

M1 課題レポート 第1回目

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Technical Report for M1 Labwork 1-st

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Abstract In this first C workshop, we will use C language to simulate the workflow of a QPSK modulation and detection system over AWGN channel. In the begin, this report will introduce the overall design of the communication system. Then the background knowledge is introduced. Final part is the simulation design come with simulation result compared to theoretical value.

1. Introduction

QPSK is kind of digital phase shifting modulation method, which conveys data by changing the phase of a constant amplitude high frequency carrier. Compared with BPSK, which can only use two phases, QPSK can utilize four phases, and one symbol is able to convey 2 bits of information. QPSK is widely deployed in system like wireless LANs, RFID, Bluetooth, etc. To map the bit to QPSK symbol, we also adopt gray code which is an ordering of the binary numeral system that two successive values differ in only one bit. Gray code is an effective strategy to improve total system performance. Corresponding bit mapping is in Table 1.

The channel we choose to conduct the simulation is AWGN, which is the simplest model to mimic the effect of many random process that occurs in nature due to thermal phenomenon. The expression formula is as followed:

$$R(t) = S(t) + N \quad (1)$$

$R(t)$ is received signal and $S(t)$ is transmitted signal, N is AWGN. The characteristic of AWGN is a normal distribution in time domain, Gaussian distribution in amplitude and is able to directly add in original signal [1].

In the receiver side, we use MLE as our estimation method to determine received symbol in constellation diagram [2]. MLE is a method to estimate parameters of a

Table 1 MAPPING TABLE OF PHASE

bitA	bitB	$\Delta\theta_i$
0	0	$\frac{\pi}{4}$
1	0	$\frac{3\pi}{4}$
1	1	$\frac{5\pi}{4}$
0	1	$\frac{7\pi}{4}$

Table 2 ACRONYMS AND FULL MEANING

Acronyms	Full Form
MLE	Maximum Likelihood Estimator
QPSK	Quadrature Phase Shift Keying
SNR	Signal Noise Ratio
CNR	Channel Noise Ratio
BPSK	Binary Phase Shift Keying
AWGN	Additive White Gaussian Noise
BW	Band Width

probability distribution by maximizing a likelihood function. The general form of MLE is shown:

$$\hat{\theta} = \arg \max_{\theta \in (\frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4})} \|R(t) - \theta_i\| \quad (2)$$

In our case, the likelihood function is the distance between received signal and constellation diagram.

2. Simulation and Result

In our simulation, first we use C standard library rand() function to generate information bits, and then convert serial bit to 2 parallel bit and map the bit to QPSK sym-



REFERENCE

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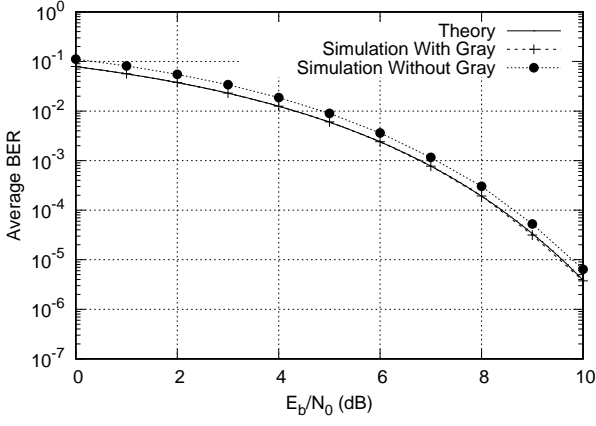


Fig. 1 QPSK BER IN DIFFERENT SNR

bol. To generate noise to simulate channel, we adopt Box-Muller method, the formula is shown:

$$n_k = \sqrt{-\sigma_n^2 \ln(u_1)} e^{j2\pi u_2} \quad (3)$$

In this equation, u_1 and u_2 are uniform distribution ranging from 0 to 1, which can be generated by C rand() function. The σ_n^2 is noise power which is:

$$\sigma_n^2 = 10^{-\frac{CNR}{10}} \quad (4)$$

CNR in our cases is **SNR** add 3 dB, because according to [3], modulation rotation gain of QPSK is 3 dB. Finally, we use the MEL mentioned earlier to estimation received signal and calculate BER.

In order to verify the validity of the Gray code, we run simulation on **SNR** from 0 to 11 dB in using gray code and without gray code two cases. The simulation parameter is shown in Table 3 and simulation result is in Figure 1. The BER of QPSK modulation over AWGN is shown as follow:

$$\frac{1}{2} \text{erfc}\left(\sqrt{\exp\left(\text{SNR} \cdot \frac{\ln 10}{10}\right)}\right) \quad (5)$$



3. Conclusion

From Figure 2 we can see that the simulation result is very close to the theoretical value. And the BER curve without gray code is obviously higher than deployed, this shows that Gray Code can effectively improve system performance.

Table 3 SIMULATION CONDITIONS

ITEMS	CONDITIONS
Moduation Method	QPSK
Transmission Bits	128
Channel	AWGN
Detection	MLE
Number of Trials	10^6

