BPSK AND QPSK

SECTION 4 QUESTION 1 (2 points possible)

The low pass filter at the transmitter is used to restrict the spectral content of the transmitted signal so that it is contained within the frequency range allocated to the transmitter. Usually the bandwidth of the low pass filter is chosen so that the frequency content of the transmitted signal fully occupies, but does not exceed the allocated spectrum. How will the eye diagram of a BPSK signal at the receiver change if the bandwidth of the the low pass filter at the transmitter is chosen so that the signal occupies less than its allocated spectrum?

Please select the correct answer.

- (selected) It will remain the same. ✗
- It will become more open.
- It will become more closed. ✓
- Not enough information is given to determine that.

You have used 1 of 1 submissions

SECTION 4 QUESTION 2 (2 points possible)

Which of the following statments are true about QPSK (may be more than one)?

Please select all of the correct options—there may be more than one!

- [ ] The I and Q channel carrier signals are have the same phase.

Modulation

Topic 10: Summary and Review

Final Exam

Final Exam
Final Exam due Dec 07, 2015 at 16:00 UTC

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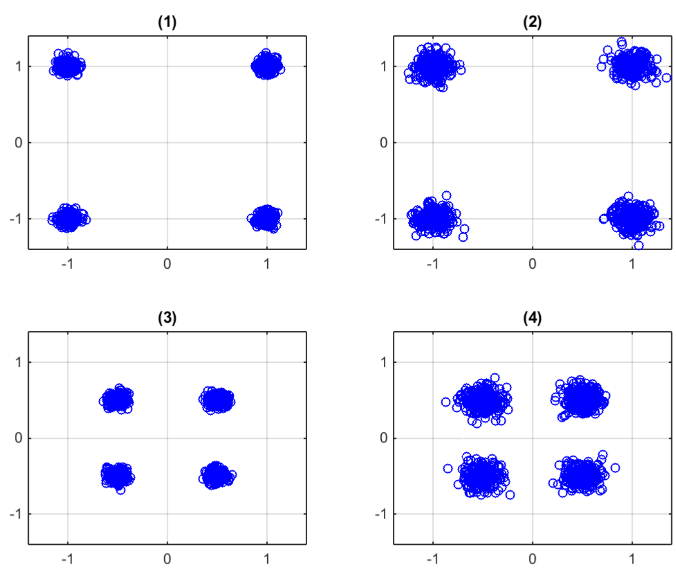
Post Course Survey

- [x] The bandwidth efficiency of QPSK is twice that of BPSK.
- [x] Phase mismatch between transmitter and receiver does not cause problems in the demodulation of a QPSK signal.
- [ ] BPSK and QPSK have the same constellation diagrams, except for a rotation.
- [x] Each constellation point's position indicates the amplitude and the phase of the transmitted waveform.

You have used 1 of 1 submissions

SECTION 4 QUESTION 3 (2/2 points)

Comparing the following four constellation diagrams, which system has the highest bit error rate?



Please select the correct answer.

- ( ) (1)

(2)

(3)

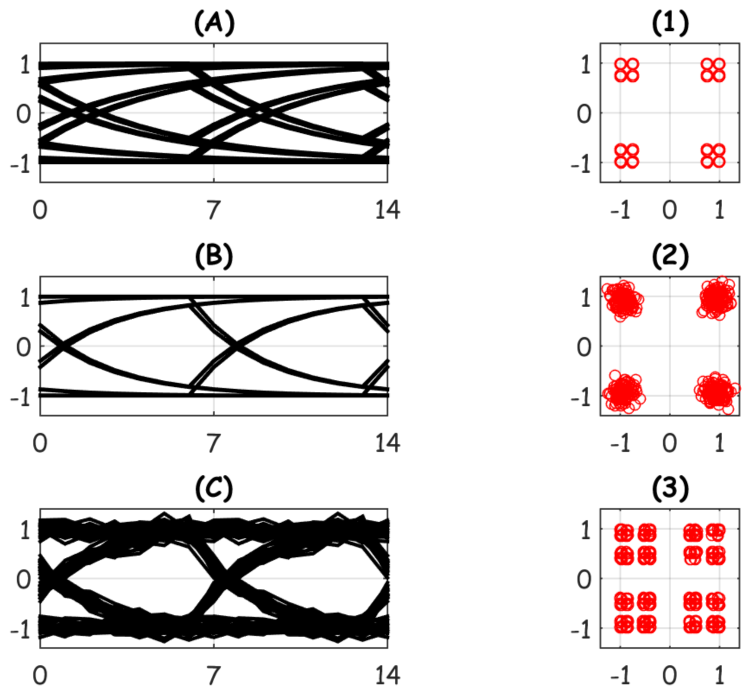
(4) ✔

You have used 1 of 1 submissions

SECTION 4 QUESTION 4 (2/2 points)

The figures on the left below show the eye diagrams at the I channel of the receiver in three different QPSK systems, labelled by A, B and C. Assume that the eye diagrams of the Q channels are similar to those of the I channel. The horizontal axis indicate sample index. The waveforms were transmitted using a bit period of 7 samples per bit.

