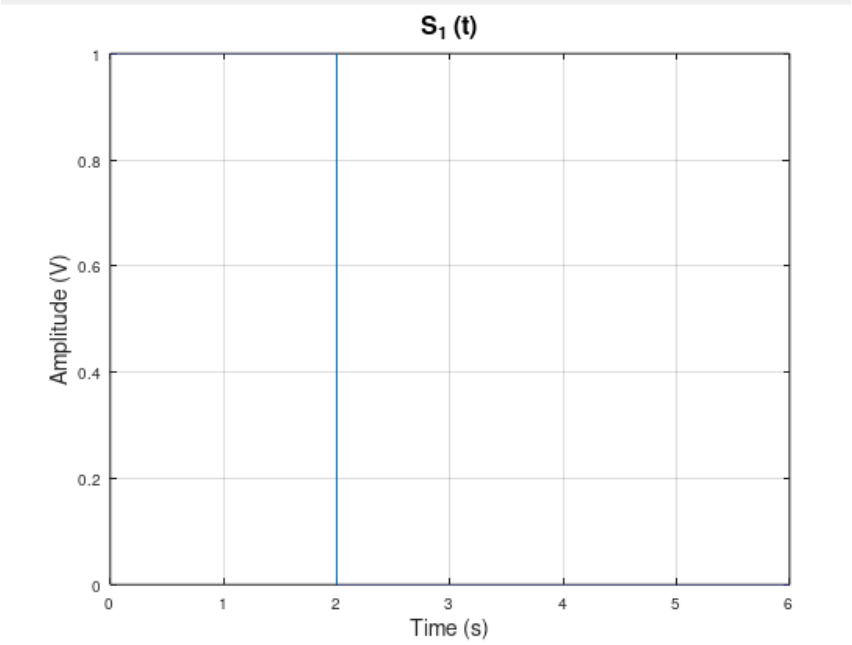
Part 1

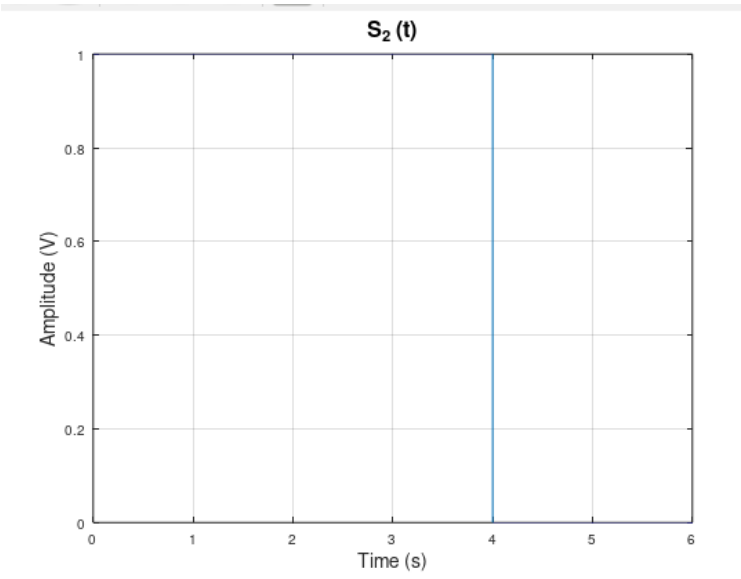
Example 1

Note: Assume T = 6s.

