ELEC96008 COMMUNICATION SYSTEMS COURSEWORK

DS-QPSK SYSTEMS

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Abstract

This assignment is related to designing and analysing the performance of a Quadrature Phase Shift Keying(QPSK) Digital Communication System under ideal and non-ideal conditions, such as presence of noise and jammer interference. The system is then extended to a Direct Sequence(DS) QPSK Spread Spectrum (SS) System, whose performance is examined under both noise and jammer interference.

Task 1

The input message signal is transmitted through a noiseless channel. After being converted to 8-bit ANSI sequences, the message signal array is converted into a symbols array, which will be demodulated in the receiver. The angles of each of the reference symbols s_1(00), s_2(01), s_3(11) and s_4(10) are used as the decision boundaries. The code below checks between which two symbols the argument of the incoming symbols array is. It then compares the difference between this argument with the angle of symbols s_i and s_{i+1} respectively and maps it to the closest of the two symbols. If the transmitted symbol angle is greater than the angle of s_4, the symbol is mapped to s_4 and if it is smaller than the argument of s_1, the symbol is interpreted as s_1.

```
%demodulation
dm=[];
for ind=1:length(angles)
    if(ref_angles(1)<=angles(ind))&&(angles(ind)<=ref_angles(2))
        if(abs(angles(ind)-ref_angles(1))<= abs(ref_angles(2)-angles(ind)))
            dm=[dm 0,0];
        else
            dm=[dm 0,1];
        end
    elseif (ref_angles(2)<=angles(ind))&&(angles(ind)<=ref_angles(3))
        if(abs(angles(ind)-ref_angles(2))<= abs(ref_angles(3)-angles(ind)))
            dm=[dm 0,1];
        else
            dm=[dm 1,1];
        end
    elseif (ref_angles(3)<=angles(ind))&&(angles(ind)<=ref_angles(4))
        if(abs(angles(ind)-ref_angles(3))<= abs(ref_angles(4)-angles(ind)))
            dm=[dm 1,1];
        else
            dm=[dm 1,0];
        end
    elseif(angles(ind)>ref_angles(4))
        dm=[dm 1,0];
    else
        dm=[dm 0,0];
    end
end
```

