$, where i can be any row 1 to 7, depending on the matching in above step.

xi) Take the first 3 bits from d and subtract from original message m gives $error = d(1:3) - m$.

xii) Repeat for all row of the matrix A.

xiii) Find the total no. of error in the whole 999 received bits.

xiv) Repeat all the above steps with snr varying from 0:2:20 dB as done in the first assignment.

xv) Plot your conclusion.

———————————- WELL, It's DONE ———————————