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# PSK modulation and emodulation

athuranathan      ⊘ October 19, 2010      ▤ Digital Modulations, Latest Articles, Matlab Codes      💬 19 Comments

⭐⭐⭐⭐⭐ (**10** votes, average: **3.80** out of 5)

post is a part of the ebook : Simulation of digital communication systems using Matlab – available in PDF and EPUB format.
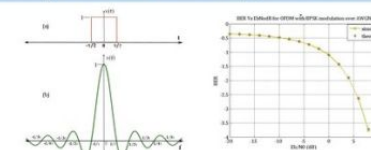
## QPSK Modulation:

In digital modulation techniques a set of basis functions are chosen for a particular modulation scheme.Generally the basis functions are orthogonal to each other. Basis functions can be derived using 'Gram Schmidt orthogonalization' procedure.Once the basis function are chosen, any vector in the signal
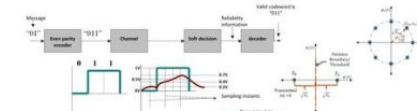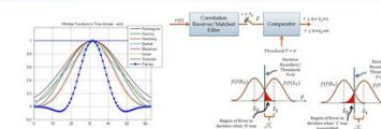
space can be represented as a linear combination of the basis functions.

In Quadrature Phase Shift Keying (QPSK) two sinusoids (sin and cos) are taken as basis functions for modulation. Modulation is achieved by varying the phase of the basis functions depending on the message symbols. In QPSK, modulation is symbol based,where one symbol contains 2 bits. The following equation outlines QPSK modulation technique.

$$s_i(t) = \sqrt{\frac{2E_s}{T}} cos(2\pi f_c t + (2n-1)\frac{\pi}{4}) \quad ,\text{n=1,2,3,4}$$

When $n = 1$, the phase shift is 45 degrees. This is called pi/4 QPSK.The constellation diagram of QPSK will show the constellation points lying on both x and y axes.This means that the QPSK modulated signal will have an in-phase component (I) and also a quadrature component (Q). This is because it has only two basis functions.

A QPSK modulator can be implemented as follows. A demultiplexer (or serial to parallel converter) is used to separate odd and even bits from the generated information bits. Each of the odd bits (quadrature arm) and even bits (in-phase arm) are converted to NRZ format in a parallel manner. The signal on the in-phase arm is multiplied by cosine component and the signal on the quadrature arm is multiplied by sine component. QPSK modulated signal is obtained by adding the signal from both in-phase and quadrature arm.
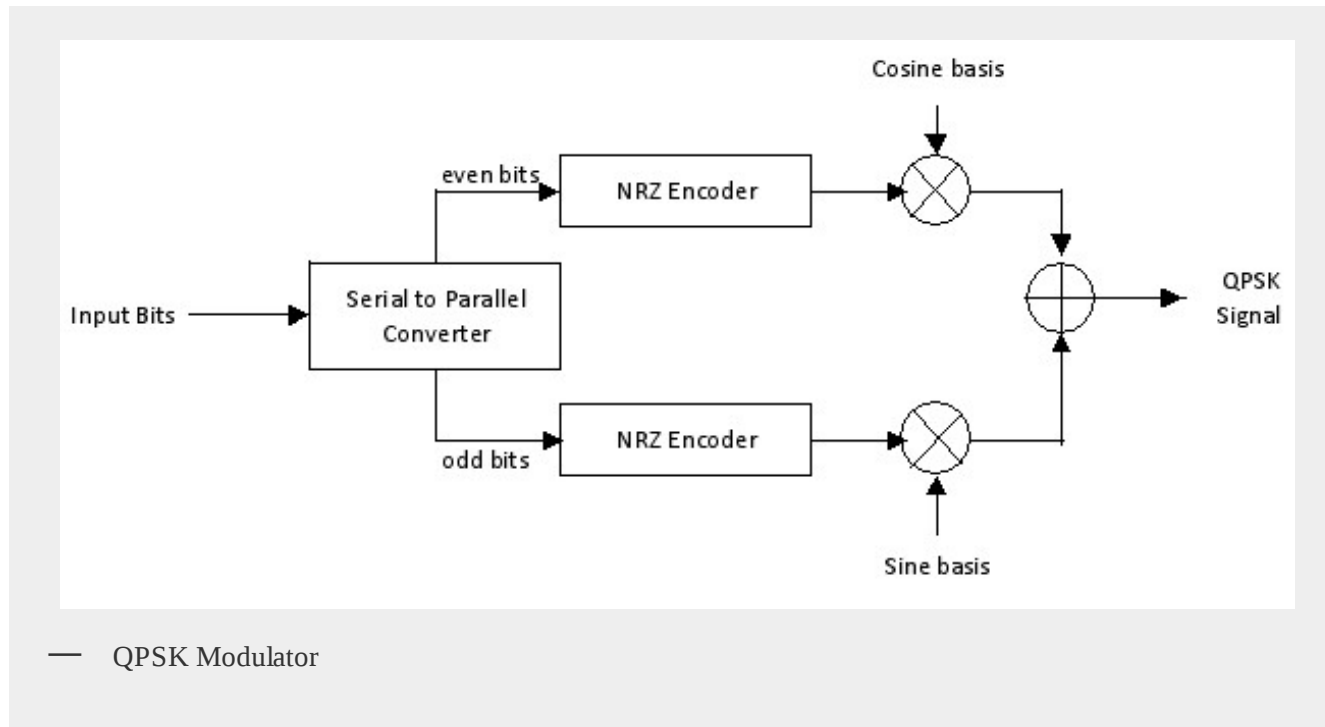
— QPSK Modulator