Figure 1. Demodulation decision rule code

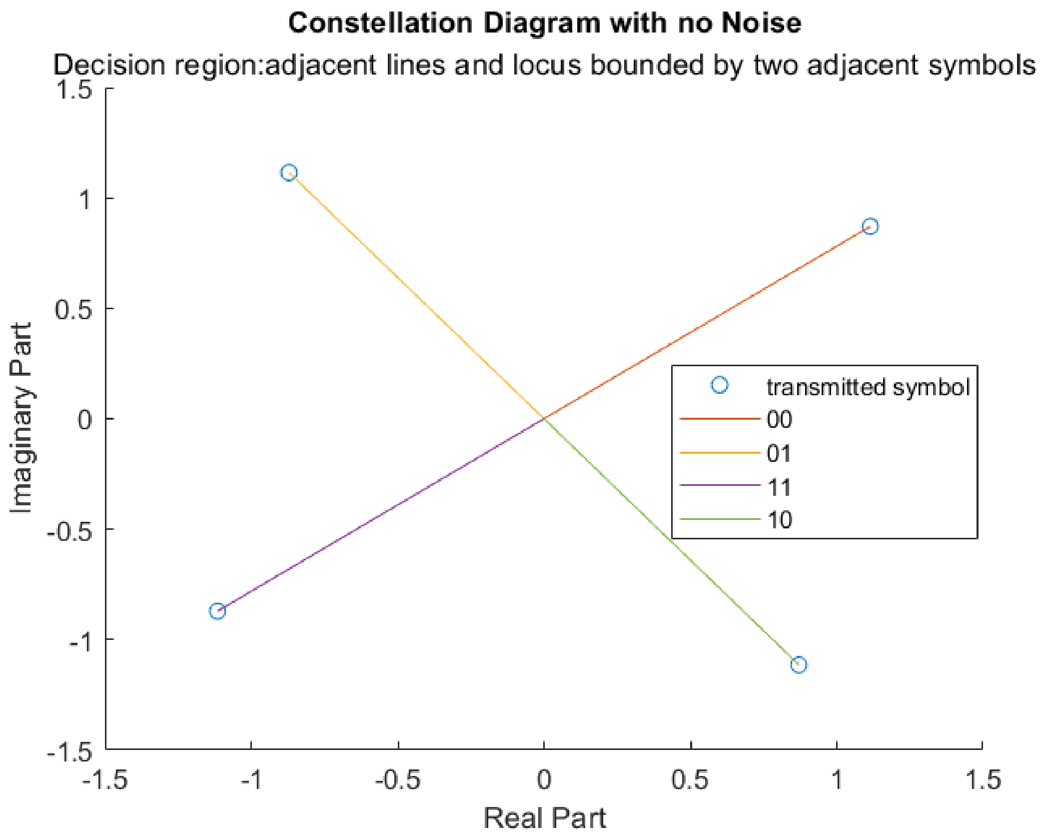

Figure 2. Plot of constellation diagram with decision regions – noiseless case

<u>Tasks 2,3</u>

The transmitted signal is corrupted by additive white complex Gaussian noise with a Signal to Noise ratio (SNR) of 30dB and 20 dB for tasks 2 and 3 respectively. The complex noise has been constructed using the randn() MATLAB function, which generates samples of a standard normal distribution [1]. It is then added to the transmitted signal and demodulated using the same decision rule as in task 1.

Given that the SNR in task 3 is smaller than in task 2, there will be a larger deviation in the complex symbols array from the reference symbols s_1(00), s_2(01), s_3(11) and s_4(10), in task 3. The constellation diagrams for tasks 2 and 3 are found below.

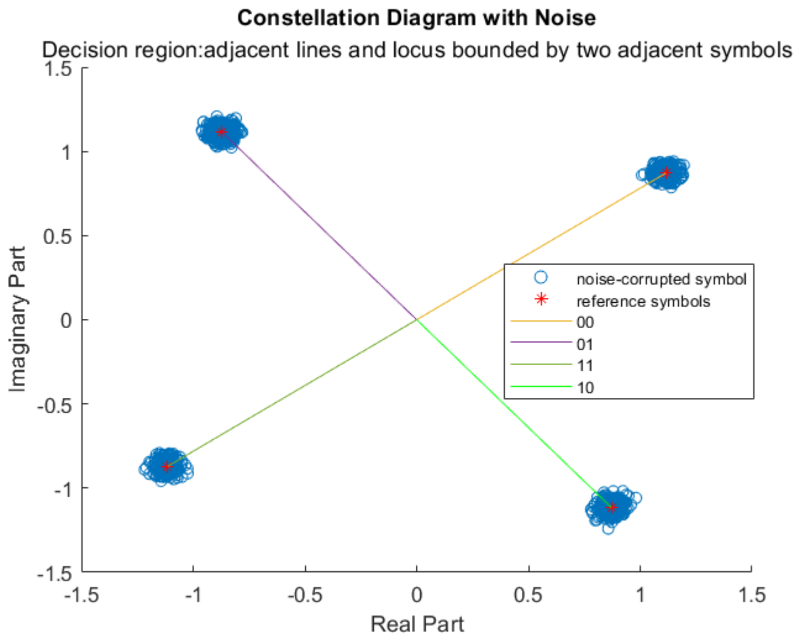

Figure 3. Plot of constellation diagram with decision regions – noisy case (30 dB SNR)

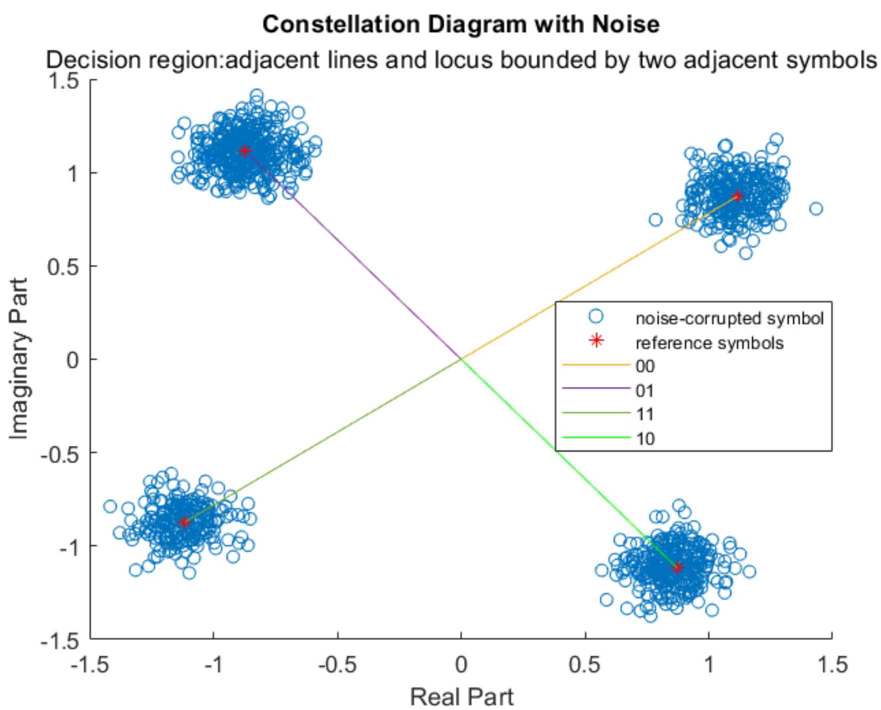

Figure 4. Plot of constellation diagram with decision regions – noisy case (20 dB SNR)

