EE3-03 – Communication Systems – Coursework
DS-SSS-QPSK

In this document, we will 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.

With reference to Figure-1 a message of 300 characters is applied at point A2 of a Digital Communication System (this is the "desired" message).

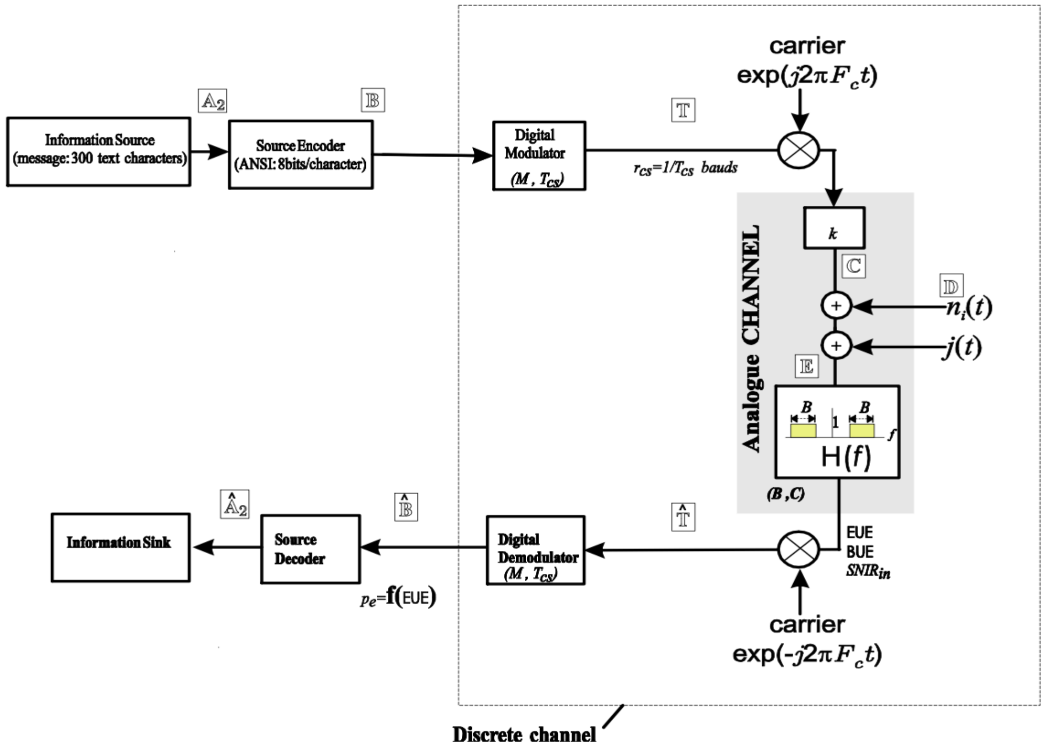

Figure 1 - A Conventional Digital Communication System Operating in the Presence of a Jammer

The text file containing the message is “**message.txt**”:
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The transmitted signal is corrupted by additive white Gaussian noise and a jamming signal, which also consists of a 300-character text file “**jammer.txt**”:
4eKwQNUfNC7InAnbiUpHPwFxcjdPrAzQRkPlvMLYLiq05Dica623TifThHGLumgpLxOGMpy00hN9MqDfvhjo4XSLKFzWFrMPUkt78zSWyATOb2riMMoC5BfVrbEM3xNLQ4U6F6qzXyrL8wwyW2w9NQvUdXnuDnXilifJoRPa9tIBo6c7oABM8QcGk9Vmx5NcMubmJg5Jnxsee1dv9QYZLVVmFxt3wROxznnMM9Jm7yB35DeFAo0wXGjbeRooWhEx3ocVyEsttn5Z5GTvslilL0X3G9qQnN6cwd59mhuile7.

The system involves a **QPSK modulator** with its constellation diagram shown in **Figure-2**. We therefore expect four channel symbols travelling through the channel.

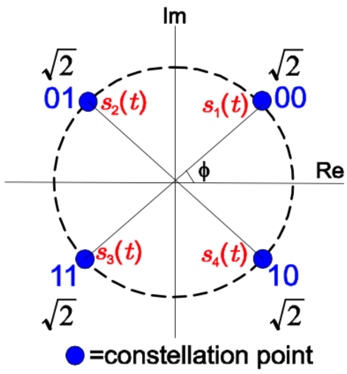


Figure 2 - QPSK Constellation Diagram

The angle ϕ is chosen to be 18°.

For each of the following tasks, we will get the message at point $\hat{A}_2$ (see Figure-1) and plot on the constellation diagram the receiver's decision variables.