Assume that bits are decoded by sampling the waveforms at sample index 6 on the eye diagram. The diagrams on the right show the resulting constellation diagrams in random order, but labelled from top to bottom by 1, 2 and 3. Thus, constellation diagram (1) does not necessary correspond to the eye diagram (A). Match the eye diagrams on the left with the correct constellation diagrams on the right.



Eye diagram A matches with constellation diagram

3 ✔ **Answer:** 3

3

Eye diagram B matches with constellation diagram

1 ✔ **Answer:** 1

1

Eye diagram C matches with constellation diagram

2 ✔ **Answer:** 2

2

You have used 1 of 1 submissions

SECTION 4 MATLAB QUESTION (3 points possible)

In this exercise, your job is to implement a 16 Quadrature Amplitude Modulation (**16 QAM**) communication system, which can be thought as an extension of **QPSK**. In the **QPSK** modulation scheme, two carriers with the same frequency but different phases are modulated by two waveforms, where each waveform encodes one bit sequence by holding the amplitude at +1 for one bit period if the input bit is 1 and at -1 for one bit period if the input bit is 0. Thus, at any time, the amplitude of the modulating waveform is chosen from one of two different values (+1 or -1).

In this exercise you will implement **16 QAM**, where each carrier is modulated by a waveform that encodes two bit streams simultaneously by changing the amplitude among four different values (here -3, -1, 1 and 3). Thus, with **16 QAM**, we can send four bits of information at the same time (two on the I channel and two on the Q channel). These four bits can either come from the same bit sequence (e.g. from bits n to n+3) or from four independent bit sequences. In this task, we will consider the latter situation. Since four bits can encode any one of 16 possible values, we call this **16 QAM**.

In the initial MATLAB code shown below, we create and store four text messages in the variable **textmsg{c}** where **c**=1..4. Then, for each text message we create a waveform where each bit is encoded by holding the amplitude at either 0 or 1 for **SPB** samples per bit (see Lab 5 and Part I). Each waveform is stored in the variable **signal(c,:)**, where the first index specified the text message and the second index is the sample index of the waveform.

The initial code then transmits the first and the third message using **QPSK** by creating the waveform **tx_wave** for transmission, and then sending it over the channel using the function **txrx**. The receiver then tries to recover four messages over the channel, assuming they were transmitted using 16 QAM using the function **rx_16_QAM**, which also plots the constellation diagram at the reciever. Initially, this constellation diagram shows four points, since the transmitter used QPSK. The x and y coordinates of the points are at +0.5 and -0.5 since the amplitude of the received signal at baseband is half that of the transmitted signal, although we can correct this by multiplying the amplitude of the carrier used in demodulation by two. Finally, the code compares the transmitted and the received messages. However, in this case, only two of the messages are recovered correctly. The other two are not.

Your task is to modify the current transmitter in order to send the four messages using the **16 QAM** scheme. Basically, the messages 1 and 2 should modulate the amplitude of cosinusoidal carrier in the I channel, while the messages 3 and 4 should modulate the amplitude of sinusoidal carrier in the Q channel.

We describe the process for the I channel in this paragraph. The two waveforms **signal(1,:)** and **signal(2,:)**, which encode text messages 1 and 2, should be combined into a single waveform which has value

- -3 if **signal(1,n)**=0 and **signal(2,n)**=0
- -1 if **signal(1,n)**=0 and **signal(2,n)**=1
- +1 if **signal(1,n)**=1 and **signal(2,n)**=0
- +3 if **signal(1,n)**=1 and **signal(2,n)**=1

for all sample indices n. The modulating waveform should then be low pass filtered with cutoff frequency **Fcutoff** to limit the transmit bandwith, and then used to modulate the cosinusoidal carrier $\cos(2\pi F_c t)$.

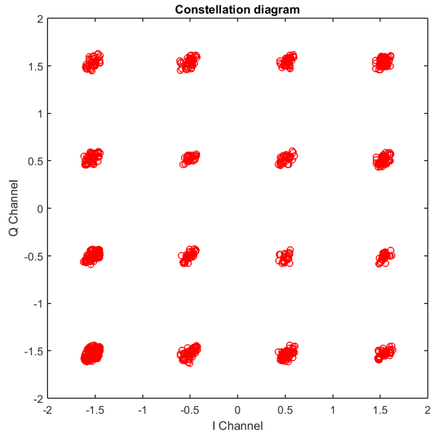
Recall that in BPSK and QPSK, we could create a modulating signal that varied between +1 and -1 by the operation

mod_signal = 2*signal(2,:)-1

You may be able to add something to this expression to find a similar expression that combines **signal(1,:)** and **signal(2,:)** appropriately for 16 QAM. Note that if **signal(1,n)** is constant, then the two values of the modulating waveform differ by 2, whereas if **signal(2,n)** is constant, the two values of the modulating waveform differ by 4.

