

Probability density
function for qpsk
health and social care
essay



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Figure 10: BPSK Tx/RxSource: Figure 23: BPSK transmitter/receiver in CDMA communication [8]Channel ModelThe transmitted waveform gets corrupted by Additive White Gaussian Noise , [8]. with and . References: The sources are listed in numbered accordingly, as in the following article.[8] <http://www.dsplg.com/2007/08/05/bit-error-probability-for-bpsk-modulation/>Calculate the probability of errorFor received signalWhen bit 1 is sentWhen bit 0 is sentBelow we have two cases of probability distribution function of [8]

- Figure 11: BPSK probability densityFigure 11: BPSK Conditional probability density function [8]References: The sources are listed in numbered accordingly, as in the following article.[8] http://www.dsplg.com/2007/08/05/bit-error-probability-for-bpsk-modulationLet's assume that and are both evenly probable then optimal decision boundary is formed by the threshold 0 [8].•When received signal is and it is greater than zero then the receiver assume was transmitted.•When received signal is and it is less or equal to zero then the receiver assume was transmitted.

- 1) Given the Probability of error that was transmitted [8]2) Given the Probability of error that was transmitted [8]Probabilities of errors given by and are represented in the figure 11 [8]: Total probability of bit error

- At the beginning we have assumed and are equally probable hence the bit error probability given by below equation [8], References: The sources are listed in numbered accordingly, as in the following article.[8] [https://assignbuster.com/probability-density-function-for-qpsk-health-and-social-care-essay/](http://www.https://assignbuster.com/probability-density-function-for-qpsk-health-and-social-care-essay/)

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dsplot. com/2007/08/05/bit-error-probability-for-bpsk-modulation/Figure 12: Bit error rate probability program with matlab Figure 13: Bit error probability curve for BPSK Modulation AS we can see here BPSK' s bit error rate of 10^{-5} only required around 9db of EB/NO 03. 02 Pulse Amplitude Modulation (4-PAM) For 4 PAM the constellation energy in average and this is assuming all alphabets are equally likely is [9],

- After normalization constellation diagram of the 4-PAM signal is shown below [9]. Channel Model The transmitted waveform gets corrupted by Additive White Gaussian Noise with and . then received signal would be or or . Case 01 when was transmitted. References: The sources are listed in numbered accordingly, as in the following article. [9] <http://www.dsplot.com/2007/10/07/symbol-error-rate-for-pam/> Below it is shown the conditional probability distribution function of when was transmitted [9].

- Figure 14 probability distribution function when was transmitted Source: Figure: Probability distribution function when the alphabet +3 is sent [9] Considering between the +1 and +3 midway points for received signal (threshold) [9]

- The area show in blue color is the probability of error given is transmitted with threshold [9]:

- -3 and +3 is symmetric Constellation is normally intuitive and the probability of error given is transmitted [9].

- References: The sources are listed in numbered accordingly, as in the following article.[9] [http://www.dsplog.com/2007/10/07/symbol-error-rate-for-pam/Case 02](http://www.dsplog.com/2007/10/07/symbol-error-rate-for-pam/Case%20when%20is%20transmitted) when is transmitted Below it is shown the conditional probability distribution function of when was transmitted show in red and green areas of the diagram [9].

- Figure 15 Probability distribution function when the alphabet +1 is Transmitted Source: Figure: Probability distribution function when the alphabet +1 is sent [9] Since +1 and -1 constellation is symmetric, it is normally intuitive and probability of error given transmitted [9] Assuming that the S_0 S_1 S_2 are similarly probable

- References: The sources are listed in numbered accordingly, as in the following article.[9] <http://www.dsplog.com/2007/10/07/symbol-error-rate-for-pam/> Figure 16 ; 4 PAM matlab work Figure 17: Symbol error probability curve for 4PAMAS we can see here 4-PAM' s bit error rate of 10^{-5} only required around 17db of EB/NO 03. 03 Symbol Error Rate (SER) for QPSK (4-QAM) modulation Figure 18: QPSK Constellation plot Source: Figure: Constellation plot for QPSK (4-QAM) [10] To normalize the average energy we use scaling factor of and also like above we assume all the points equally

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likely in constellation [10]. Noise modelThe transmitted waveform gets corrupted by Additive White Gaussian Noise [10]. with and . References: The sources are listed in numbered accordingly, as in the following article.[10] [http://www.dsplog.com/2007/11/06/symbol-error-rate-for-4-qam/Calculating the error probability](http://www.dsplog.com/2007/11/06/symbol-error-rate-for-4-qam/Calculating-the-error-probability)Case 1) using the symbolThe conditional probability distribution function (PDF) of given was transmitted is: [10].

