DS/QPSK Spread Spectrum Systems

EE303 Communication Systems Coursework

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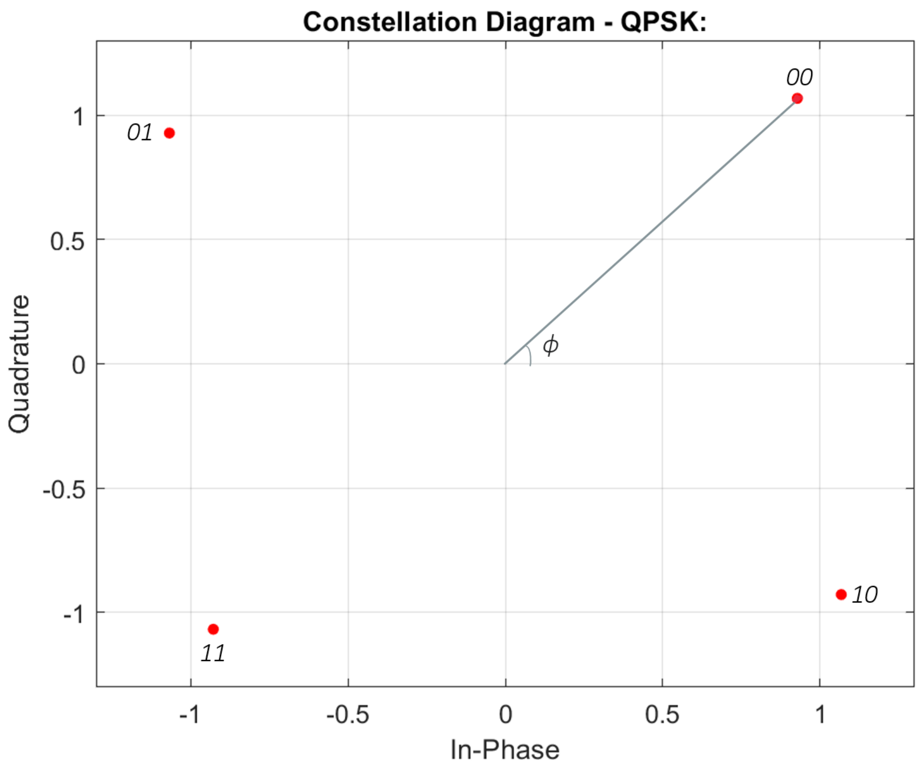
Introduction

The main objective of this assignment was to design and analyse the performance of a QPSK Digital Communication System in the presence of noise in Tasks 1-5, then with the additional presence of a jammer in Task 6. This was then extended to a Direct Sequence QPSK Spread Spectrum Communication System to understand how the effects of a jammer are mitigated in Task 7.

The ZIP file provided should contain three mlx files (matlab live scripts), the "message" and "jammer" text files, along with this pdf.

Code written in mlx format, and so step by step process displayed clearly within the code. Code should also work for messages of any length.

Tasks 1-5



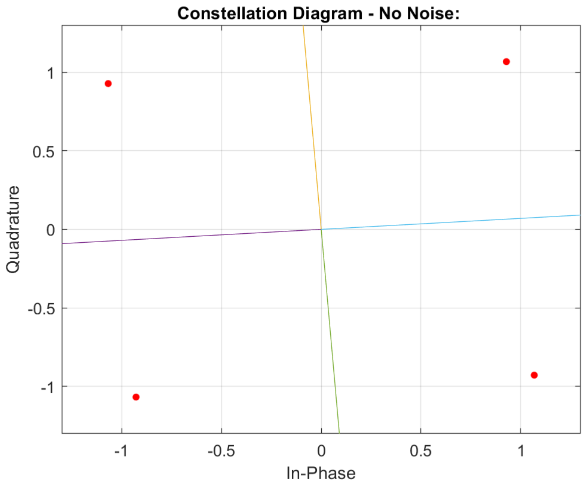
$$\phi = K * 2S = 11 + 2 * 19 = 49 \text{ degrees.}$$

Figure above shows the constellation diagram of the transmitted signal using QPSK, with ϕ being calculated using my own initials and the formula shown above.

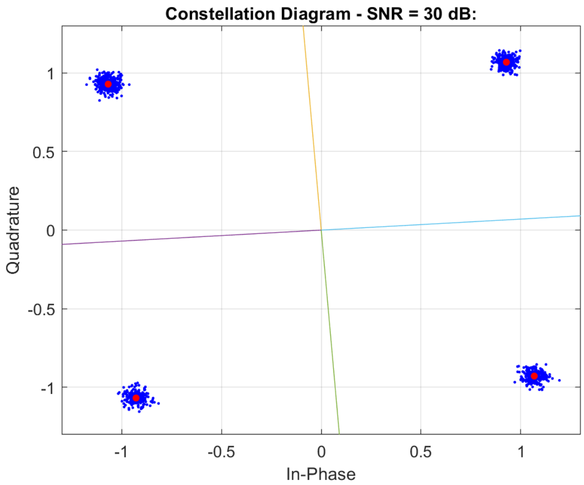
Decision Boundaries

The received signal is mapped to the transmitted signal from which it has the smallest euclidean distance (on the constellation diagram). The loci formed by the four points (aka the decision boundaries) have been plotted on the constellation diagrams below. Each boundary line is perpendicular to its adjacent boundary lines, and is exactly 45 degrees from the respective signal points. Anything within the quadrant formed by two boundary lines is mapped to its respective symbol. For example, points in the quadrant formed by the blue and yellow lines are mapped to $s_1(t)$).