# QPSK Demodulation:

For QPSK demodulator , a coherent demodulator is taken as an example. In coherent detection technique the knowledge of the carrier frequency and phase must be known to the receiver. This can be achieved by using a PLL (phase lock loop) at the receiver. A PLL essentially locks to the incoming carrier frequency and tracks the variations in frequency and phase. For the following simulation , a PLL is not used but instead we simple use the output of the PLL. For demonstration purposes we simply assume that the carrier phase recovery is done and simply use the generated reference frequencies at the receiver ($\cos(\omega t)$) and ($\sin(\omega t)$).

In the demodulator the received signal is multiplied by a reference frequency generators ($\cos(\omega t)$) and ($\sin(\omega t)$) on separate arms (in-phase and quadrature arms). The multiplied output on each arm is integrated
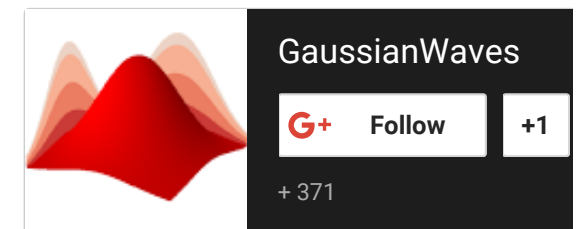
over one bit period using an integrator. A threshold detector makes a decision on each integrated bit based on a threshold. Finally the bits on the in-phase arm (even bits) and on the quadrature arm (odd bits) are remapped to form detected information stream. Detector for in-phase arm is shown below. For quadrature arm the below architecture remains same but sin(ωt) basis function must be used instead.



— QPSK Demodulator – In-phase arm
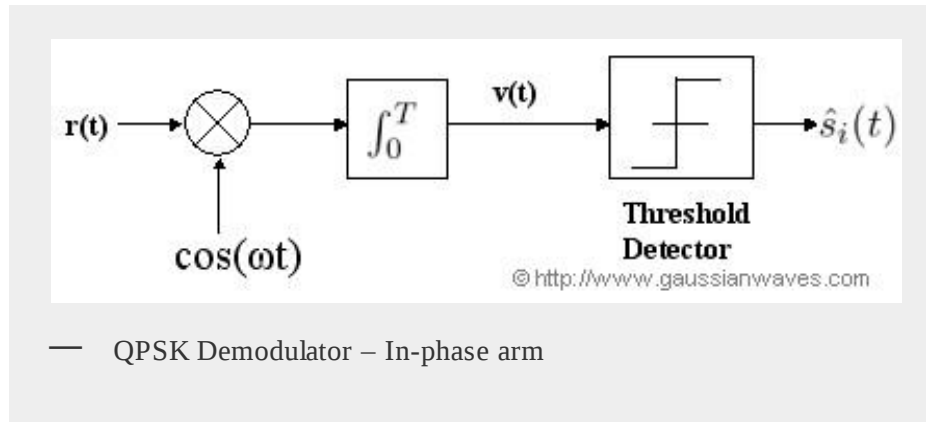
# Matlab Code:

# File1: QPSK.m

```matlab
1   % Demonstration of QPSK Modulation and Demodulation
2
3   %
4
5   %    Author: Mathuranathan for http://www.gaussianwaves.com)
6
7   %    License : creative commons : Attribution-NonCommercial-ShareAlike 3.0
8
9   %    Unported
10
11  clear; %clear all stored variables
12  N=100; %number of data bits
13  noiseVariance = 0.1; %Noise variance of AWGN channel
14  data=randn(1,N)&gt;=0; %Generate uniformly distributed random data
15  Rb=1e3; %bit rate
16  amplitude=1; % Amplitude of NRZ data
```

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```
17
18   oddBits = data(1:2:end);
19   evenBits= data(2:2:end);
20
21   [evenTime,evenNrzData,Fs]=NRZ_Encoder(evenBits,Rb,amplitude,'Polar');
22   [oddTime,oddNrzData]=NRZ_Encoder(oddBits,Rb,amplitude,'Polar');
```

Check this book for full Matlab code.

Simulation of Digital Communication Systems Using Matlab – by Mathuranathan Viswanathan

# File2: NRZ_Encoder.m

Check this book for full Matlab code.

Simulation of Digital Communication Systems Using Matlab – by Mathuranathan Viswanathan

The output of the Matlab code provides more insight into the QPSK modulation technique. Apart from plotting the modulated and demodulated signal it also shows the constellation at transmitter/receiver. This Matlab code is written without using any of the inbuilt functions from communication toolbox.

# Simulation Result:

generator

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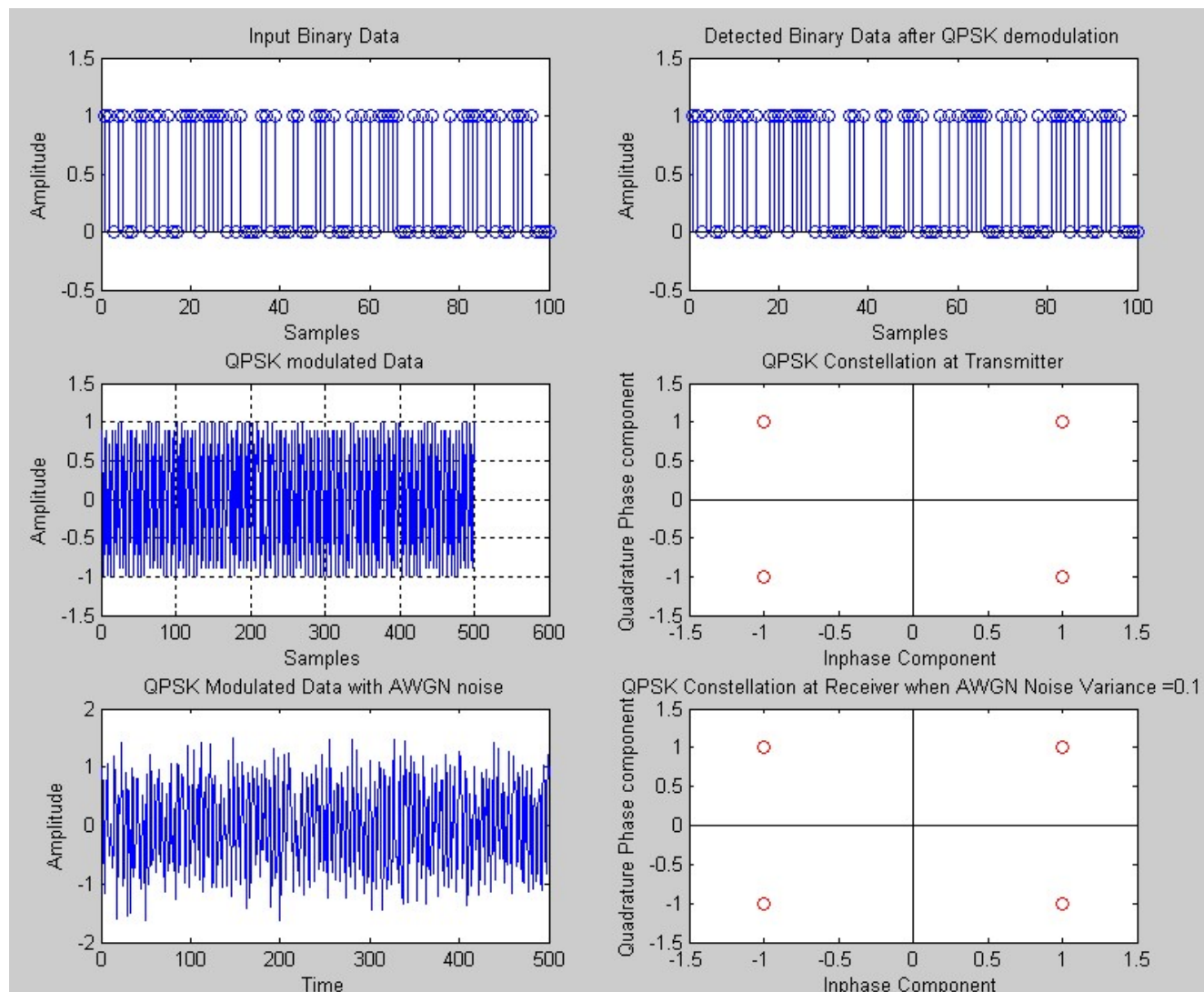
## See also:

[1] [BER Vs Eb/N0 for 8-PSK modulation over AWGN](#)

[2] [BER Vs Eb/N0 for M-PSK modulation over AWGN](#)

[3] [BER Vs Eb/N0 for QPSK modulation over AWGN](#)

Mathuranathan - Dara_parsavand, Thanks for adding your insights an...

dara_parsavand - Mathuranathan, Good point about context. I agree ...

Tariq - Dear @dara_parsavand:disqus , I really appreciate ...

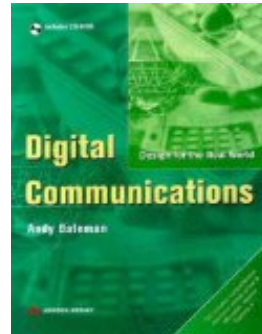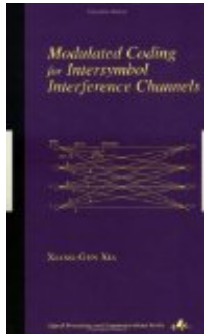siva kumar reddy - Solid discussion...thnk u so much for sharing........

Mathuranathan - That's not necessarily true. Phase noise assumptio...

dara_parsavand - If you first generate a real noise signal x, with ...

[4] [Simulation of BER Vs Eb/N0 for BPSK modulation over AWGN in Matlab](#)

[5] [Intuitive derivation of Performance of an optimum BPSK receiver in AWGN channel](#)

# Recommended Books





Michael Schwager - Hi, I'm trying to figure out how to convert the la...

Mathuranathan - Good catch. Yeah I missed the -1/Fs part in the co...

no name - method : sum of sinusodial model of channel??? w...

SSS - I think Seba is right. If you see the code suppose...

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### Mathuranathan

[Mathuranathan Viswanathan](#) – Founder and Author @ gaussianwaves.com which has garnered worldwide readership. He is a masters in communication engineering and has 7 years of technical expertise in channel modeling and has worked in various technologies ranging from read channel design for hard drives, GSM/EDGE/GPRS, OFDM, MIMO, 3GPP PHY layer and DSL.
