Communications Lab 3 Report B05901092 歐瀚墨

1. Preface

   My code is uploaded to the following link:

   https://github.com/ouhanmo/Comm_Lab

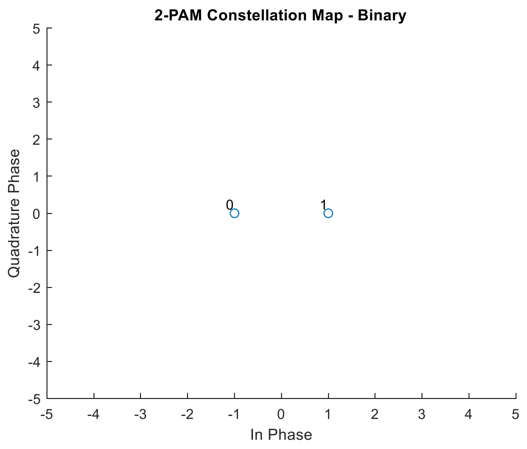
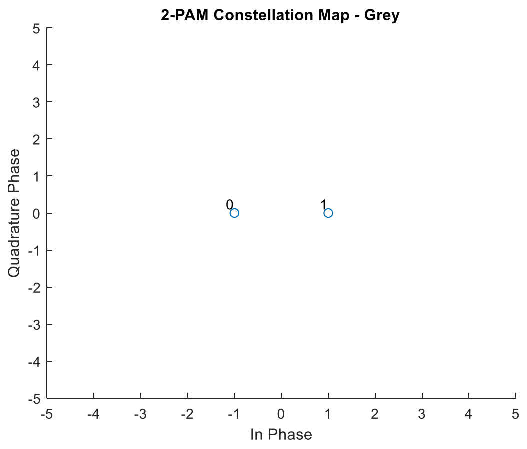
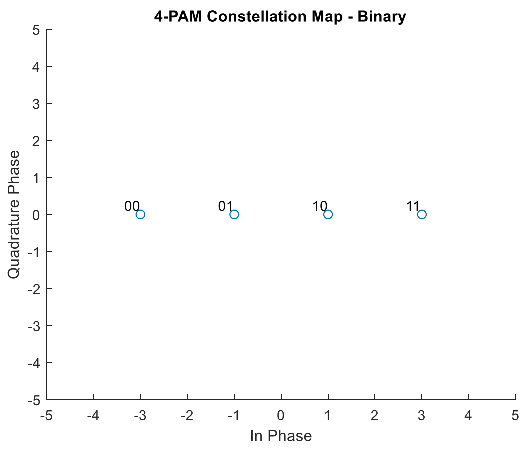
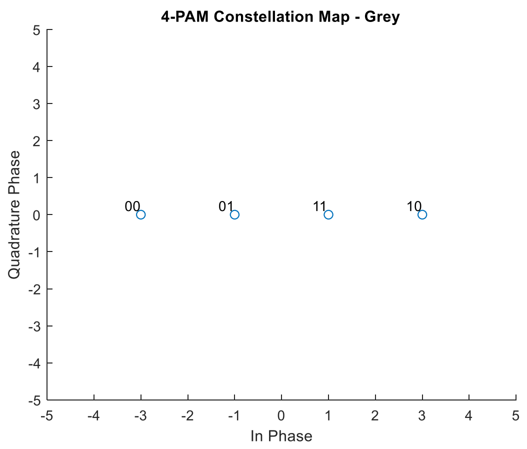
   The main program is lab3.m

   To run the program, please set the exper variable to the experiment number (1-5).

2. Experiment Results

   I. Symbol Mapping

   PAMs:

M	Binary	Grey
2		
4		

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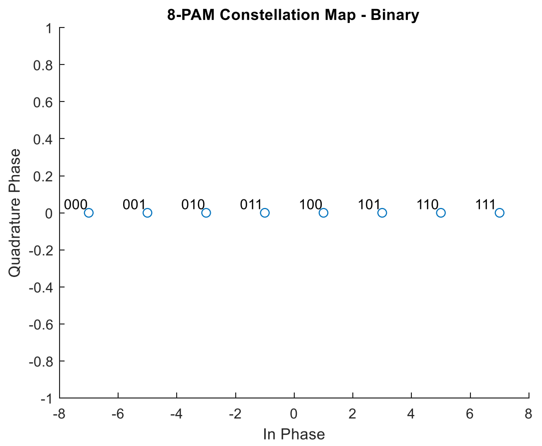
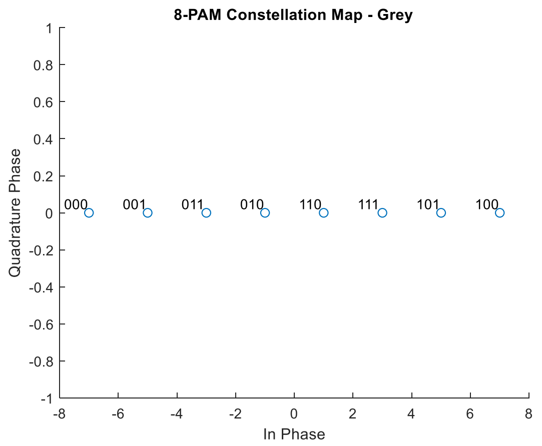
<tr><td>8</td><td>
</td><td>
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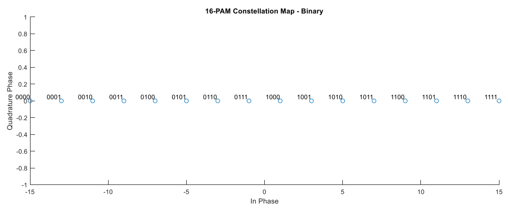
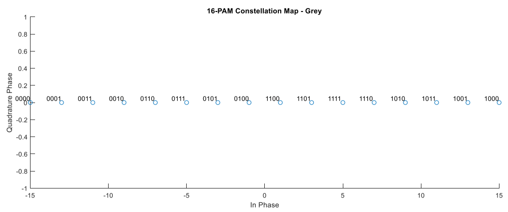
<tr><td>16</td><td>
</td><td>
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PSK:

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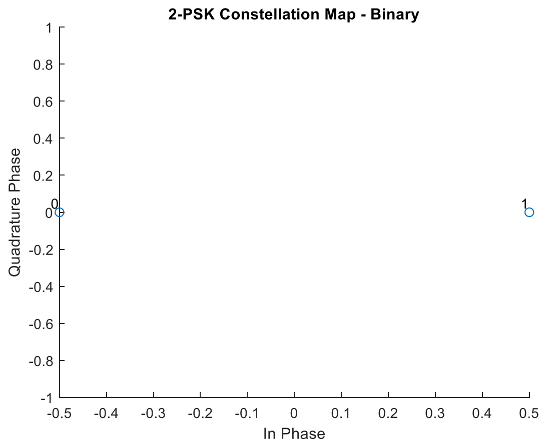
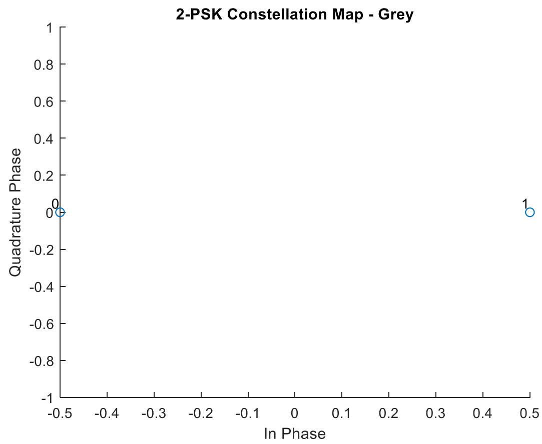
<tr><td>2</td><td>
</td><td>
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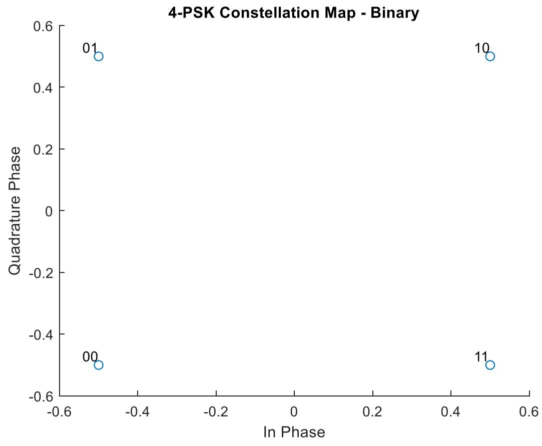
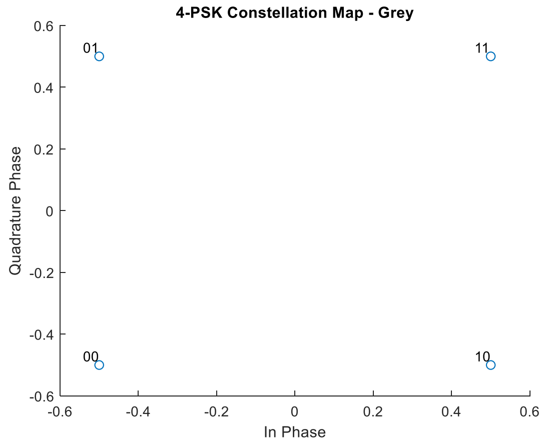
<tr><td>4</td><td>
</td><td>
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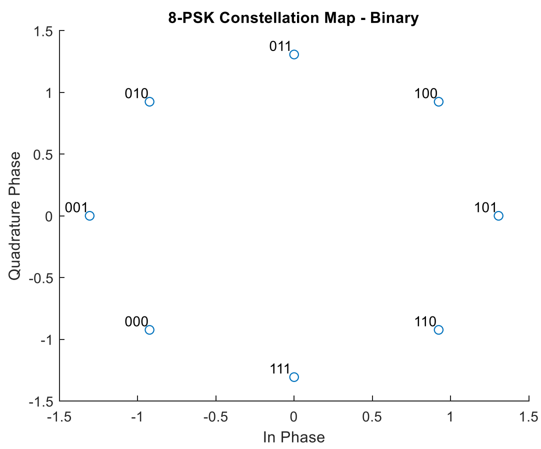
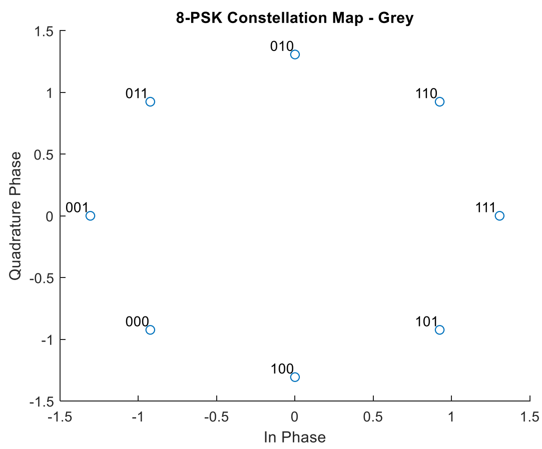
<tr><td>8</td><td>
</td><td>
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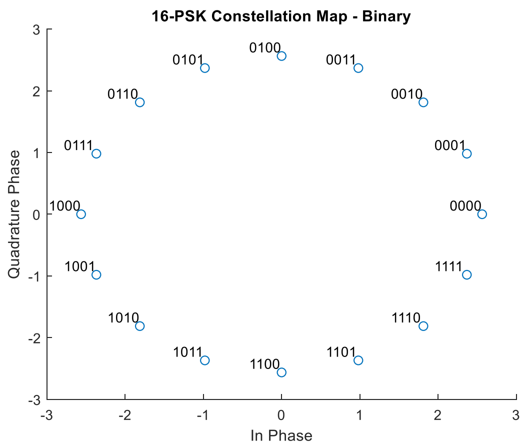
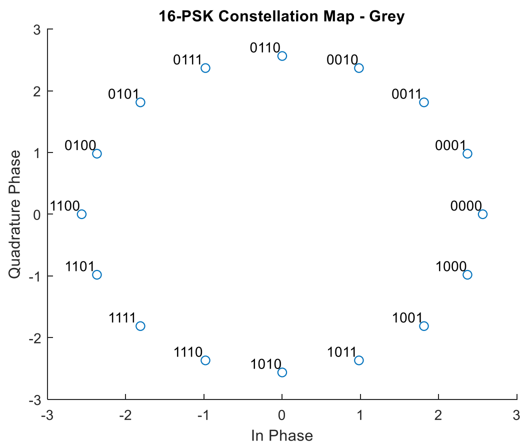
<tr><td>16</td><td>
</td><td>
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QAM:

<table>
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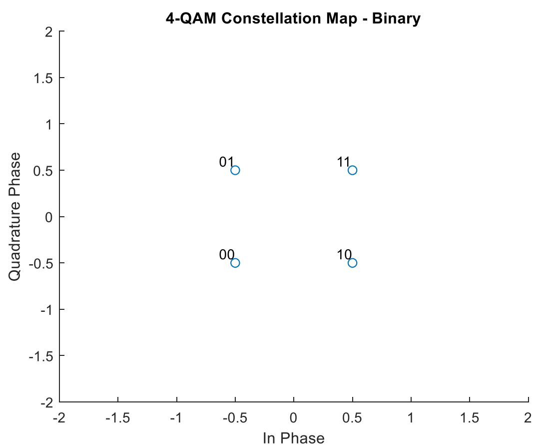
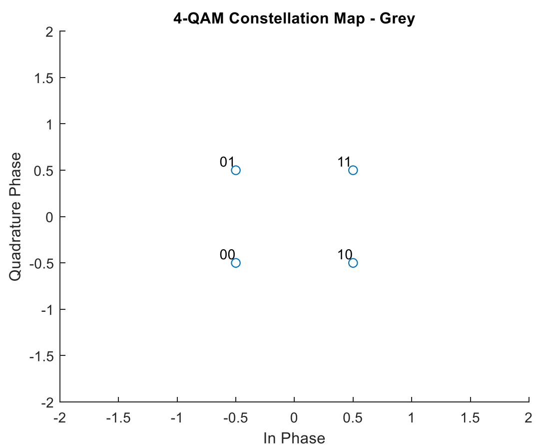
<tr><td>4</td><td>
</td><td>
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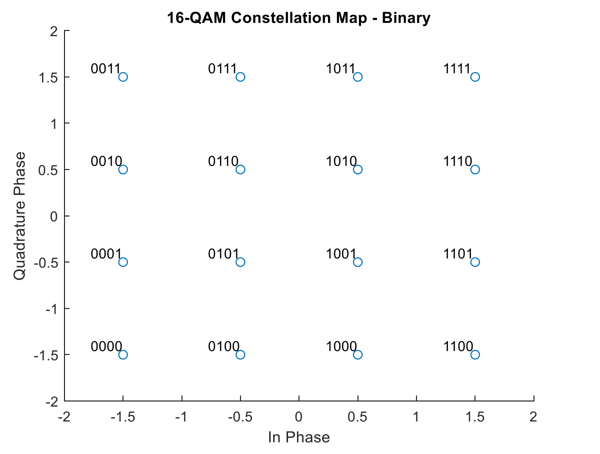
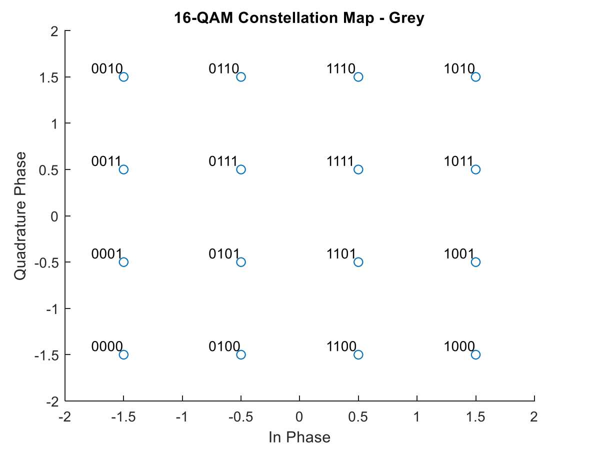
16