Task 1: Absence of both noise and jammer

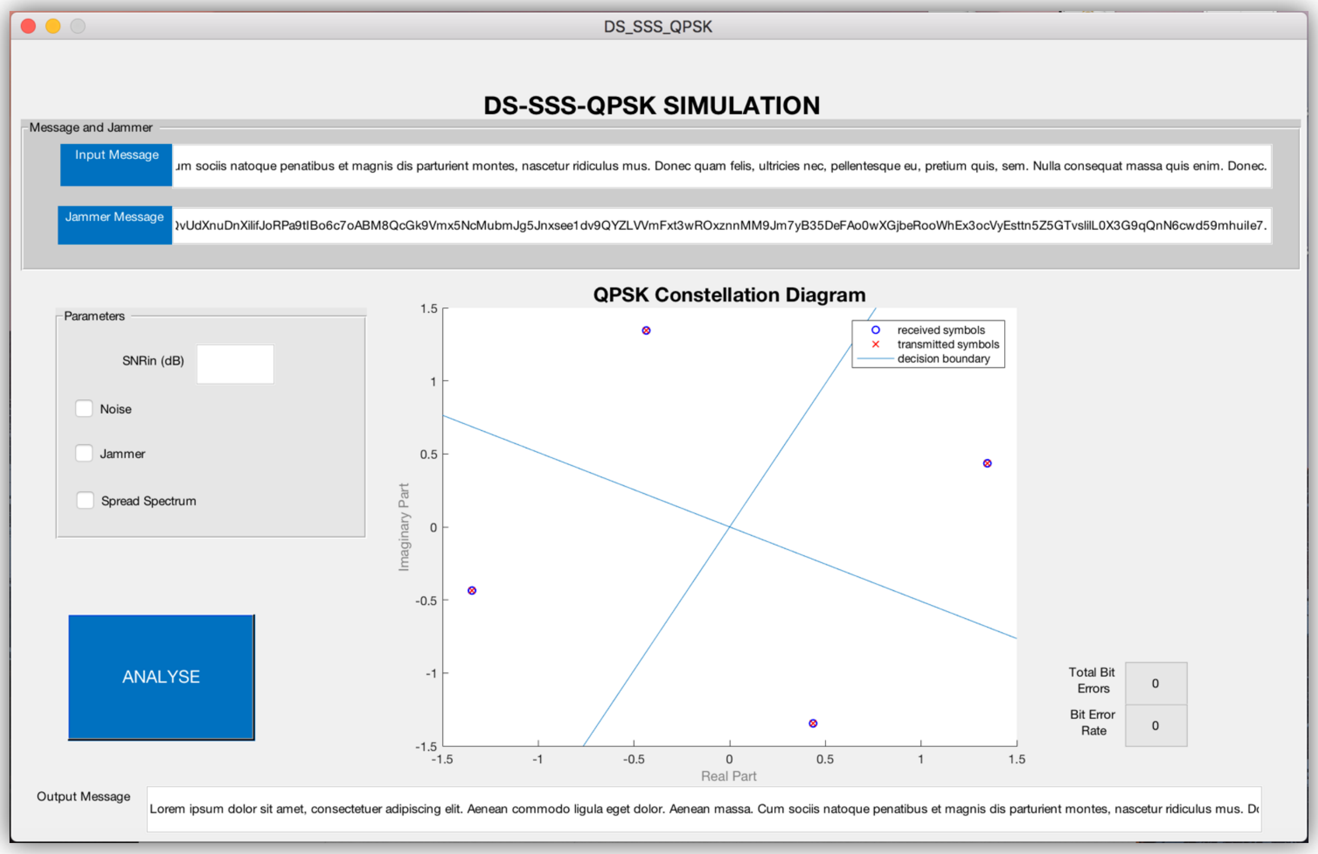


Figure 3 - Simulation for Task 1

The output message at point $\hat{A}_2$ is:

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Aenean commodo ligula eget dolor. Aenean massa. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Donec quam felis, ultricies nec, pellentesque eu, pretium quis, sem. Nulla consequat massa quis enim. Donec.

<u>Comments</u>

In the absence of noise and jammer, the message travels through the channel without being corrupted and the received symbols are exactly those that were transmitted, as can be seen in the constellation diagram.

Task 2: For SNR_{in}=30dB and absence of jammer

Let's investigate the effects of adding white Gaussian noise through the channel.