He also specializes in tutoring on various subjects like signal processing, random process, digital communication etc..,

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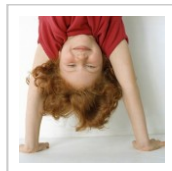
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### About Mathuranathan

[Mathuranathan Viswanathan](#) - Founder and Author @ gaussianwaves.com which has garnered worldwide readership. He is a masters in communication engineering and has 7 years of technical expertise in channel modeling and has worked in various technologies ranging from read channel design for hard drives, GSM/EDGE/GPRS, OFDM, MIMO, 3GPP PHY layer and DSL. He also specializes in tutoring on various subjects like signal processing, random process, digital communication etc.., [LinkedIn Profile](#)

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**Shahid ullah** · 6 months ago

Hello sir,
I need The Matlab code of QPSK 2*2 MIMO with no channel coding using MMSE Receiver and hard detection. (Rayleigh channel) used BER curves to show performance...plz i need it

## Tags

AR ARMA ARMA model Auto-Correlation Auto regressive AWGN BPSK Channel Capacity Channel Coding Channel Modelling cholesky Cramer Rao Lower Bound CRLB Cross-Correlation Digital Modulations Estimation Fading FFT Fisher Information Fisher Matrix Fourier Analysis Fourier transform gray code M-QAM Matlab Code matrix algebra Maximum Likelihood Estimation Minimum Variance Unbiased Estimator MLE Multi-carrier Modulation OFDM Orthogonal Frequency Division Multiplexing oversampling positive definite Power spectral Density PSD Pulse Shaping Random Process Random Variables Rayleigh Score Shannon Capacity Signal Processing Spread Spectrum Tips & Tricks

urgently.... my Email numb is .. shahidwazir_90@yahoo.com

∧ | ∨ • Reply • Share ›

**Narimane Hadjadji** • 6 months ago

Hello Sir:

thank you for all this infromations.

i want to use the Square Root Raised Cosine encoder in place of NRZ Encoder for QPSK modulation.
my idea is used the ideal pulse and after that we using the the Square Root Raised Cosine filter.is this correct and i want to know what is the transfer function of this filter. if you can help me with this program.

∧ | ∨ • Reply • Share ›

**Shahab Shariat Bagheri** ➜ Narimane Hadjadji • 6 months ago

Actually, Just for checking a Theoretical important problem, Square Root Raised Cosine filter does not have a relation with your NRZ Stream, it's just a pulse shaping of your NRZ Stream it means that you wanna send for example 1 -1 1 -1 -1 1 , ... then the signal analogue that specifies to 1 will be 1 * Cosine filter and for -1 will be (-1)* Cosine wave, ... which effectively depends on your sampling frquency of filter that you have choosen and the rol of factor of pulse,

So my solution for you is at first upsample of your NRZ data arbiary (4,8 or 16 , ...) and then taking convolution of upsampled data and root raised cosine filter will have give simply the output that you need. and now it's your ready signal to modulation.

Matlab code :
N = 10^4 ; % number of data
up = 4; % upsampling data
d = randsrc(1,N);

du = upsample (d,up);
x = conv(du,Root_Raised_Cosine); % your ready signal to go to modulate