Task 4

A 0 dB SNR indicates that signal and noise power are equal. This suggests that the effect of noise on the message signal will be more prevalent compared to its effect in tasks 2 and 3, as seen in the following constellation diagram. Both the theoretical and experimental BER values increase significantly in this case.

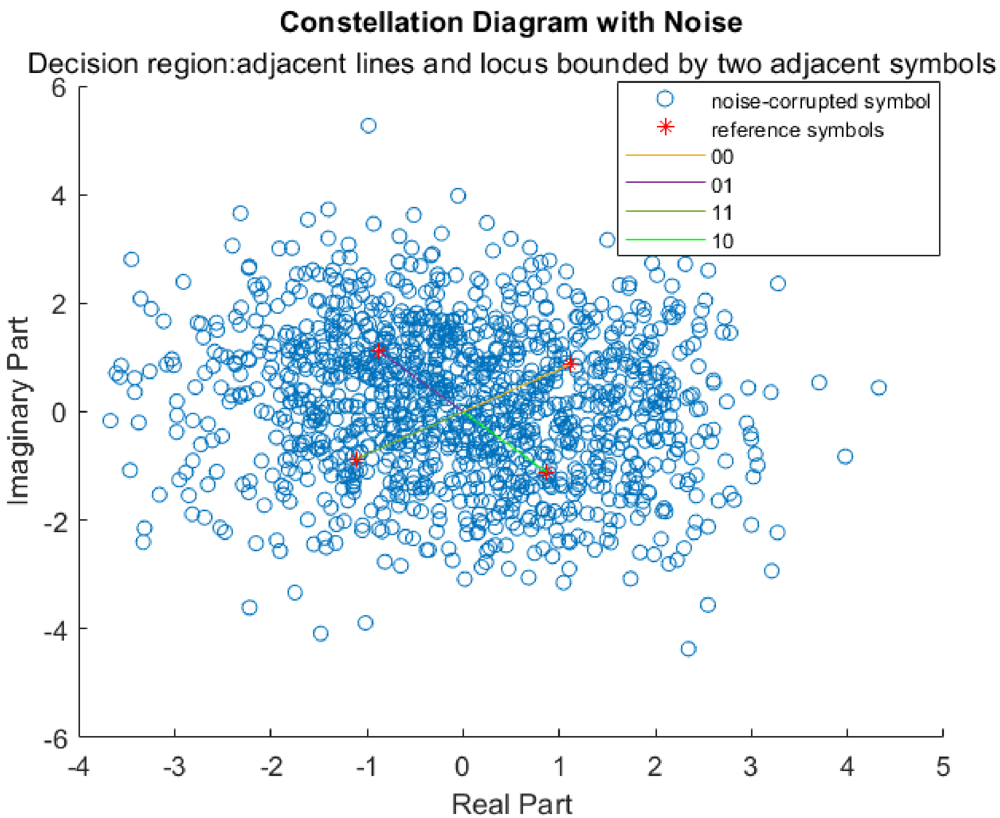

Figure 5. Plot of constellation diagram with decision regions – noisy case (0 dB SNR)

Task 5

The results regarding the number of bits in error, the BER and the theoretical BER values are summarised in Table 1. A QPSK system consists of two Binary Phase Shift Keying systems (BPSK) operating independently simultaneously[2]. One is responsible for modulating the in-phase signal component and the other for the quadrature part[2]. The resultant QPSK signal is obtained by adding the two components[3]. The system's performance in the presence of additive white Gaussian noise is identical to that of a BPSK system, whose theoretical bit error probability is given by the expression $\text{p\_error} = T(\sqrt{2 * EUE})$. The equation can be rewritten using the following facts:

- $r_b = 2 * r_{cs}$, where r_b denotes the bit rate and r_{cs} the channel symbol rate
- $B = r_{cs}$ given that the noise is bandpass at the receiver input

$$\text{p\_error} = T(\sqrt{2*EUE}) = T(\sqrt{2*BUE*SNR}) = T\left(\sqrt{2*\frac{r_{cs}}{2*r_{cs}}*SNR}\right) = T(\sqrt{SNR})$$

SNR(dB)	SNR (absolute value)	Theoretical BER	Experimental BER	Number of bits in error
30	1,000	8.9792×10^{-220}	0	0
20	100	7.6199×10^{-24}	0	0
0	1	0.1587	0.1592	382

Table 1. Summary table for theoretical BER, experimental BER and number of bits in error for message signal transmission in the presence of additive white Gaussian noise.