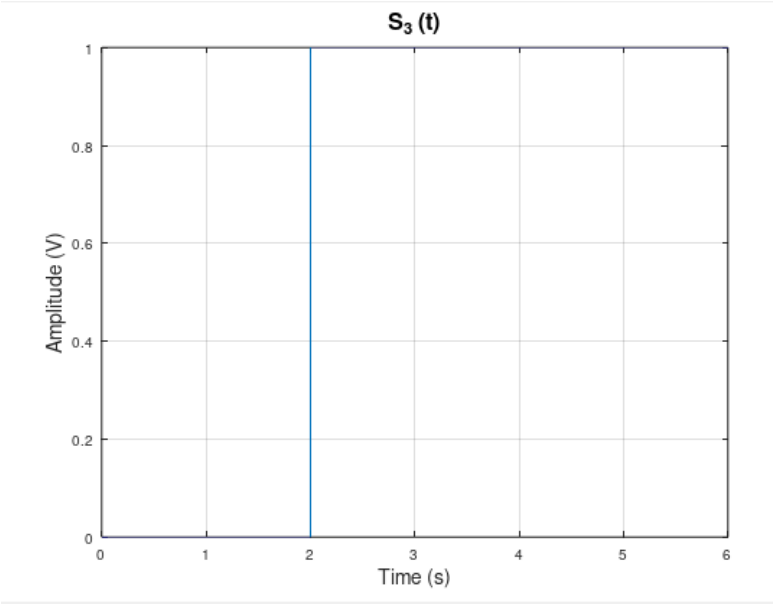
Signal 1



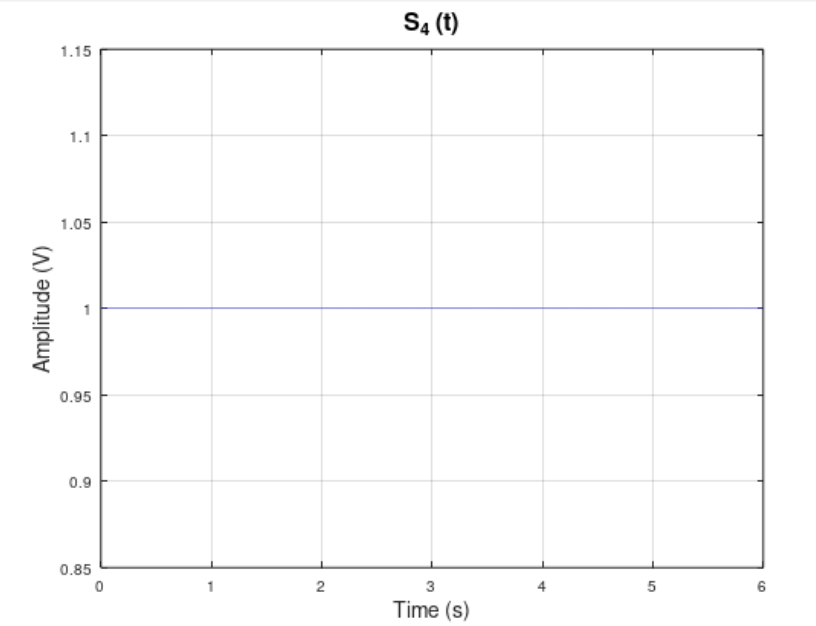
Signal 2



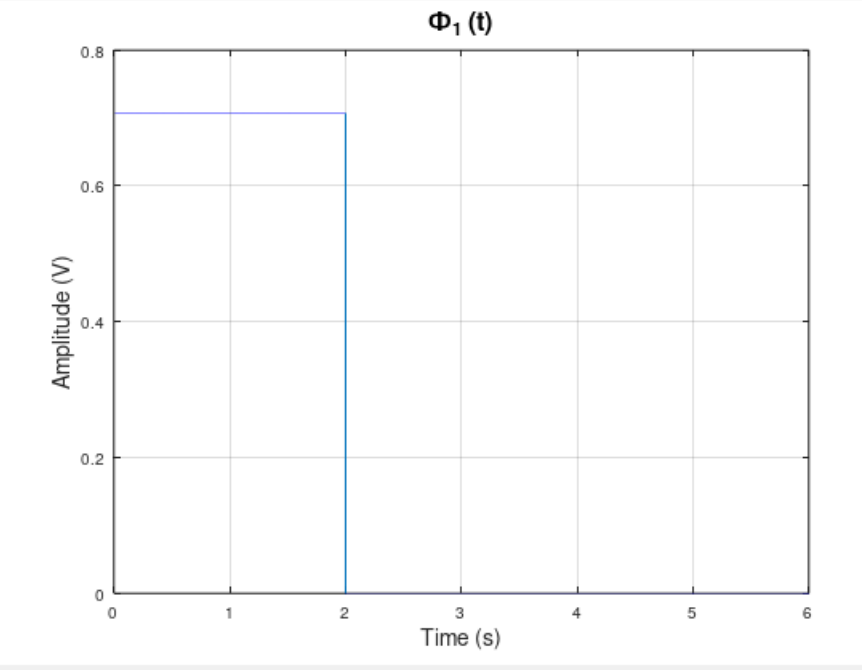
Signal 3



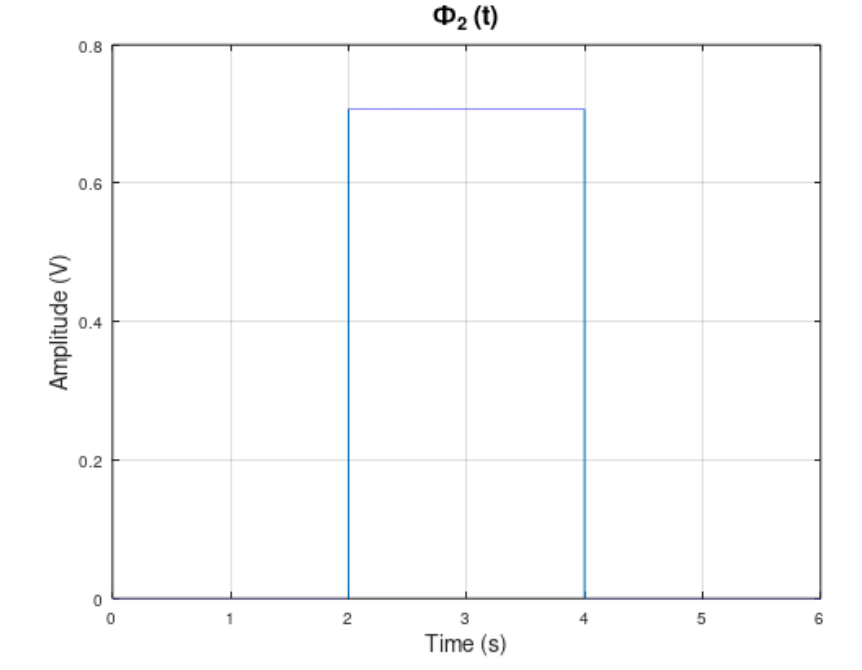
Signal 4



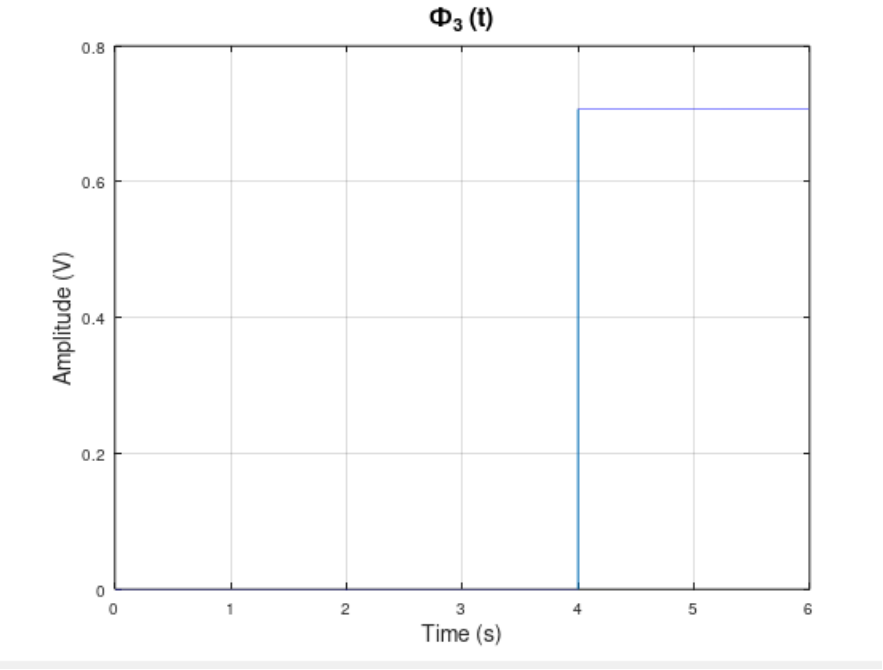
Phi 1


Φ_1 (t)