˄ | ˅ • Reply • Share ›

**Mathuranathan** `Mod` ➜ Narimane Hadjadji • 6 months ago
The equation and Matlab code for SRRC filter is given here.
http://www.gaussianwaves.com/2...

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**mounica suryadevara** • a year ago
Hi I tried the program for QPSK modulation and demodulation .... but am getting an error consistently...

Error in ==> QPSK at 10

[evenTime,evenNrzData,Fs]=NRZ_Encoder(evenBits,Rb,amplitude,'Polar');

What do I do for this... Is there something I need to do to prevent this error....

˄ | ˅ • Reply • Share ›

**Mathuranathan** `Mod` ➜ mounica suryadevara • a year ago
The ebook contains the function "NRZ_Encoder.m". Please check page 191 in the PDF version. Just copy the code and save it as NRZ_Encoder.m in the same location as your current working directory.

ebook here: http://www.gaussianwaves.com/s...

˄ | ˅ • Reply • Share ›

**AMM** ➜ Mathuranathan • 7 months ago
I just bought the ebook and copied the same code for the two m files. I got the same error message.

Undefined function or variable "output".
Error in NRZ_Encoder (line 31)
output=[output amplitude*(-1)^(1+input(count))];
Error in QPSK_modulation_demodulation (line 10)

[evenTime,evenNrzData,Fs]=NRZ_Encoder(evenBits,Rb,amplitude,'Polar');

∧ | ∨ • Reply • Share ›

**Mathuranathan** Mod → AMM • 7 months ago
The programs are already checked for correctness and they will run without any problem.

Can you check whether the code in your file (NRZ_ENcoder.m) declares the following on line 11, just before the switch statement on line 12 as shown below?
line 11: output=[];

line 12: switch lower(style)

Thanks for your support !!!

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**itsluser** • 3 years ago
I mean, in the program provided by you, I changed one of the input parameter in NRZEncoder function from polar to unipolar.

∧ | ∨ • Reply • Share ›

**Mathuranathan** → itsluser • 3 years ago
Hi,
QPSK modulation is achieved using NRZ (polar) encoding method. If you use unipolar encoding the constellations in trasmitter and receiver will be different.
QPSK modulation has to be simulated with polar encoding. Simulating using unipolar, zeros out the sine/cos components. Because of that your bits are detected wrongly

In QPSK, the inphase component is multiplied by cos and quadrature component by sine. For polar encoding, inphase and quadrature phase components are either +1 and -1 . So there is no problem here.
But when you use unipolar encoding, the inphase or quadrature phase components take value 0 or 1. The value '0' will nullify the corresponding cos or sine component and there

is no way to recover from this error.

It is not recommended to use unipolar encoding for QPSK modulation as it defeats the basic architecture of the modulation itself.

Hope this helps.

⌃ | ⌄ · Reply · Share ›

**QPSK_passband** ↱ Mathuranathan · 2 years ago

Hello Mathuranathan
I tried to get BER Vs Eb/N0 graph of passband QPSK modultion.
I chosed N = 1e6 samples of bits and used your code in a loop.