Task 6

The message signal is now transmitted in the presence of both noise and jammer interference. The power of the jammer (P_j) has been defined as 10dB greater than the message signal power(P_s), which has been calculated to be equal to 2. Through this relation, the amplitude of the jammer symbols ($\sqrt{Ej}$) on the constellation diagram can be derived:

$$10*\log(Pj)=10*\log(Ps)+10*\log(10) \Rightarrow Pj=10*Ps \Rightarrow Ej=10*Es=20 \Rightarrow \sqrt{Ej}=\sqrt{20}$$

The sequence at the receiver input is the sum of the message signal, the jammer signal and the complex noise. The BER of this system is approximately 0.33. The high BER is attributed to the strength of the jammer message. Consequently, the recovered message is identical to the jammer message. As it can be observed in the constellation plot below, the complex symbols sequence is arranged into clusters that occupy every quadrant of the complex plane.

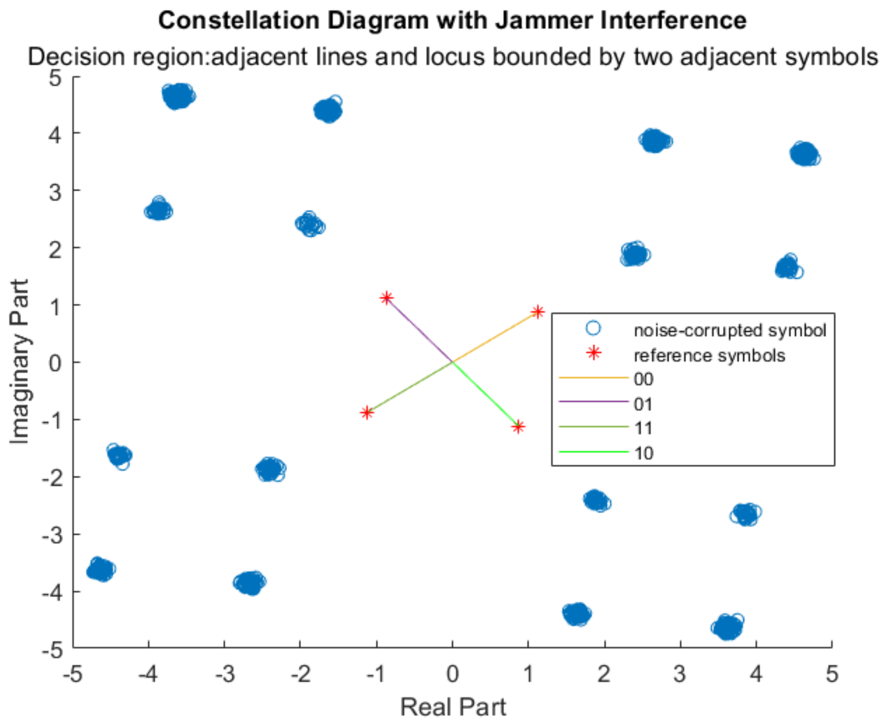

Figure 6 . Constellation diagram for task 6 (30 dB SNR with jammer)

Task 7

The conventional QPSK system is replaced by a SS QPSK system. The complex message symbols and jammer symbols arrays are extended such that each of their samples can be multiplied by the message signal and jammer signal PN codes respectively. This process occurs in the spreader block of the SS diagram depicted in figure 7 [4]. Following the addition of channel noise, the inverse process is implemented in the despreader block [4]. The output of the despreader block is obtained by averaging every 31 samples of the channel output array, which is the sum of the PN modulated message, jammer and noise signals , and 31 being the primitive polynomial period. By using a significantly higher channel bandwidth than conventional systems, the bit error probability is minimised. In this task, the number of bits in error and the BER are both 0, which suggests that the jammer no longer affects the system's performance.

