Part-2 Coursework EE303: Communication Systems "DS/QPSK Spread Spectrum Systems"

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Aims

The main objective of this assignment-study is to design and analyse the performance of a QPSK Digital Communication System which is then extended to a Direct-Sequence QPSK Spread Spectrum Communication System operating in the presence of a Jammer.

Bit pairs of the messages are mapped according to a QPSK coding, mapping bit pairs to:

$$s(t) = \sqrt{2}\exp(2\pi F_c t + \frac{\pi}{2}(i-1) + \phi)$$

Where i = 1, 2, 3 and 4, and ϕ = (22 + (2 x 18)) = 58º

As ϕ = (alphabetical order of the 1st letter of your surname) + 2*(alphabetical order of the 1st letter of your formal first name) = "V" + 2*"R" = 22 + 2*18.

Task 1

System involves a QPSK modulator/demodulator, with absence of both noise and jammer:

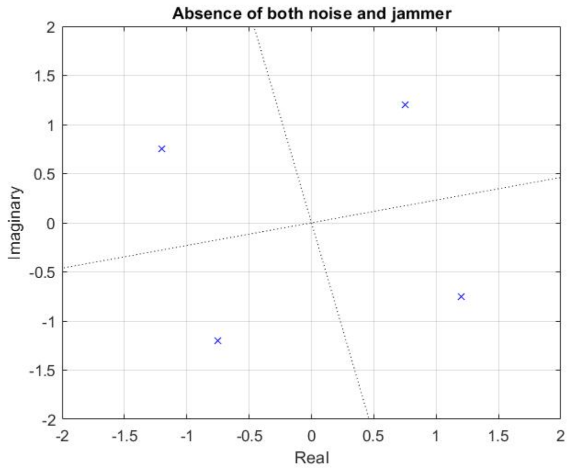


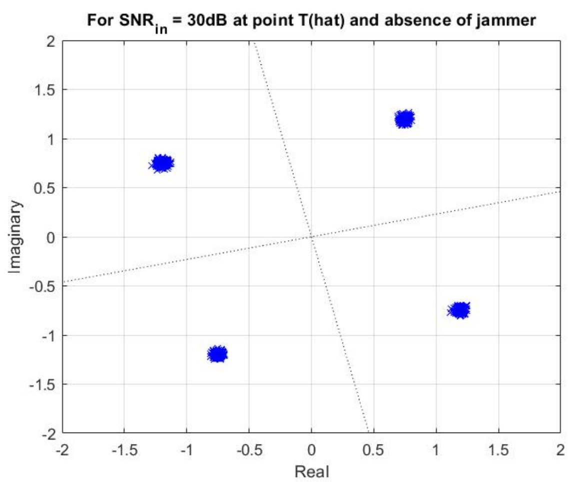
Figure 1 - Received symbols for absence of noise and jammer

It can be seen from the figure how the demodulation is done without any perturbation, which makes sense as no noise or jammer are interfering.

Hence, demodulation gives zero error as bits can be recovered perfectly.

Task 2

System involves a QPSK modulator/demodulator, for SNR_{in} = 30dB at point $\hat{T}$ and absence of jammer:



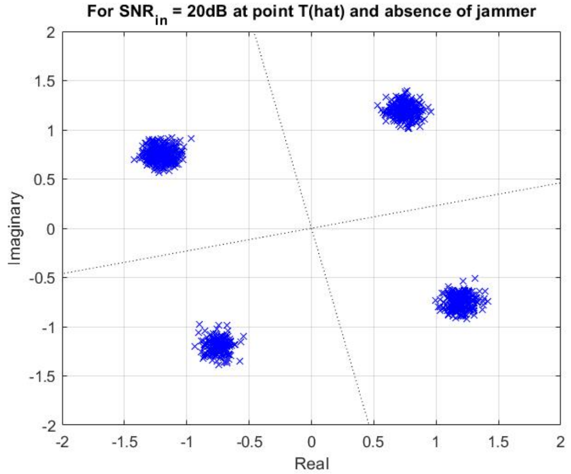
From the figure it can be seen how the symbols are now received with a little perturbation from the added noise. However as the SNR_{in} is high the symbols are still far from the decision lines for demodulation.

As a result perfect demodulation can be achieved giving zero bit error rate.