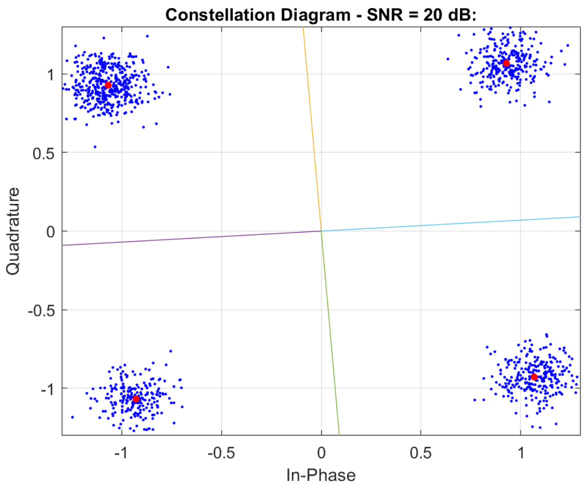
Obtained Results



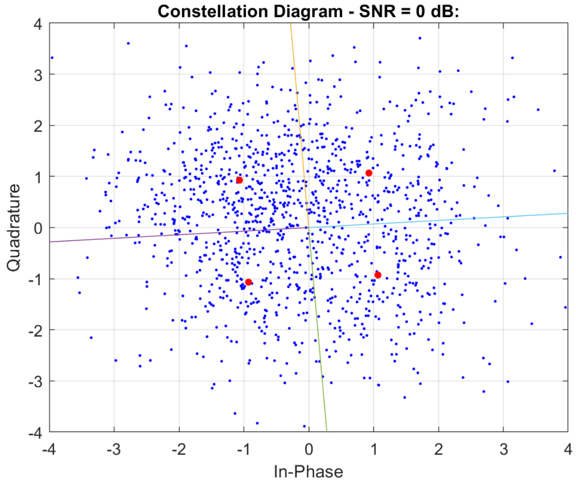
Case 1 : No noise
Total number of its in error: 0
Obtained BER: 0



Case 2 : SNR = 30dB
Total number of its in error: 0
Obtained BER: 0



Case 3 : SNR = 20dB
Total number of its in error: 0
Obtained BER: 0



Case 4 : SNR = 0dB
Total number of its in error: 385
Obtained BER: 0.160 (to 3 s.f.)

Theoretical BER

Theoretical BER for QPSK is the same as for BPSK, given by the following expression:

$$p_e = T\left(\sqrt{2\frac{E_b}{N_0}}\right)$$

This can be expressed in terms of the SNR like so:

$$p_e = T\left(\sqrt{2\frac{E_b}{N_0}}\right) = T\left(\sqrt{\frac{E_{cs}}{N_0}}\right) = T\left(\sqrt{\frac{E_{cs}B}{P_n}}\right) = T\left(\sqrt{\frac{E_{cs}r_{cs}}{P_n}}\right) = T\left(\sqrt{\frac{P_s}{P_n}}\right) = T\left(\sqrt{SNR}\right)$$

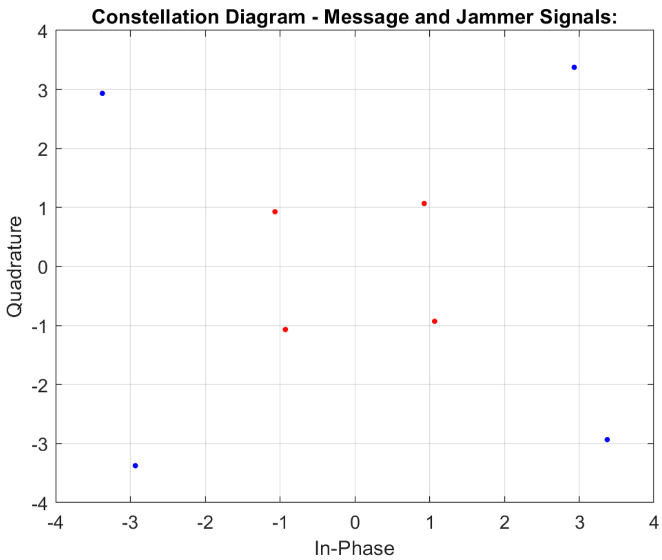
SNR(dB)	Total Bits In Error	Obtained BER	Theoretical BER
30	0	0	$T(\sqrt{1000}) = 8.9792 \times 10^{-220} \approx 0$
20	0	0	$T(\sqrt{100}) = 7.6199 \times 10^{-24} \approx 0$
0	385	0.16	$T(\sqrt{1}) = 0.1587$

n.b. it can be noted that the number of bits in error will vary slightly every time the program is run. This is due to the random generation of noise. More specifically, the variance of the discrete values of noise generated is not exactly equal to Pn.