The result was that the BER was zero every time even if I had increased the noise varianc (I actually deceased the SNR).
How can I get the BER Vs Eb/N0 graph for passband ?

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**itsluser** · 3 years ago

I tried this code using unipolar and polar line coding. With polar coding, the reconstructed bit sequence was okay. but with unipolar coding, the reconstructed bit sequence always appeared same (all 1s) in almost all cases. Can anyone tell me the reason for this behaviour ?

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**Mathuranathan** ↱ itsluser · 3 years ago

Hi can you paste your modified main program.. I will try it out and let you know ...

⌃ | ⌄ · Reply · Share ›

**Unknown** · 4 years ago

hi
i think there is a small error in the line:
'Modulation is achieved by varying the phase of the basis functions depending on the message symbols.'

instead of the word 'phase' in the above line, it should be amplitude of the basis functions depends on the message symbol. the linear combination of the basis functions in turn results in the output function whose phase depends on the message symbol.

ʌ  |  ˅  ·  Reply  ·  Share ›

**mathuranathan**  ·  4 years ago

Hi Naveed,

Understand that the NRZ encoder converts 0's and 1's into -1 and +1 respectively. In any digital modulation technique, the user input interms of 0's and 1's has to be converted to -1's and +1s, each bits with a definite bit duration. For this purpose, a NRZ encoder is used.

ʌ  |  ˅  ·  Reply  ·  Share ›

**Naveed**  ·  4 years ago

Hello sir,

I am trying to understand this program.I unable to understand what is the need for NRZ encoder.Can you explain me please....

ʌ  |  ˅  ·  Reply  ·  Share ›

**bahpullo**  ·  4 years ago

Hi Mathuranathan,

I am new to MATLAB and i need some help in generating MATLAB code for QPSK. I have tried to modify your code to produce the required result but no success. I need to generate/plot a polarised version of the bit stream "00 01 01 01 01 10 11 10" for input into a QPSK modulator (odd bits = 00 00 01 11; even bits =01 11 10 10). I also need a polarised version of the odd and even bits plotted. The odd and even bits are then multiplied by +/-(sqrt2) and then modulated by carriers cos(wt) and -sin(wt). The two modulated signals are then combined to produce QPSK. plots of the modulated odd bits, modulated even bits and the QPSK signals included. The carrier frequency is 1600Hz with two cycles of carrier during each symbol (baud rate =800 symbols per sec, symbol duration =1.25mS).

At the other end, a plot of the two demodulated signals and the instantaneous waveforms of the

integrators.

⌃ | ⌄ • Reply • Share ›

**mathuranathan** • 5 years ago

That is equation is for non-offset QPSK. PSK modulation has lot of variations like OQPSK (offset QPSK), pi/4-QPSK, DQPSK (differential QPSK),etc..,

In reality pi/4-QPSK modulation uses two constellations (dual constellations) which are shifted by

« Generation of Gold Codes and their cross-correlation          BER Vs Eb/N0 for QPSK modulation over AWGN »

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