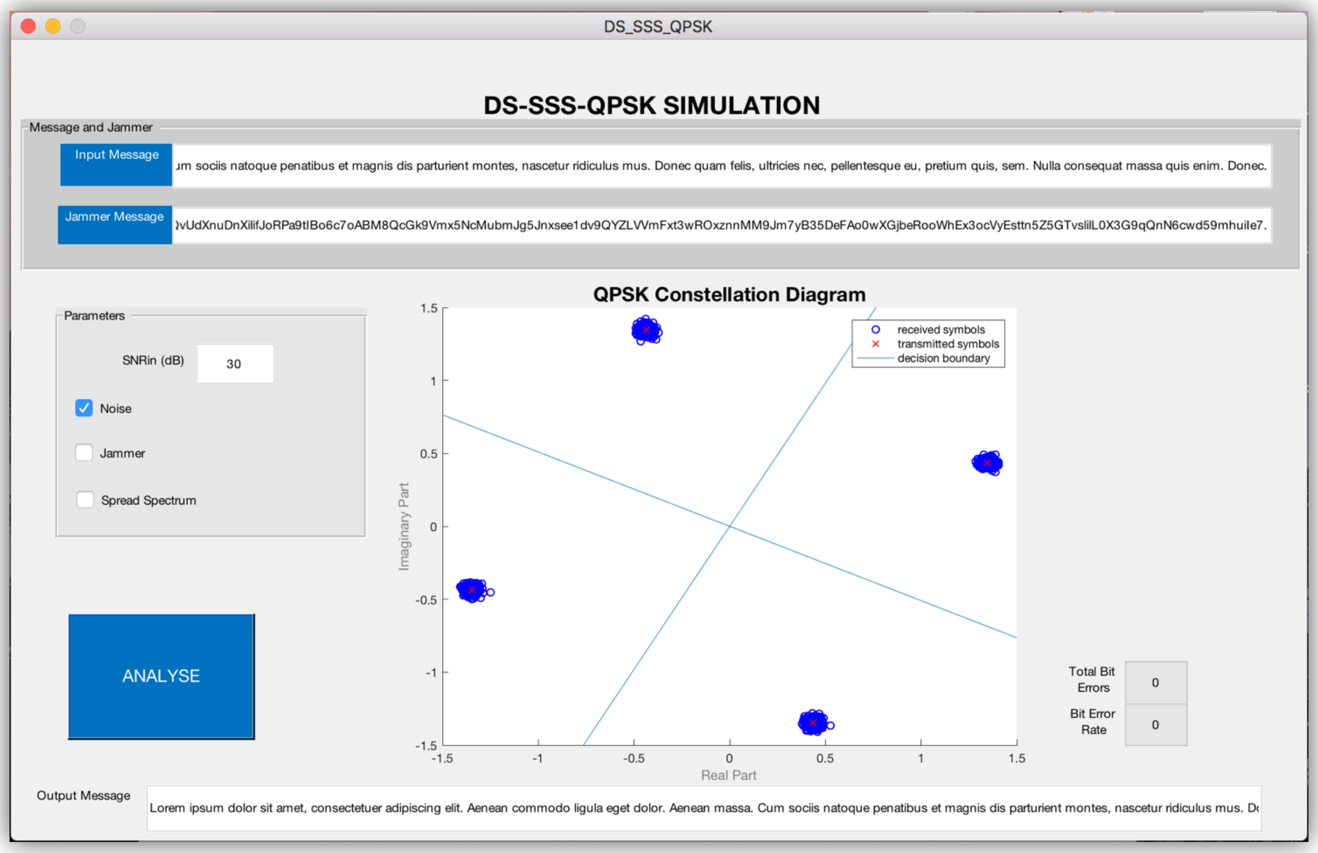


Figure 4 - Simulation for Task 2

The output message at point $\hat{A}_2$ is:
Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Aenean commodo ligula eget dolor. Aenean massa. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Donec quam felis, ultricies nec, pellentesque eu, pretium quis, sem. Nulla consequat massa quis enim. Donec.

<u>Comments</u>

- The received symbols are not exactly those that were transmitted; they lie in a region around. Those perturbations are explained by the addition of white Gaussian noise.
- At a high SNR_{in}, the message is not too corrupted by the noise. Indeed, we only observe small perturbations.
- The demodulator can thus still correctly demodulate the received signal. Indeed, the received symbols are still far from the demodulator's decision boundary.

Task 3: For SNR_{in}=20dB and absence of jammer

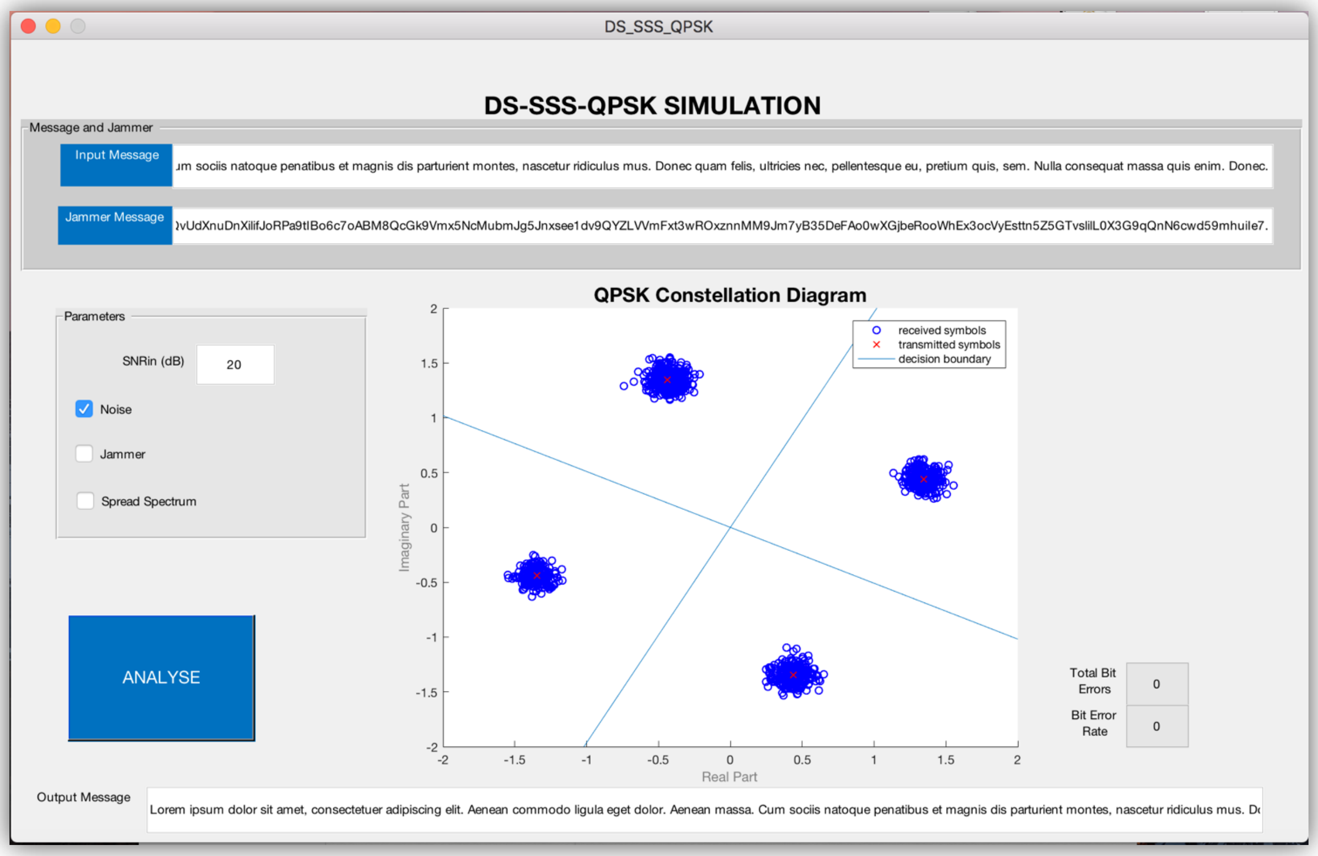


Figure 5 - Simulation for Task 4

The output message at point $\hat{A}_2$ is:

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Aenean commodo ligula eget dolor. Aenean massa. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Donec quam felis, ultricies nec, pellentesque eu, pretium quis, sem. Nulla consequat massa quis enim. Donec.