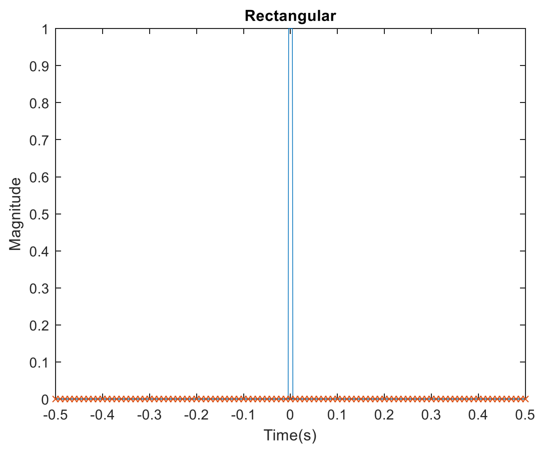


I tried using a non-brutal way to implement the function. However, the complexity of the Grey code map and the lack of consistency between different Ms made the job rather hard. Therefore, I ultimately turned to a brutal approach. After finishing binary coding, the Grey code constellation is mapped by the grey_seq vector to its correspondent binary code and later mapped by the binary constellation to reuse my code.

II. Pulse Shaping:

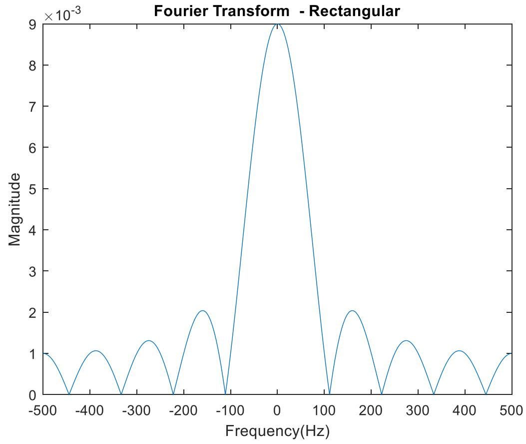
a) Rectangular Function

Time domain:



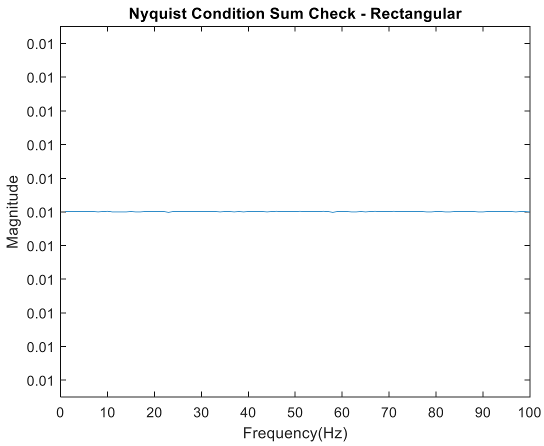
Nyquist condition satisfied without doubt.

Frequency domain:



Nyquist Condition:

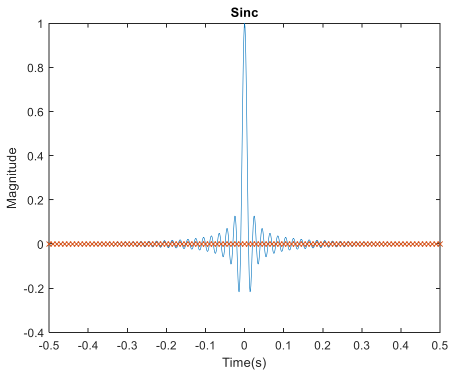
$$\sum G\left(f-\frac{m}{T}\right)=\mathrm{T}$$

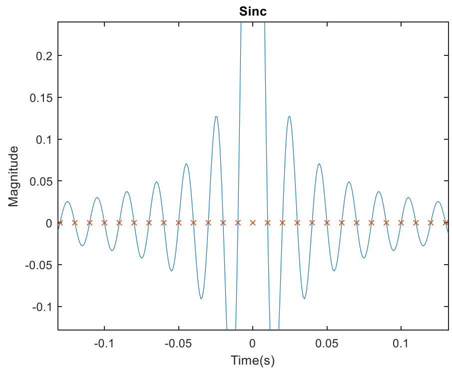


As $\mathrm{T}=\frac{1}{2\mathrm{W}}=0.01$, condition satisfied

b) Sinc

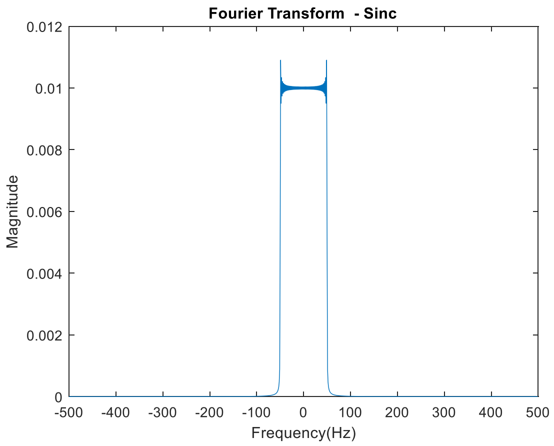
Time domain:



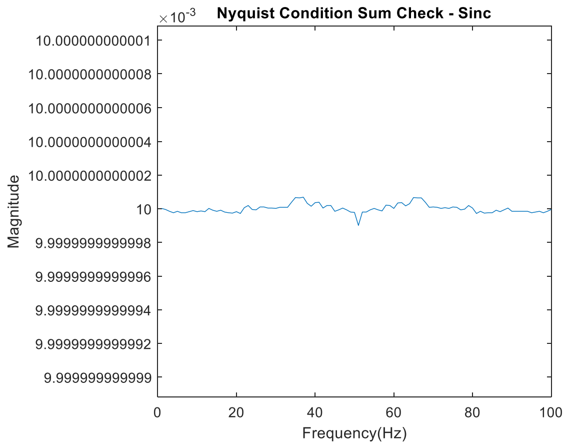


Nyquist condition satisfied as all x's are on x axis.