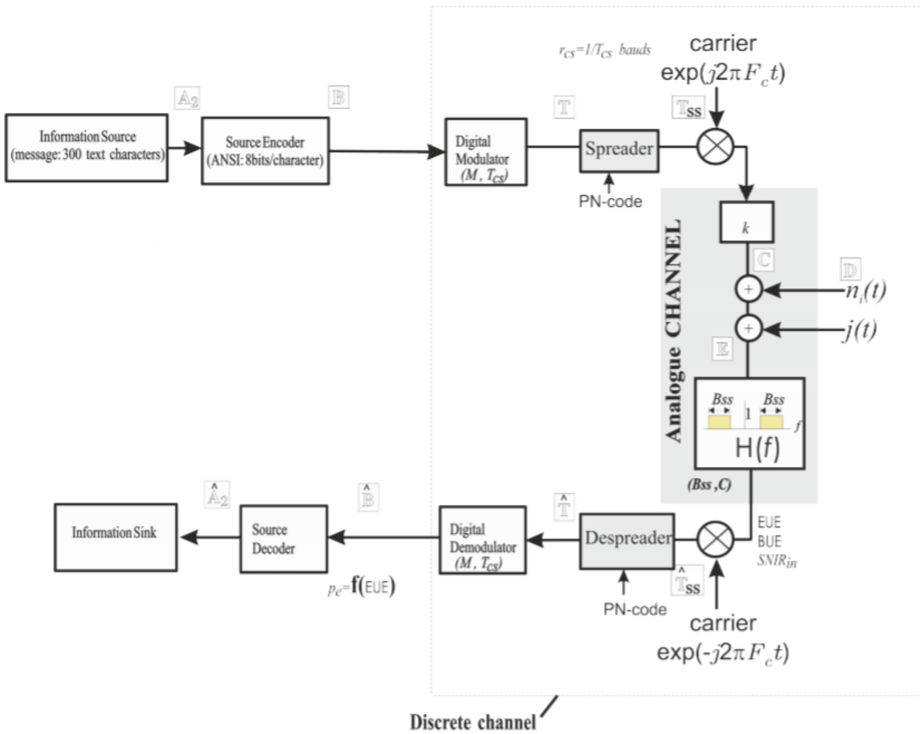

Figure 7. Block diagram of Spread Spectrum QPSK system [4]

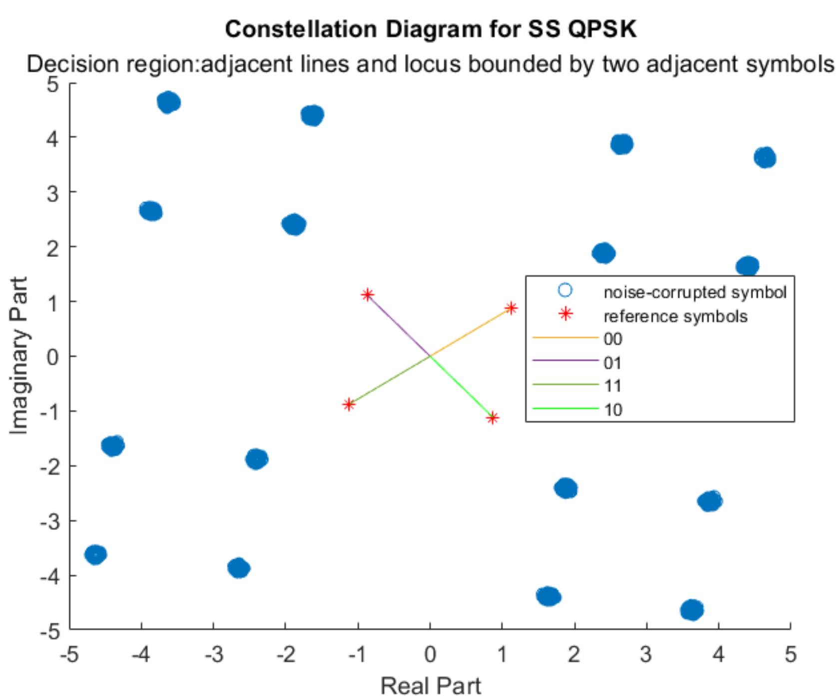

Figure 8. Constellation diagram of Spread Spectrum QPSK system

References

[1]"Normally distributed random numbers - MATLAB randn." uk.mathworks.com. https://uk.mathworks.com/help/matlab/ref/randn.html (accessed 20 Dec. 2020).

[2]"GPSK Modulino Definition." maximintegrated.com. https://www.maximintegrated.com/en/design/technical-documents/tutorials/6/686.html (accessed 02 Jan 2021).

[3]M. Viswanathan, "QPSK modulation & demodulation (MATLAB and Python)." gaussianwves.com. https://www.gaussianwaves.com/2010/10/qpsk-modulation-and-demodulation-2/ (accessed 05 Jan. 2021).

[4]A. Manikas. (2020). QPSK DS Spread Spectrum Comm. System [5].Available: https://skynet.ee.ic.ac.uk/notes/CS_CW_2012_13_18_2019.pdf