<u>Comments</u>

- The received symbols dispersion is greater as a result of a lower SNR_{in} (higher relative noise power).
- The SNR_{in} is still sufficiently high enough for the demodulator to correctly demodulate the text message, as can be seen in the constellation diagram (we can still "see" four distinct cluster of symbols).

Task 4: For SNR_{in}=0dB and absence of jammer

For an SNR_{in} of 0dB, the noise has the same power as the message. We would therefore expect the output message to be greatly affected by the noise.

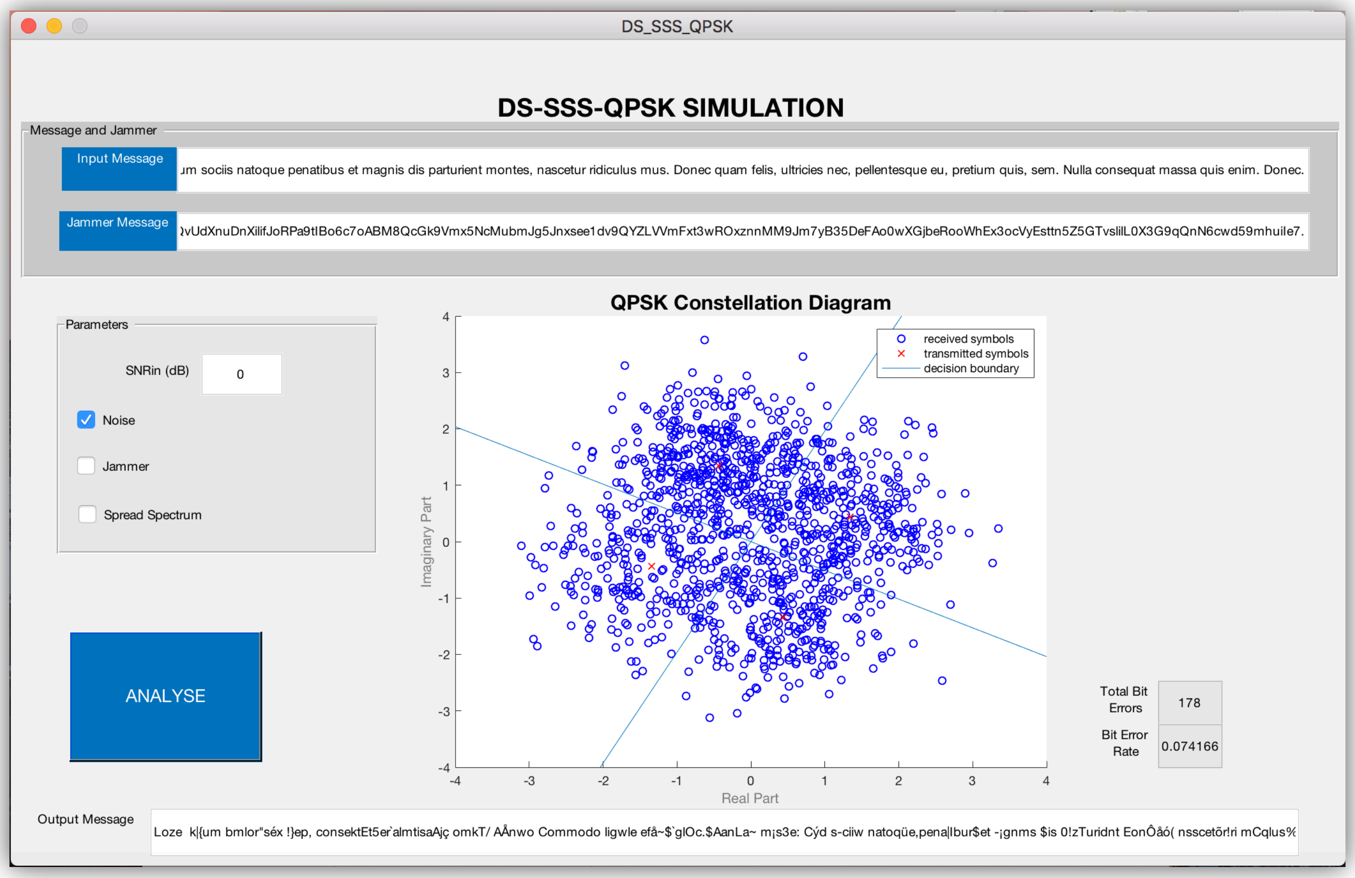


Figure 6 - Simulation for Task 4

The output message at point $\hat{A}_2$ is:

Loze k|{um bmlor"séx !}ep, consektEt5er`almtisaAjç omkT/ AÅnwo Commodo ligwle efå~$`glOc.$AanLa~ mįs3e: Cýd s-ciiw natoqüe,pena|Ibur$et -ịgnms $is 0!zTuridnt EonÔåó(nsscetõr!rimCqlus%eñ3. Dofec qqqmddelis$

<u>Comments</u>:

- White Gaussian noise and message have the same power.
- Received symbols form one big cluster of points in the constellation diagram, going well beyond all four decision boundaries.
- The message is clearly not demodulated correctly.
- 178 bits are wrongly detected which gives a bit error rate of 0.074166.

Task 5: Bit Error analysis for tasks 2, 3 and 4

From the previous experiments conducted for tasks 2, 3 and 4, we observed the following results (see Figures 4 to 6):

	Total Bit Errors	Bit Error Rate
Task 2: SNR_{in} = 30dB	0	0
Task 3: SNR_{in} = 20dB	0	0
Task 4: SNR_{in} = 0dB	178	0.074166

We can also obtain the theoretical Bit Error Rate from noting that a QPSK system can be seen as two independent BPSK system and conclude that:

$$BER = T\{\sqrt{2\,EUE}\} = T\left\{\sqrt{2\frac{E_b}{N_0}}\right\}$$

From the above formula, the tail function graph can be used to find:

	Theoretical Bit Error Rate
Task 2: SNR_{in} = 30dB	N/A
Task 3: SNR_{in} = 20dB	N/A
Task 4: SNR_{in} = 0dB	0.0786

Note that for Tasks 2 and 3, the value of of the bit error rate is so low that it can't be read off the tail function graph.