Frequency domain:

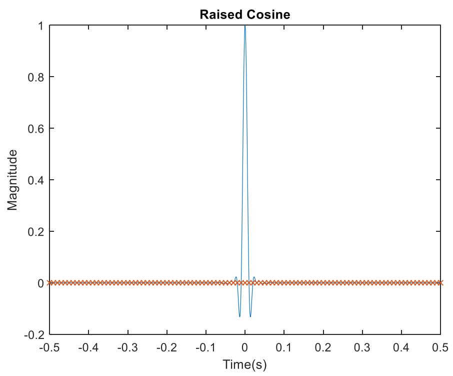


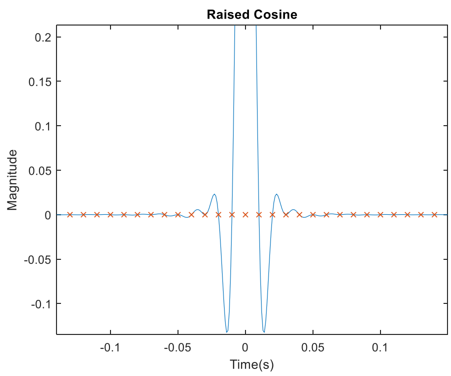
Nyquist condition (frequency):



c) Raised Cosine

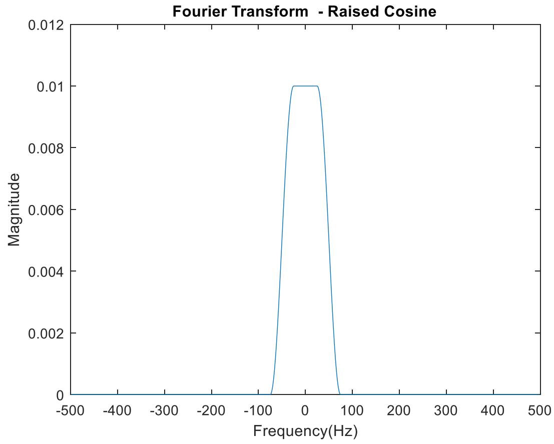
Time domain:



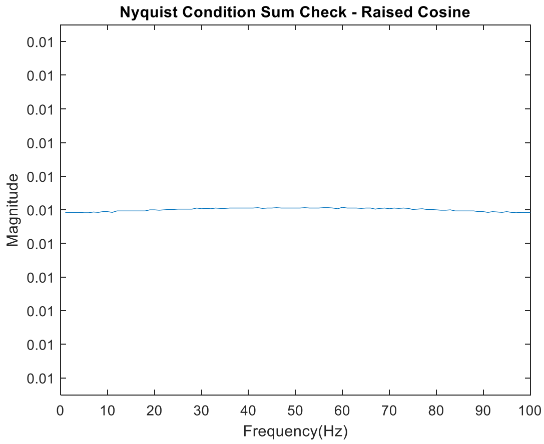


Nyquist condition satisfied as all x’s are on x axis.

Frequency domain:



Nyquist(frequency):



d) Choose Pulse:

I choose raised cosine as it has a smaller bandwidth than rectangular pulse shaping, while using finite time, an advantage over sinc, which needs infinite time to provide finite bandwidth.

e) Pulse Shaping

The problem here is to determine p, using matched filter. We get:

$$\mathrm{g} = \mathrm{p} * \mathrm{q} = \mathrm{p}(\mathrm{t}) * \mathrm{p}^*(-t)$$
$$\mathrm{G} = \mathrm{PP}^* = |P|^2$$

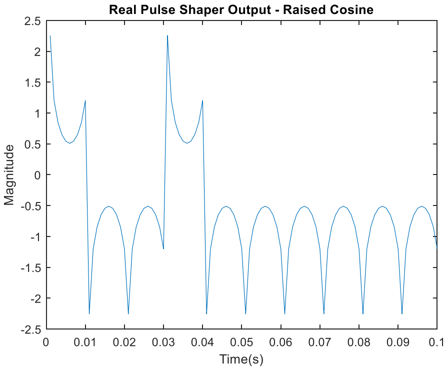
Therefore, we choose $\mathrm{P} = \sqrt{\mathrm{G}}$.

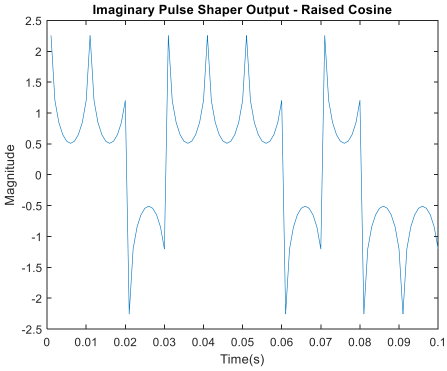
f) Random Sequence:

11 10 00 11 10 10 00 10 00 00

QPSK modulation with raised cosine used.

