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Introduction

This project is a MATLAB implementation of bit error rate (BER) or symbol error rate (SER) calculation and plotting of digital signal modulation schemes: BPSK, BFSK, BASK and MPSK in additive white Gaussian channel (AWGN).

Main function file `main.m` reads requirements from `Test.csv` , calling relative functions to calculate BER or SER and plotting curves according to requirements. Parameters in `Test.csv` include:

- Levels (*string*): Number of levels to be modulated
- Scheme (*string*): Modulating schemes to be used
- N (*double*): Number of input bits
- Theoretical (*string*): If the value is '-1', not plot theoretical BER/SER curve
- Simulated (*string*): If the value is '-1', not plot simulated BER/SER curve
- Approximate (*string*): If the value is '-1', not plot approximate BER/SER curve
- SNR (*string*): SNR (in dB) range of AWGN channel

Function Implementation

Additive White Gaussian Channel (AWGN)

AWGN is a Gaussian distribution with mean $\mu = 0$ and variance (σ^2) which is denoted as $N(0,\sigma^2)$. For AWGN channel, the noise variance $\sigma^2 = \frac{N_0}{2}$ where $N_0 = \frac{1}{\log_2(M) * SNR_{per\_bit}}$. Thus:

$$AWGN \sim N(0,\sigma^2) = \sigma \cdot N(0,1) = \sqrt{\frac{1}{2\log_2(M) * SNR_{per\_bit}}} \cdot N(0,1)$$

and $N(0,1)$ can be generated by `randn` in MATLAB.

Binary Phase Shift Keying (BPSK)

Calculating Bit Error Rate (BER) of Binary Phase Shift Keying (BPSK).

Usage

BERs = BPSK(sig,n,SNR)		
Parameters:	● sig (*vector*):	Modulating bit stream
	● n (*double*):	Number of input bits
	● SNR (*vector*):	SNR (in dB) range of AWGN channel
Returns:	● BERs (*vector*):	BER of different SNR

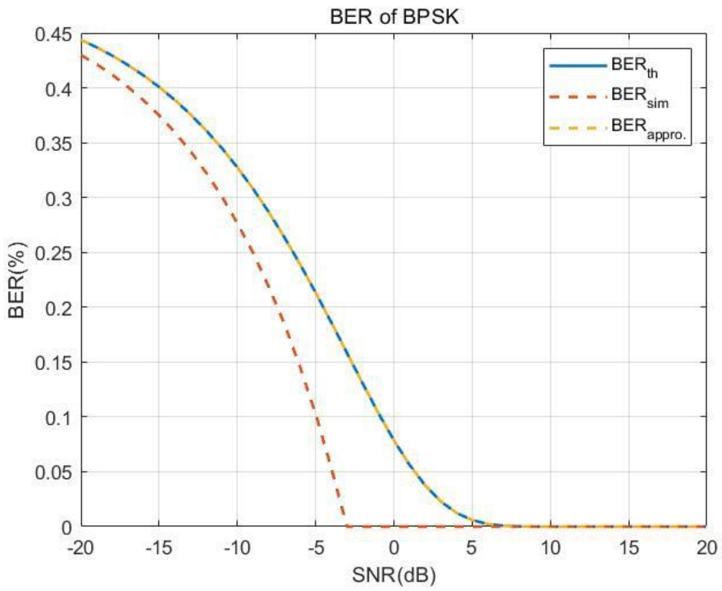
In BPSK, a carrier signal of constant amplitude jumps between two different phases, usually 180 degrees apart, as two signals, m_1 and m_2 (representing binary data 1 and 0), change. BPSK bit error rate given that:

$$\text{Pe} = Q\left(\sqrt{2E_b / N_0}\right) = \frac{1}{2} erfc\left(\sqrt{E_b / N_0}\right)$$

At the receiver, if received data > 0, then returns 1, else returns 0.

Example

Given `N=1000000`, `SNR=[-20:1:20]`, plotting all curves.



Binary Amplitude Shift Keying (BASK)

Calculating Bit Error Rate (BER) of Binary Amplitude Shift Keying (BPSK).

Usage

BERs = BASK(sig,n,SNR)		
Parameters:	● sig (*vector*):	Modulating bit stream
	● n (*double*):	Number of input bits
	● SNR (*vector*):	SNR (in dB) range of AWGN channel
Returns:	● BERs (*vector*):	BER of different SNR