For Task 4, we notice that the experimental bit error rate is not too far from the theoretical value.

Task 6: For SNR_{in}=30dB and presence of jammer

Let's now investigate the behaviour of the system in the presence of both noise and jammer with the following ratios:

- SNR = 30dB
- SJR = -10dB

The latter indicates that the jammer has a power ten times greater than the message's.

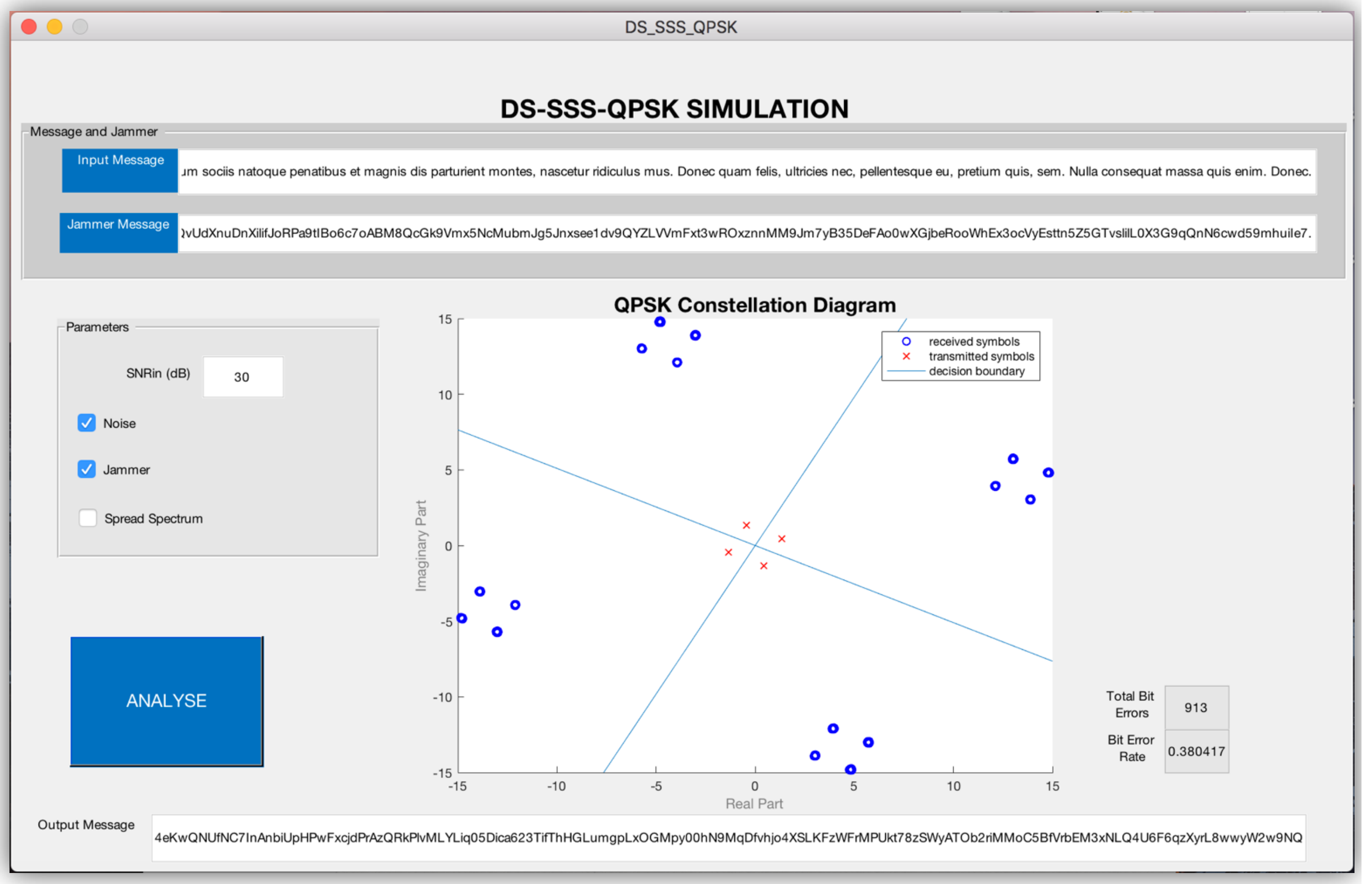


Figure 7 - Simulation for Task 6

The output message at point $\hat{A}_2$ is:
4eKwQNUfNC7InAnbiUpHPwFxcjdPrAzQRkPlvMLYLiq05Dica623TifThHGLumgpLxOGMpy00hN9MqDfvhjo4XSLKFzWFrMPUkt78zSWyATOb2riMMoC5BfVrbEM3xNLQ4U6F6qzXyrL8wwyW2w9NQvUdXnuDnXilifJoRPa9tIBo6c7oABM8QcGk9Vmx5NcMubmJg5Jnxsee1dv9QYZLVVmFxt3wROxznnMM9Jm7yB35DeFAo0wXGjbeRooWhEx3ocVyEsttn5Z5GTvslilL0X3G9qQnN6cwd59mhuile7.

<u>Comments</u>:

- The jamming signal has much greater power (ten times more) than the message signal.
- The output message is exactly the jamming signal, which is expected.
- The constellation diagram shows four main clusters of symbols which correspond to the jammer symbols. Then four other small groups of symbols represent those of the message. This naturally comes from the jammer having greater power.
- The noise is irrelevant and thus negligible in this experiment.