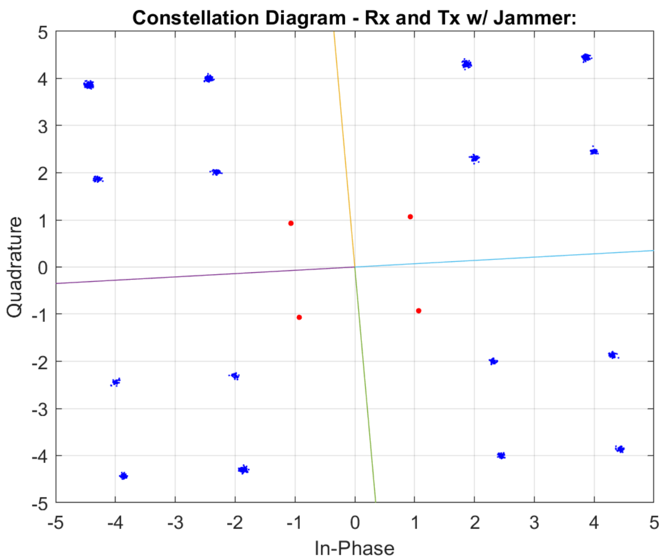
Task 6

This task introduces the presence of a jammer to our system which has its own message. It is noted in the specification that the jammer signal received is 10dB greater than that of the message signal and hence an SJR of -10dB. The jammer message is modulated in the same manner as the message signal. To meet the SJR, we modulate the jammer signal with an energy ten times greater in order to satisfy this, we make $E_{cs} = 20$.

The constellation diagram with both the jammer and the message are shown below (message in red and jammer in blue):



The constellation diagram for the received signal is shown below (red denoting Tx and blue denoting Rx):



It is noted that the received signal is demodulated to exactly the jammer message (The 'jammer bit error rate' is zero). This is expected, given that the jammer signal is modulated identically, whilst being considerably more powerful.

Task 7

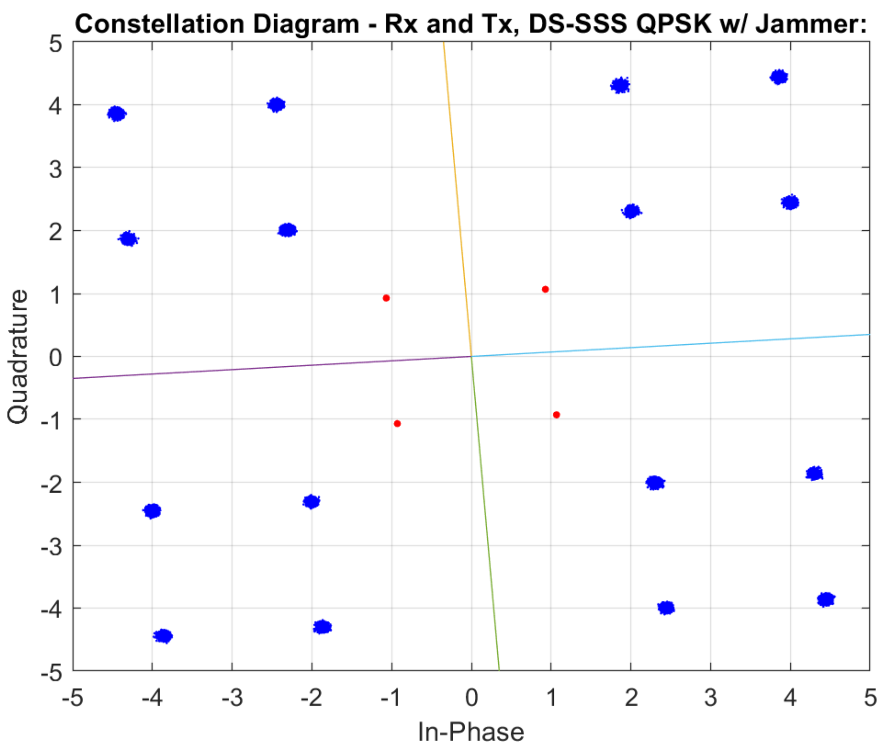
For this task, we mitigate the effects of the jammer displayed in the task 6 by employing the Spread Spectrum System. This meant the addition of a 'spreader' and 'despreader' block (as specified in the specification)

Value of K was determined with the following restraint:

$$K \geq (K + S) \mod 31 = (19 + 11) \mod 31 = 30$$

For the message signal, K = 31 was used (equivalent of k = 0), and for jammer signal K = 30 was used.

The constellation diagram for the received signal is shown below:



The SSS is incredibly effective, with the BER = 0. The modulation scheme is also very effective at reducing the impact of the noise, with the BER equal to 0 when the SNR = 0dB. Sacrificing the BUE has resulted in the a system that is considerably more robust to both noise and a jammer.