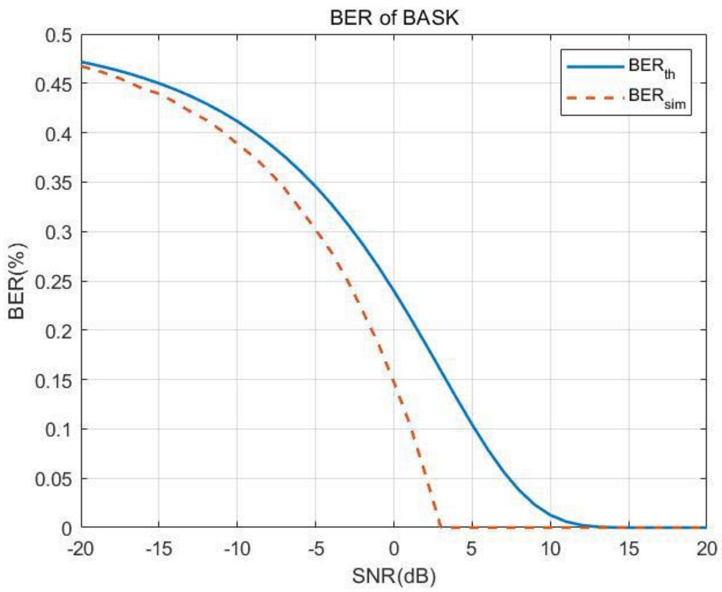
In BASK, the amplitude of a frequency-invariant carrier signal varies with 0 and 1. BASK's BER given that:

$$\text{Pe} = Q\left(\sqrt{2E_b / N_0}\right) = \frac{1}{2} erfc\left(\sqrt{\frac{E_b / N_0}{4}}\right)$$

At the receiver, if received data > 0.5, then returns 1, else returns 0.

Example

Given `N=100000`, `SNR=[-20:1:20]`, without plotting approximated curves.



Binary Frequency Shift Keying (BFSK)

Calculating Bit Error Rate (BER) of Binary Amplitude Shift Keying (BFSK).

Usage

BERs = BFSK(sig,n,SNR)		
Parameters:	• sig (*vector*):	Modulating bit stream
	• n (*double*):	Number of input bits
	• SNR (*vector*):	SNR (in dB) range of AWGN channel

Returns:	●	BERs (*vector*):	BER of different SNR

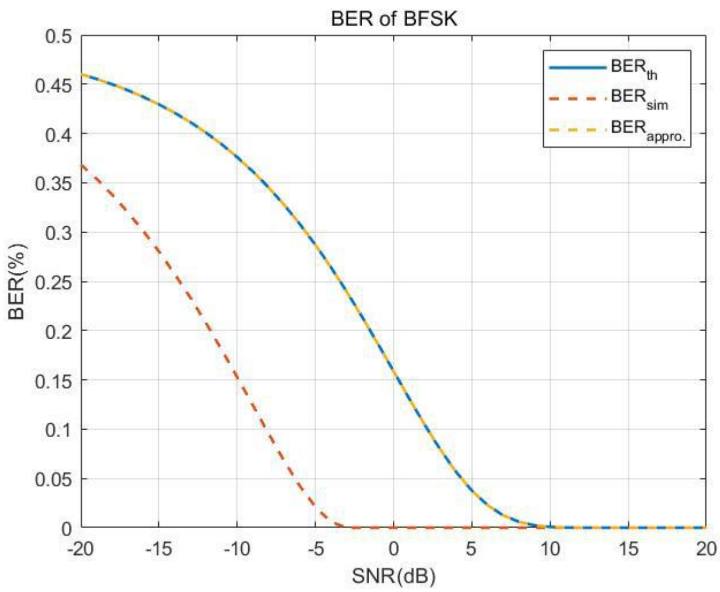
In BFSK, the frequency of an amplitude-invariant carrier signal is switched with two information states 0 and 1. Adjacent bits are either phase continuous or phase discontinuous. BFSK's BER given that:

$$\mathrm{Pe} = Q\left(\sqrt{2E_b / N_0}\right) = \frac{1}{2} erfc\left(\sqrt{\frac{E_b / N_0}{2}}\right)$$

At the receiver, if phase of received data > $\frac{\pi}{4}$, then returns 0, else returns 1.

Example

Given `N=10000000`, `SNR=[-20:1:20]`, plotting all curves.



M-Phase Shift Keying (MPSK)

Calculating Symbol Error Rate (SER) of M-Phase Shift Keying (MPSK).

Usage

SERs = MPSK(sig,M,SNR)		
Parameters:	● sig (*vector*):	Modulating bit stream
	● M (*double*):	Number of phases
	● SNR (*vector*):	SNR (in dB) range of AWGN channel
Returns:	● SERs (*vector*):	SER of different SNR

Take the nearest proximity of MPSK error rate:

$$P_s \approx 2Q\left(\sqrt{2}A\,sin(\pi/M)/\sqrt{N_0}\right) = 2Q\left(\sqrt{2r_s}\,sin(\pi/M)\right)$$

Wherein, the signal-to-noise ratio:

$$r_s = E_s / N_0$$

Bit signal-to-noise ratio:

$$r_b = E_b / N_0 .$$

The relationship between symbol error rate P_s and bit error rate P_b in multi-base system, the relationship between symbol SNR and bit SNR is as follows:

$$r_b = r_s / \log_2(M)$$
$$P_b \approx P_s / \log_2(M)$$

Therefore, the MPSK symbol error rate:

$$P_s \approx 2Q\left(\sqrt{2\log_2 M \times \frac{E_b}{N_0}} \times sin(\pi/M)\right)$$

At the receiver, received data will be decoded as the symbol which has the nearest distance to it.

Example

Given `N=100000`, `SNR=[-20:1:20]` and `M=8`, plotting all curves.