The same process holds for the Q channel, except that we use **signal(3,:)** and **signal(4,:)** and modulate the sinusoidal carrier $\sin(2\pi F_c t)$. The waveforms for the I and Q channels should then be combined and stored in the variable **tx_wave**, much in the same way as in QPSK. You should be able to base your code off of what was used for the QPSK communication system, just changing the modulating signal appropriately. You are free to use any of the functions used in the previous labs.

If you implement the **16 QAM** modulation scheme correctly, the four messages will be recovered correctly and the constellation diagram will show 16 points distributed on a rectangular lattice, as shown below. Each of the 16 points corresponds to a different combination of four bits (two on each channel, I and Q).



Modify the code between the lines

% % % % Revise the following code % % % %

and

% % % % Do not change the code below % % % %

Please, do not change other parts of the code.

```
%% code
% initalization
Fs=1e6;                 %sampling frequency
Fc=100e3;               %carrier frequency for messages
Fcutoff = 50e3;         %cutoff frequency of low pass filter
SPB=30;                 % samples per bit
Ts=1/Fs;                % sample period

NMSG = 4; % number of messages

textmsg = cell(NMSG,1);
% read the text file (1 byte for each character)
textmsg{1} = sprintf('%s\n%s\n%s',...
    'It was the best of times, it was the worst of times.',...
    'It was the age of wisdom, it was the age of foolishness.',.
    'It was the epoch of belief.');
```

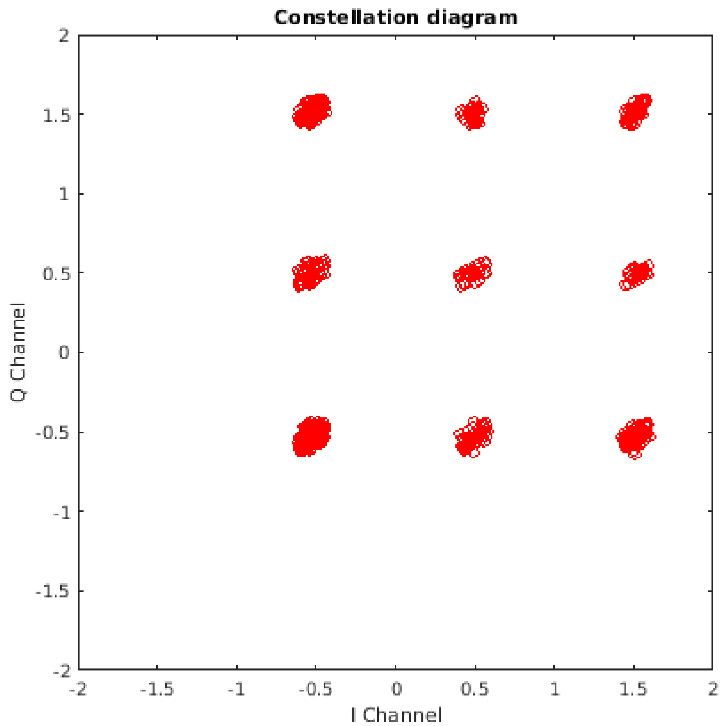
Unanswered

```
% create vector of sample times
% create channel I
Ich = 2*(2*signal(1,:) - 1) + (2*signal(2,:) - 1);
Ich = lowpass(Ich, Fs, Fcutoff);
Ich = Ich.*cos(2*pi*Fc*t);

% create channel Q
Qch = 2*(2*signal(3,:) - 1) + (2*signal(4,:) - 1);
Qch = lowpass(Qch, Fs, Fcutoff);
Qch = Qch.*sin(2*pi*Fc*t);


tx_wave = Ich + Qch;
```

Figure 1



Original Message 1 :
It was the best of times, it was the worst of times.
It was the age of wisdom, it was the age of foolishness.
It was the epoch of belief.
Recovered Message 1 :
It was the season of Light, it was the season of Darkness.
It was the spring of hope, it was the winter of despair.
It was the epoch of incredulity.
Number of Bit Errors: 117

Original Message 2 :

It was the season of Light, it was the season of Darkness.
It was the spring of hope, it was the winter of despair.
It was the epoch of incredulity.
Recovered Message 2 :
It was the best of times, it was the worst of times.
It was the age of wisdom, it was the age of foolishness.
It was the epoch of belief.
Number of Bit Errors: 128

Original Message 3 :
We barely remember who or what came before this precious moment
We are choosing to be here right now
Hold on, stay inside... (Tool, Parabola)
Recovered Message 3 :
Bosco Cappuccio, Ha un declivio verde, Come una dolce, Poltrona
Appisolarmi la, Solo, In un caffe remoto, Con una luce fievole,
Come questa, Di questa luna.
Number of Bit Errors: 130

Original Message 4 :
Bosco Cappuccio, Ha un declivio verde, Come una dolce, Poltrona
Appisolarmi la, Solo, In un caffe remoto, Con una luce fievole,
Come questa, Di questa luna.
Recovered Message 4 :
We barely remember who or what came before this precious moment
We are choosing to be here right now
Hold on, stay inside... (Tool, Parabola)
Number of Bit Errors: 145

Run Code

You have used 0 of 5 submissions