The output of pulse shaper in plotted below.

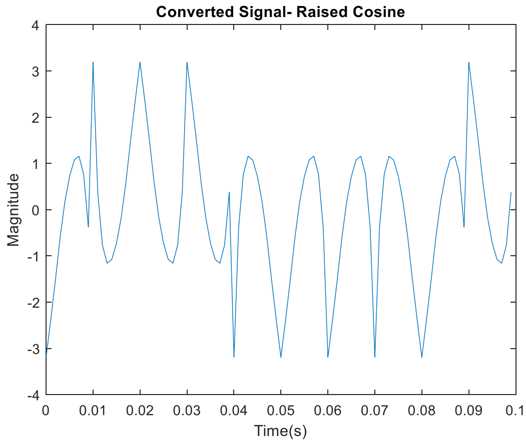




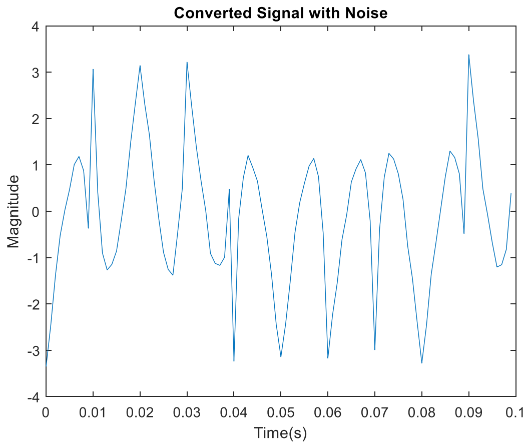
III. Baseband to Passband

a) Bits : 10 11 01 01 00 10 10 00 10 01

QPSK with raised cosine modulation.



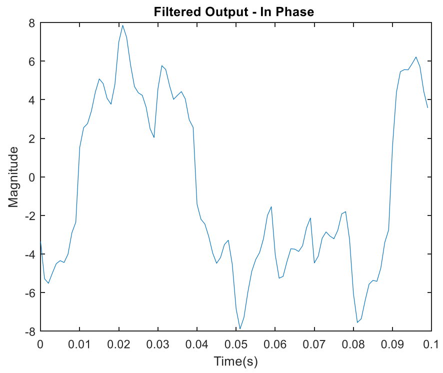
b) AWGN Noise:

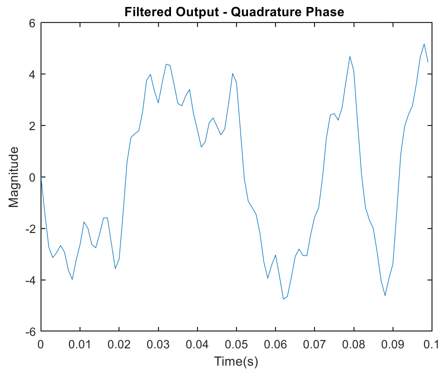


25dB is a rather large SNR, thus impact of noise is minor.

c) Baseband Signal Recovery:

Recovered signal is below, one can accurately recover the original transmitted bits by eye.

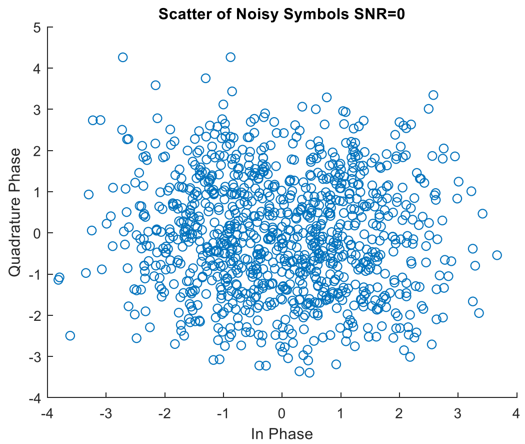


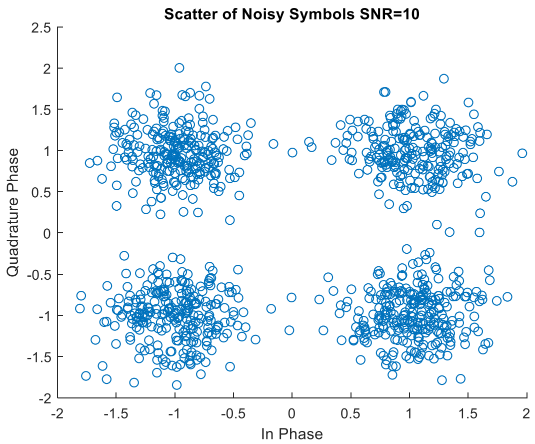


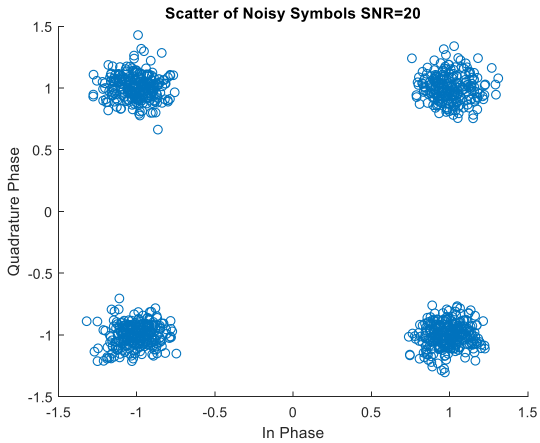
IV. Decision:

a) Noisy Symbols:

QPSK is used.