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Figure 19: QPSK function of Probability densitySource: Figure: Probability density function for QPSK (4QAM) modulation [10]If Y falls in the area of highlighted in the diagram then the symbol will be decoded [10].

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Was transmitted when the probability of real component of > 0 , that area in show in the diagram outside of the red region [10]. References: The sources are listed in numbered accordingly, as in the following article.[10] [http://www.dsplog.com/2007/11/06/symbol-error-rate-for-4-qam/Was transmitted when the probability of imaginary component of \$> 0\$](http://www.dsplog.com/2007/11/06/symbol-error-rate-for-4-qam/Was-transmitted-when-the-probability-of-imaginary-component-of-gt-0) [10]. At least one of the symbols will be decoded with errors hence the symbol will be in error, therefore symbol error probabilityReferences: The sources are listed in numbered accordingly, as in the following article.[10] <http://www.dsplog.com/2007/11/06/symbol-error-rate-for-4-qam/>Figure 20: QPSK matlab workFigure 21: QPSK probability curveAS we can see here QPSK' s bit error rate of 10^{-5} only required around 13db of EB/NO03. 04 Symbol Error Rate (SER) for 16-QAMThe average energy of the 16-QAM constellation is . The 16-QAM constellation is as shown in the figure belowFigure 22: constellation map of 16 QAMSource Figure: 16-QAM constellation [11]References: The <https://assignbuster.com/probability-density-function-for-qpsk-health-and-social-care-essay/>

sources are listed in numbered accordingly, as in the following article.[11]

[http://www.dsplog.](http://www.dsplog.com/2007/12/09/symbol-error-rate-for-16-qam/#Simulation%20ModelNoise)

[com/2007/12/09/symbol-error-rate-for-16-qam/#Simulation%20ModelNoise](http://www.dsplog.com/2007/12/09/symbol-error-rate-for-16-qam/#Simulation%20ModelNoise)

modelwith and . Computing the probability of errorConsider the symbol in

the inside, for exampleThe conditional probability distribution function (PDF)

of given was transmitted is: [11]

-

Only if falls in the area in the black hashed region Symbol is decoded correctly [11]

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Using the equations from symbol error probability of 4-PAM [11]

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The probability of being decoded incorrectly is, The conditional probability distribution function (PDF) of given was transmitted is: [11]

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References: The sources are listed in numbered accordingly, as in the following article.[11] <http://www.dsplog.com/2007/12/09/symbol-error-rate-for-16-qam/#Simulation%20Model>As can be seen from the above figure, the symbol is decoded correctly only if falls in the area in the red hashed region i. e. [11]

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The probability of being decoded incorrectly is,

- Consider the symbol which is not in the corner OR not in the inside, for example The conditional probability distribution function (PDF) of given was transmitted is: [11]

- Only if falls in the area in the blue hashed region then Symbol is decoded correctly i. e. [11]

- Using the above two cases are reference,

- The probability of being decoded incorrectly is, [11] References: The sources are listed in numbered accordingly, as in the following article.[11]

<http://www.dsplog.com/2007/12/09/symbol-error-rate-for-16-qam/#Simulation%20Model>

Figure 23: 16 QAM probability curve matlab work

Figure 24: Probability curve of 16 QAMAS we can see here 16-QAM' s bit error rate of 10^{-5} only required

around 20db of EB/NO3. 05 Symbol error rate for 16-PSK

In this post, let us try to derive the symbol error rate for 16-PSK (16-Phase Shift Keying)

modulation [12]. Consider a general M-PSK modulation, where the alphabets,

are used [12]. Figure 25: constellation plot of 16 PSK

Source: Figure: 16-PSK constellation plot [12]

Deriving the symbol error rate Let us the consider the

symbol on the real axis, i. e

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The received symbol. References: The sources are listed in numbered accordingly, as in the following article.[11] <http://www.dsplog.com/2008/03/18/symbol-error-rate-for-16psk/#Simulation%20Model>Where

the additive noise follows the Gaussian probability distribution function, [12]with and . The conditional probability distribution function (PDF) of received symbol given was transmitted is: [12]

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To derive the symbol error rate, to find the probability that the phase of the received symbol lies Boundary defined by the magenta lines i. e. from to .