Figure 2 - Received symbols for SNR_{in} = 30 dB and absence of jammer

Task 3

System involves a QPSK modulator/demodulator, for SNR_{in} = 20dB at point $\hat{T}$ and absence of jammer:

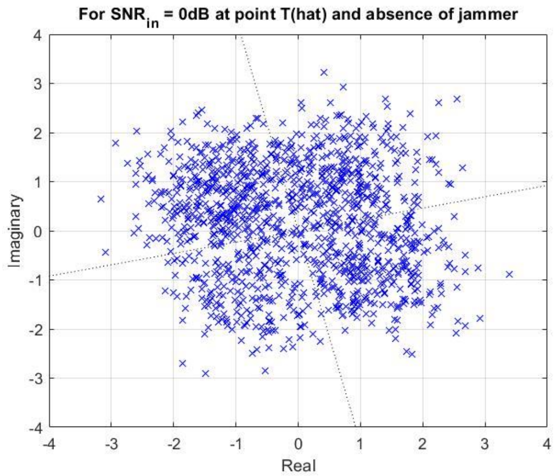


As it can be seen from the figure lower SNR_{in} increases the perturbation of the received symbols. However they are still far away from the decision thresholds and hence gives zero error and perfect demodulation.

Figure 3 - Received symbols for SNR_{in} = 20 dB and absence of jammer

Task 4

System involves a QPSK modulator/demodulator, for SNR_{in} = 0dB at point $\hat{T}$ and absence of jammer:



When the SNR_{in} is set to 0 dB results change. The perturbation due to noise is significant and hence correct demodulation is not possible for all symbols.

For this system BER ≈ 0 08.

Figure 4 - Received symbols for SNR_{in} = 0 dB and absence of jammer

Task 5

Total number of bits in error, Bit Error Rate and Theoretical BER for Tasks 2-4:

Values taken as average of 3 results:

	Number of bits in error	Calculated BER	Theoretical BER
Task 2 (SNR = 30 dB)	0	0	0
Task 3 (SNR = 20 dB)	0	0	1.0442×10^{-45}
Task 4 (SNR = 0 dB)	186	0.07737	0.0786

Table 1 - Calculated vs Theoretical BER for Tasks 2-4

Theoretical BER is calculated using the equation:

$$p_e = T\{\sqrt{SNIR_{out}}\} = T\left\{\sqrt{2EUE_{equ}}\right\} \; (for\ perfectly\ synchronized\ system)$$

However $SNR_{in} = \frac{EUE_{equ}}{BUE}$ $, where\ BUE = 1,\ giving\ EUE_{equ} = SNR_{in}$

Hence giving:

$$p_e = T\{\sqrt{2SNR_{in}}\}$$

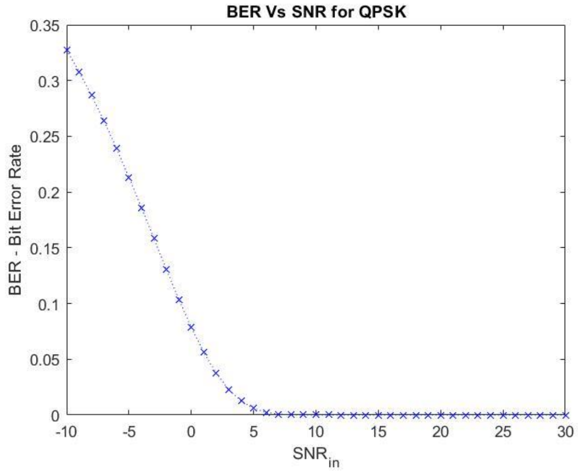


Figure 5 – Plot of BER for range of SNR_{in}

From the results it can be seen that the system matches the theory with increasing BER for decreasing SNR_{in}. The figure shows the theoretical relation between BER and SNR_{in} for QPSK modulation.

Task 6

System involves a QPSK modulator/demodulator, for SNR_{in} = 30dB at point $\hat{T}$ and presence of jammer with a power 10dB above the desired signal power:

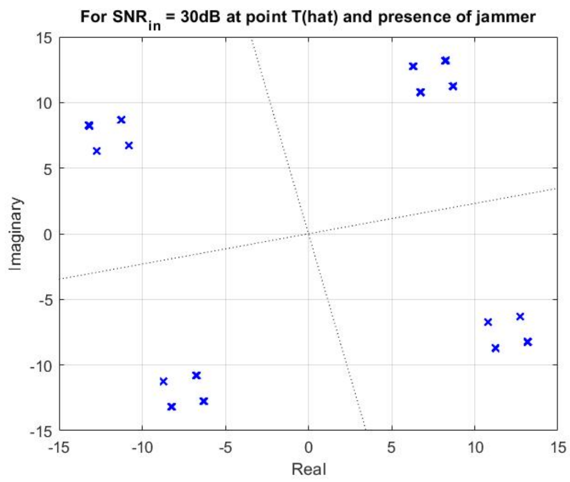


Figure 6 - Received symbols for SNR_{in} = 30 dB and presence of jammer

The figure clearly shows how the jammer corrupts the signal completely and what is demodulated is the jammer message hence giving incorrect communication. The jammer shifts the message signal to its own symbols and hence the jammer symbols are the ones being demodulated. The error for this system is BER = 0.3221 but doesn't correspond to the error of the message as the actual message is not being demodulated and it just indicates the similarity between the jammer message and the actual message.

Task 7

System involves a DS/QPSK Spread Spectrum modulator/demodulator for SNR_{in} = 30dB at point $\hat{T}$ and presence of jammer with a power 10dB above the desired signal power.

The desired PN-code and the PN-code employed by the jammer are gold sequences generated using two m-sequences with primitive polynomials shown below:

	1st Polynomial (m-sequence)	2nd Polynomial (m-sequence)
Desired:	$D^5 + D^2 + 1$	$D^5 + D^3 + D^2 + D + 1$
Jammer:	$D^5 + D^3 + 1$	$D^5 + D^4 + D^2 + D + 1$

Table 2 - Polynomials for m-sequence generation

And k (shift between sequences) satisfies:

$$k \geq (alphabetical\ order\ of\ the\ 1st\ letter\ of\ your\ surname + alphabetical\ order\ of\ the\ 1st\ letter\ of\ your\ formal\ first\ name) mod 31 =$$
("V" + "R")mod31 = (22 + 18 = 40)mod31 = 9

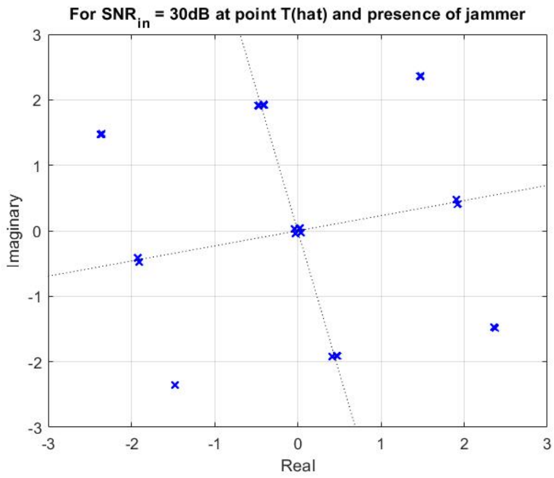


Figure 7 - Received symbols for SNR$_{in}$ = 30 dB and presence of jammer in a Spread Spectrum system

When using a Spread Spectrum system the message is correctly demodulated due to the presence of the PN code acting as a “password”. Even though the jammer has a much higher power than the message and hence would make demodulation impossible the use of the PN code allows for the message to be encoded and decoded independently of the jammer.

This results in a reception like the one shown in the figure where even though the jammer perturbs the signal considerably it still can’t manage to corrupt the signal. For this particular case the system is very close to error with some reception occurring very close to the actual threshold.

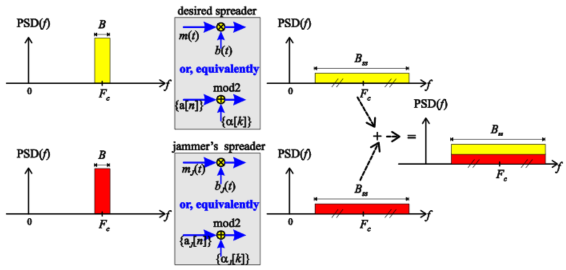


Figure 8 – Composition of transmitted signal from message and jammer

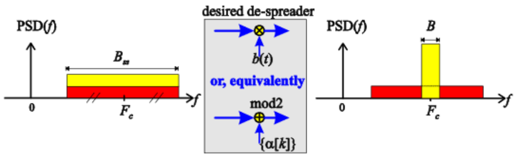


Figure 9 – De-spreading of received signal to recover original message

The above diagrams show how the modulation and demodulation work and how with a sufficiently high SNR the received signal after the de-spreader has a higher PSD than the jammer.