Task 7: Spread Spectrum System

We now extend our system to a spread spectrum system as shown in Figure-8.

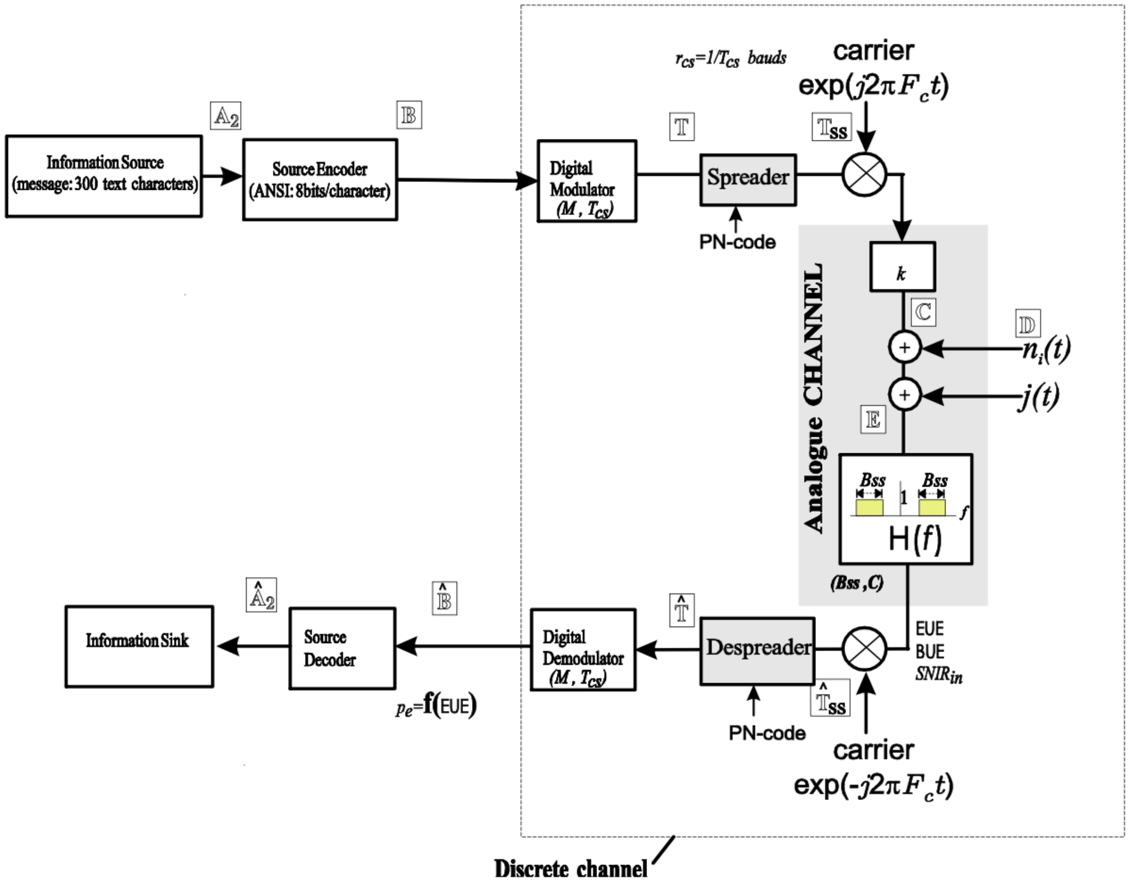


Figure 8 - A Spread Spectrum Communication System Operating in the Presence of a Jammer

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

	1st Polynomial	2nd Polynomial
Desired	$D^5 + D^2 + 1$	$D^5 + D^3 + D^2 + D + 1$
Jammer	$D^5 + D^3 + 1$	$D^5 + D^4 + D^2 + D + 1$

where the second polynomial is delayed by k=16 for the desired PN-code and k=17 for the PN-code employed by the jammer.
This yields the following two gold sequences of period 32:

- Desired PN-code: 10100010010100111011101101110100
- Jammer PN-code: 10100001110101110101011010100001

Note that 0's and 1's are later converted to 1's and -1's respectively.