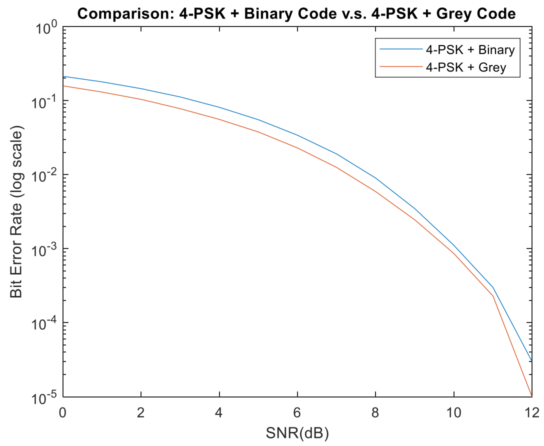
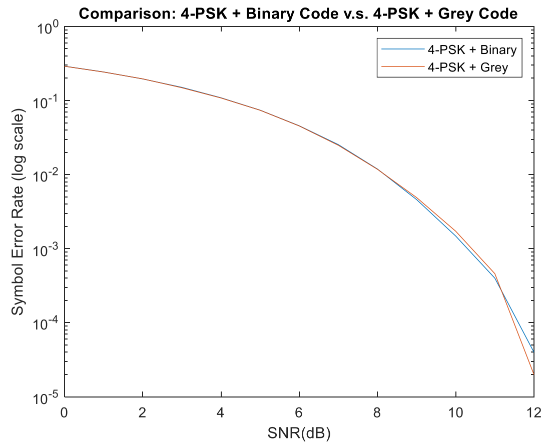
As SNR increased, the symbols converge to its corresponding constellation point, as SNR approaches 20dB, a clean cut to divide the symbols is available.

b) Demapper:

To write the demapper function, I first mapped all possibilities using the function in (I). After that, demapping using MD rule is straighrforward. The test on the 20dB case in (a) results in no errors, validating the correctness of the demapper.

c) Comparison of BERs:

Simulation uses 96000 bits. I calculated the signal power for noise power usage. The constellation map of the symbols is omitted due to the fact that it is similar to (I) and to plot all SNRs is not practical in this report. The instructions asked us to plot 0-25dB, but with high SNR usually resulting in no errors, I plotted the range of SNR with errors only for simplicity. In high SNR cases, the error rates are not as accurate since number of errors are too small.