Here use these assumptions: [12](a) The signal to noise ratio, is reasonably high. For a reasonably high value of , then the real part of the received symbol is not affected by noise i. e., andthe imaginary part of the received symbol is equal to noise, i. e. [12]

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(b) The value of M is reasonably high (typically $M > 4$ suffice)For a reasonably high value of M, the constellation points are closely spaced.

Given so, the distance of the constellation point to the magenta line can be approximated as . References: The sources are listed in numbered

accordingly, as in the following article.[12] <http://www.dsplog.com/2008/03/18/symbol-error-rate-for-16psk/#Simulation%20Model>Figure

26: distance of Constellation pointsSource: Figure: Distance between constellation points

Given the above two assumptions, it can be observed that the symbol will be decoded incorrectly, if the imaginary component of

received symbol is greater than r . The probability of being greater than r is, $P(r) = \frac{1}{2} \text{erfc}\left(\frac{r}{\sigma}\right)$. Changing the variable to x , Note: The complementary error function, $\text{erfc}(x) = 1 - \text{erf}(x)$. Similarly, the symbol will be decoded incorrectly, if the imaginary component of received symbol is less than r . The probability of being less than r is, $P(r) = \frac{1}{2} \text{erfc}\left(\frac{r}{\sigma}\right)$. The total probability of error given was transmitted is,

- References: The sources are listed in numbered accordingly, as in the following article. [12] <http://www.dsblog.com/2008/03/18/symbol-error-rate-for-16psk/#Simulation%20Model> Figure 27: 16 PSK probability curve matlab work Figure 28: Probability curve of 16 PSK AS we can see here 16-PSK's bit error rate of 10^{-5} only required around 24db of EB/NO. 06 Symbol error rate of Quadrature Amplitude Modulation (QAM)

- Defining the general M-QAM constellation Points in the constellation is defined as, [13] Out of total bits half by half represented on the real axis and imaginary axis. The in-phase and quadrature signals are independent [13]. Average energy of an M-QAM constellation In a general M-QAM constellation where M and N are even, the alphabets used are $\{a_j + jb_k\}$, where a_j and b_k are real numbers. For example, considering a 64-QAM (8×8) constellation, and the alphabets are $\{a_j + jb_k\}$ [13] To compute the average energy of the M-QAM constellation: 1. Find the sum of energy of the individual alphabets 2. Each alphabet is used $\frac{M}{2}$ times in the M-QAM constellation. Thus, to find the average energy from constellation symbols, divide the product of (1) and (2) above by M . The average energy is,

[13] References: The sources are listed in numbered accordingly, as in the following article. [13] <http://eetimes.com>. <https://assignbuster.com/probability-density-function-for-qpsk-health-and-social-care-essay/>

com/design/signal-processing-dsp/4017648/Symbol-error-rate-for-M-QAM-modulation

Plugging in the number for 64-QAM, . Plugging in the number for 16-QAM, . From the above explanations, it is reasonably intuitive to guess that the scaling factor of , which is seen along with 16-QAM, 64-QAM constellations, respectively, is for normalizing the average transmit power to unity [13]. Finding the symbol error rate consider the 64-QAM constellation define the M-QAM [13]. Figure 29 constellation plot

Source: Figure 1.

Constellation plot for 64-QAM modulation (without the scaling factor of)

[13]References: The sources are listed in numbered accordingly, as in the following article.[13] <http://eetimes.com/design/signal-processing-dsp/4017648/Symbol-error-rate-for-M-QAM-modulation>

There are three types of constellation points in M-QAM

constellation: [13]1. Constellation points in the corner (red squares). The number of constellation points in the corner in any M-QAM constellation is always 4, [13]2. Constellation points in the inside (magenta diamonds). The number of constellation points in the inside is,

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For example with $M = 64$, there are 36 constellation points in the inside. 3.

Constellation points neither at the corner, nor at the center (blue stars). The number of constellation points of this category is, [13]

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For example with $M = 64$, there are 24 constellation points in the inside.

References: The sources are listed in numbered accordingly, as in the following article.[13] <http://eetimes.com/design/signal-processing-dsp/4017648/Symbol-error-rate-for-M-QAM-https://assignbuster.com/probability-density-function-for-qpsk-health-and-social-care-essay/>

modulationFigure 30: 64 QAM probability curve matlab workFigure 31:

Probability curve of 64 QAMAS we can see here 64-QAM' s bit error rate of 10^{-5} only required around 26db of EB/NO