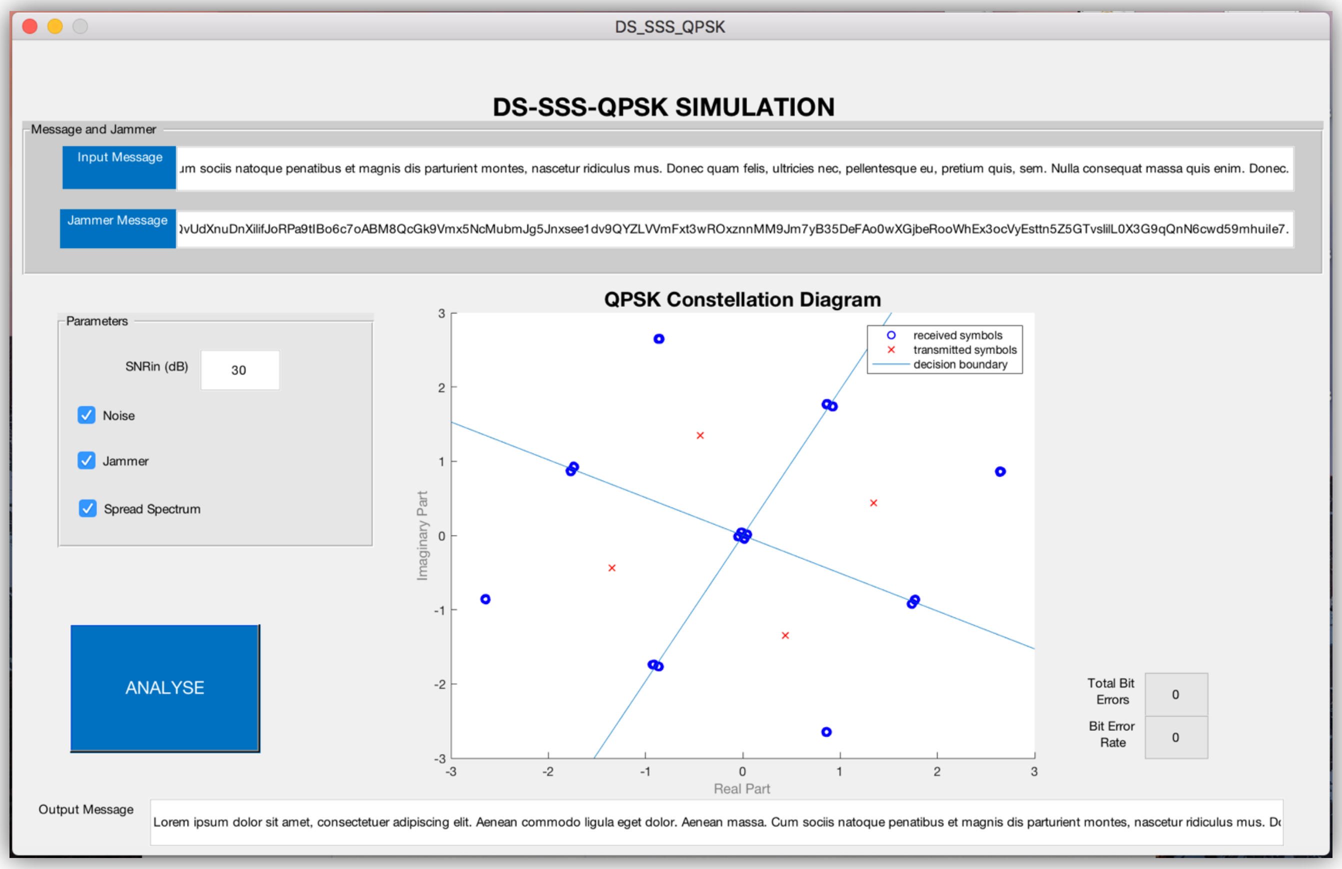


Figure 9 - Simulation for Task 7

The output message at point $\hat{A}_2$ is:
Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Aenean commodo ligula eget dolor. Aenean massa. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Donec quam felis, ultricies nec, pellentesque eu, pretium quis, sem. Nulla consequat massa quis enim. Donec.

<u>Comments</u>:

- We immediately notice the improvement of using the Spread Spectrum System. There are indeed no bit errors at all.
- Using a PN-code to spread the original text message and then using the same PN-code to de-spread it helps to separate it from the jammer which uses a different PN-code.

As a further investigation, we also test the Spread Spectrum system with only white Gaussian noise with a SNR_{in} = 0dB. Recall that in task 4, the message could not be de-coded correctly.