<table>
<tr><th></th><th>Bit Error Rate</th><th>Symbol Error Rate</th></tr>
<tr><td>1</td><td>
</td><td>
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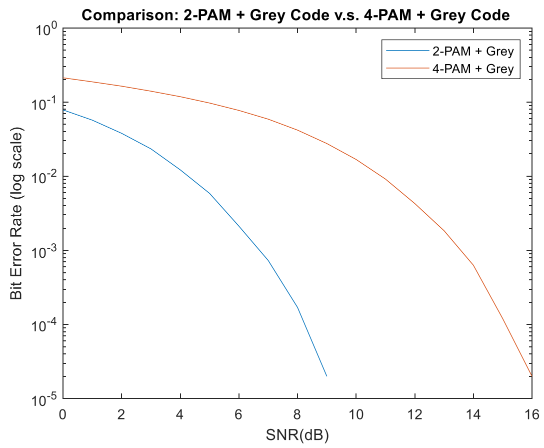
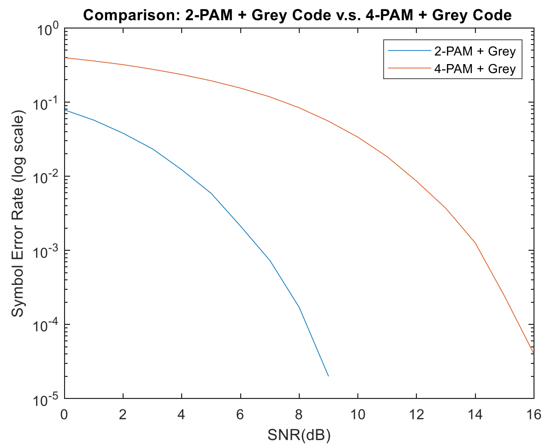
<tr><td>2</td><td>
</td><td>
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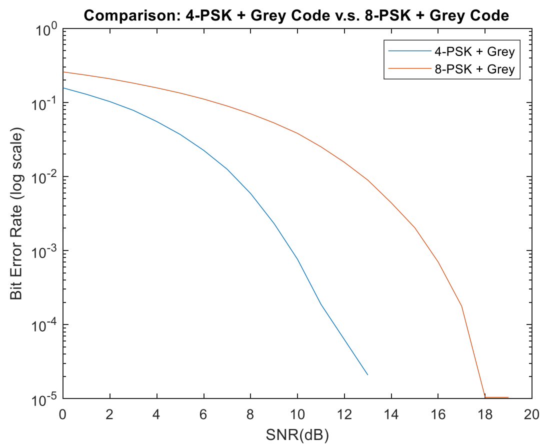
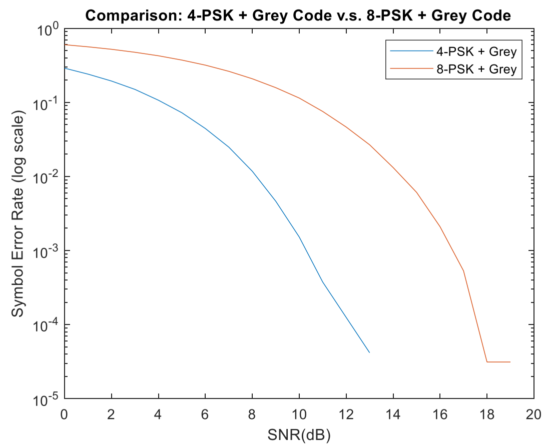
<tr><td>3</td><td>
</td><td>
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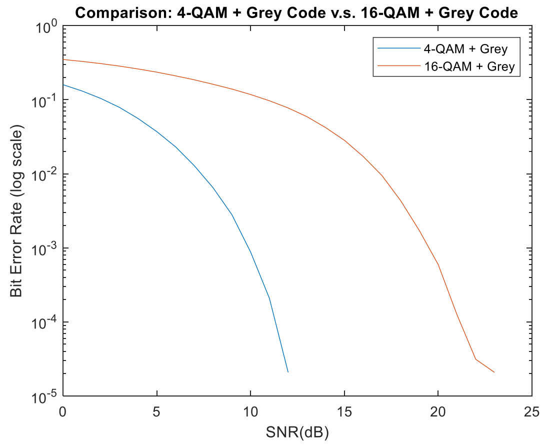
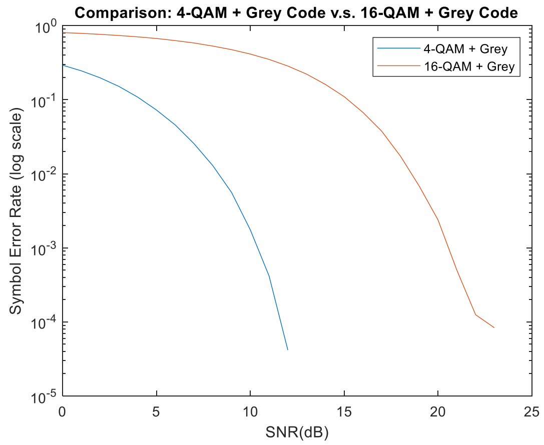
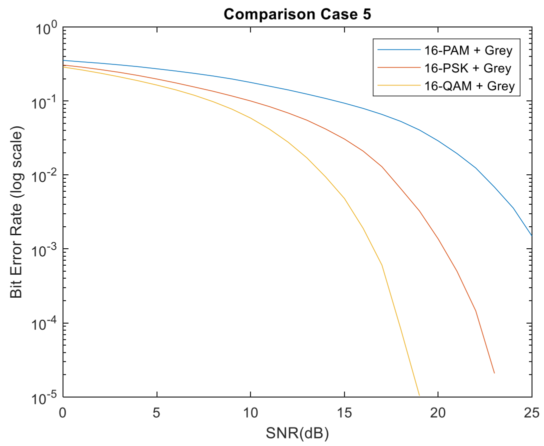
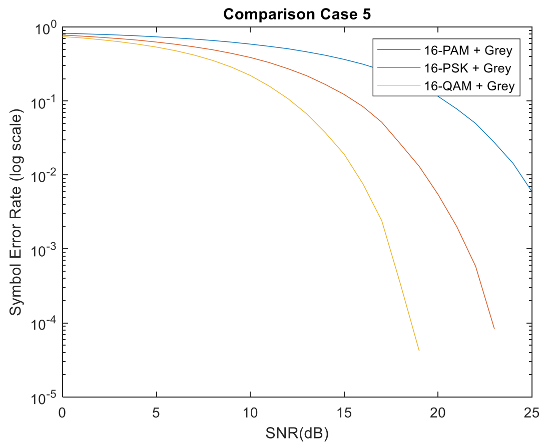
4		
5		

The first case demonstrates the advantage of Grey coding. While both mapping methods result in the same symbol error rate, Grey coding provides a better accurate in terms of bit error rates. The next three cases reveal the impact of choosing different Ms. For each case, the ones with less constellation points perform better, explaining why QPSK is so commonly used in wireless communications.

Case 5 compares the three different constellation methods, as the figures show, QAM performs better than the other two methods when M=16. We can see on the constellation map that QAM makes good use of the space near the origin, therefore saving power, resulting in lower error rates under the same SNRs.

V. Modulation with Handel

Quantization with 4 levels is used in this experiment. After modulation using QPSK, I added noise onto the symbols and demapped them. The SNR values used are 0, 10, and 20dB. 4-bit PCM is used as source coding method because errors in Huffman codes may taint the code and make it impossible to decode.

The change of amount of noise is noticeable. When SNR = 0dB, around 10% of bits are wrong. The signal sounds like plain noise, with the music barely audible. When SNR=10dB, the noise is still very intense, but the tone can be heard easily. The case SNR = 20dB resembles the original quantized signal, with only minor noises.

3. Remarks:

My opinion is that the modulation and pulse shaping part of this experiment is the more enjoyable and informative one, since it helps us to fully understand the concept of pulses, ISI, and the usage of receiving filters, as well as the relations between the units. The coding of other parts contains a lot of repeating stuff, which is quite annoying after days of hard work.