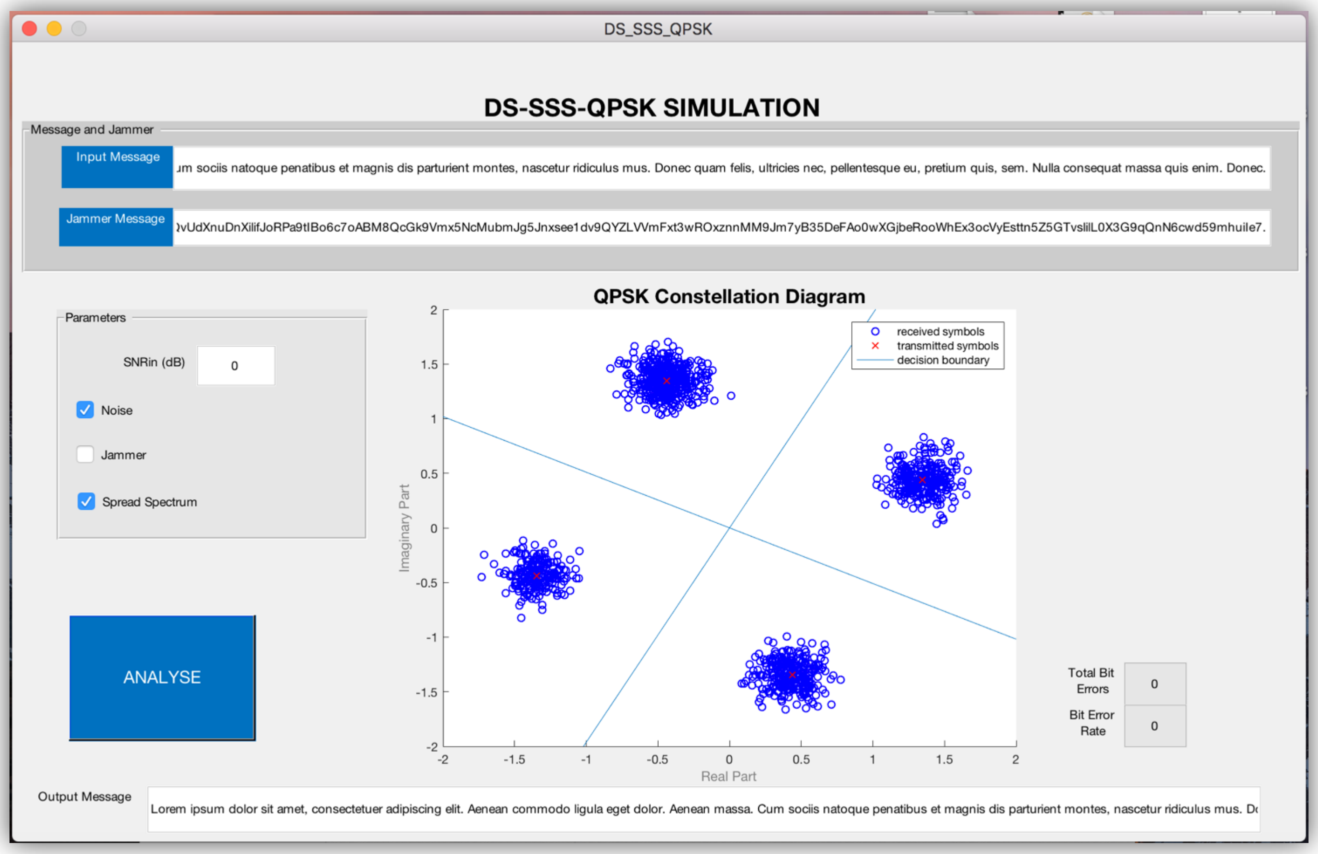


Figure 10 - Simulation of the DS-SSS-QPSK in the presence of only noise

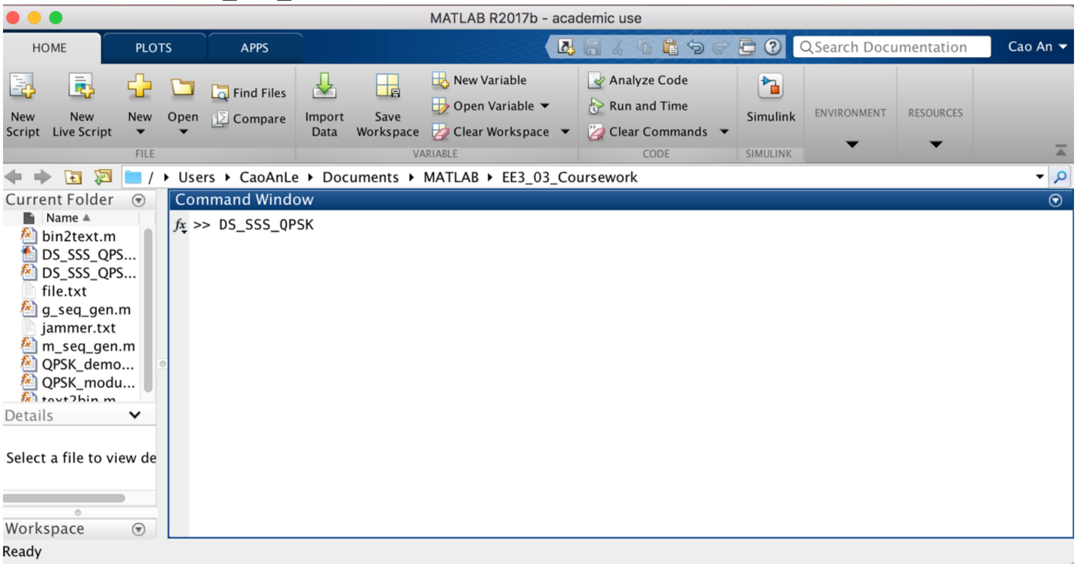
<u>Comments</u>:

- Unlike the conventional system in task 4, the one with a spreader is stronger against noise.

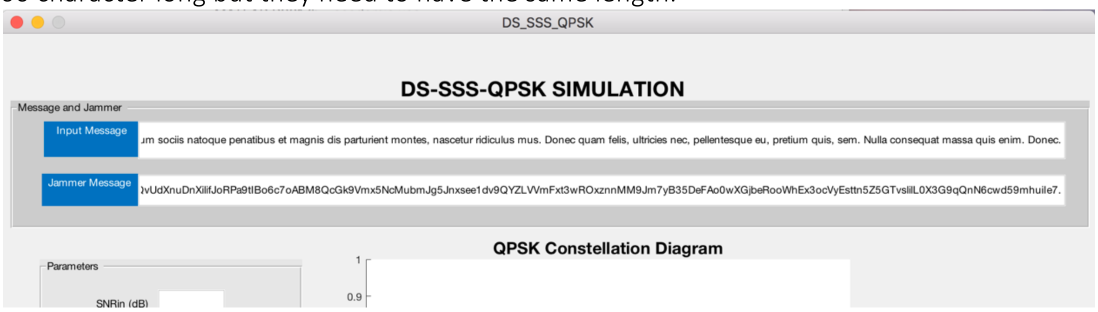
We conclude that the new Direct-Sequence QPSK Spread Spectrum Communication System is more resilient to both intentional (jammer) and unintentional (noise) interferences.

Instructions to run the program

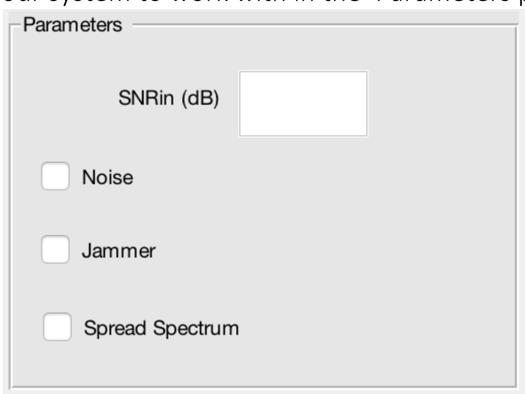
1. Open MATLAB.
2. Choose the folder “EE3_03_Coursework” as the working directory.
3. Enter the command “DS_SSS_QPSK” in the Command Window and hit ENTER.



4. Use the message.txt and jammer.txt files to get the 300 character messages. Copy and paste them in the corresponding textboxes. You can also use your own text messages. Note that they don’t need to be 300 character long but they need to have the same length.



5. Fill in the options you want your system to work with in the ‘Parameters panel.



6. Hit “ANALYSE”.
7. Observe the constellation diagram and the bit error statistics.