Amplitude (V)
Time (s)
0
0.2
0.4
0.6
0.8
0
1
2
3
4
5
6

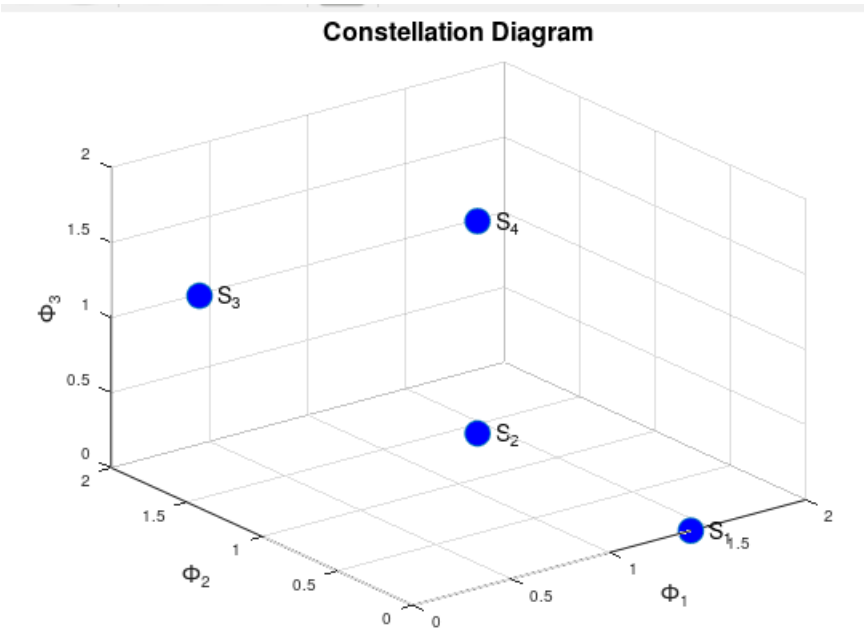
Phi 2


Φ_2 (t)
Amplitude (V)
Time (s)
0
0.2
0.4
0.6
0.8
0
1
2
3
4
5
6

Phi 3



Constellation Diagram

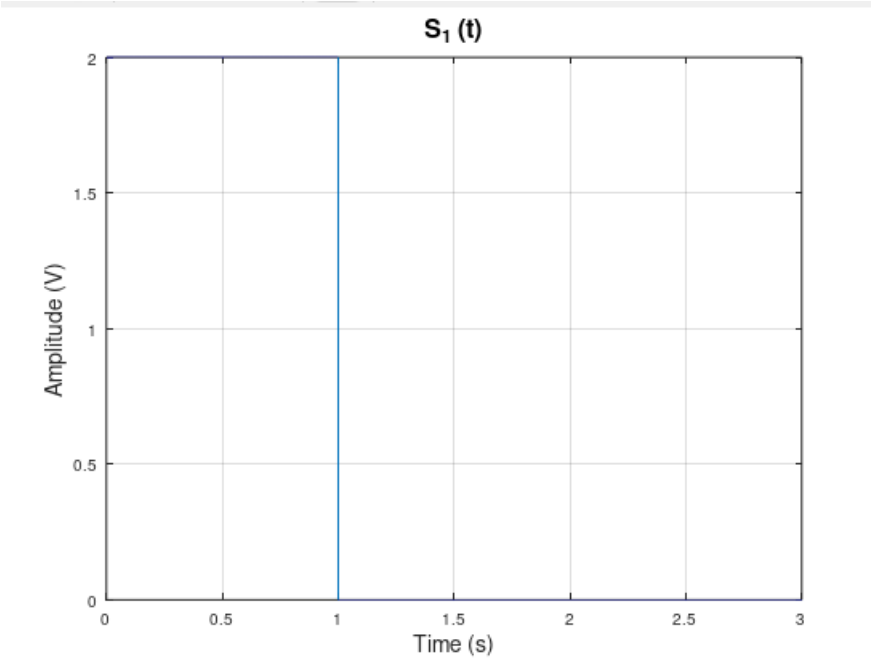


Symbol Energy

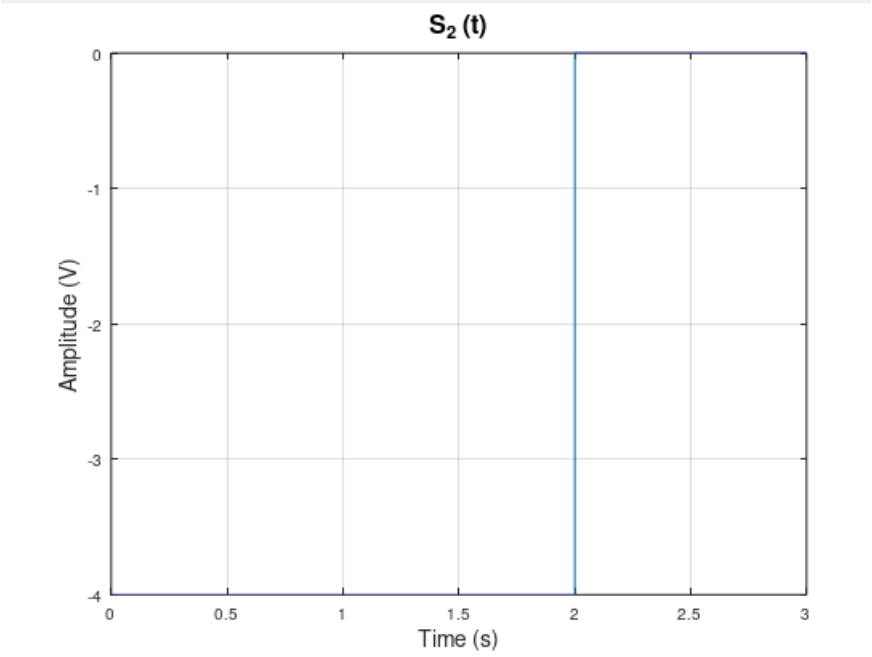
```
Command Window
How many signals do you want to input?
4
Input Signal period
6
Input Signal matrix
[2 6; 1 0]
Input Signal matrix
[4 6; 1 0]
Input Signal matrix
[2 6; 0 1]
Input Signal matrix
[6;1]
symbol_energy =

   2
   4
   4
   6

>>
```

Example 2

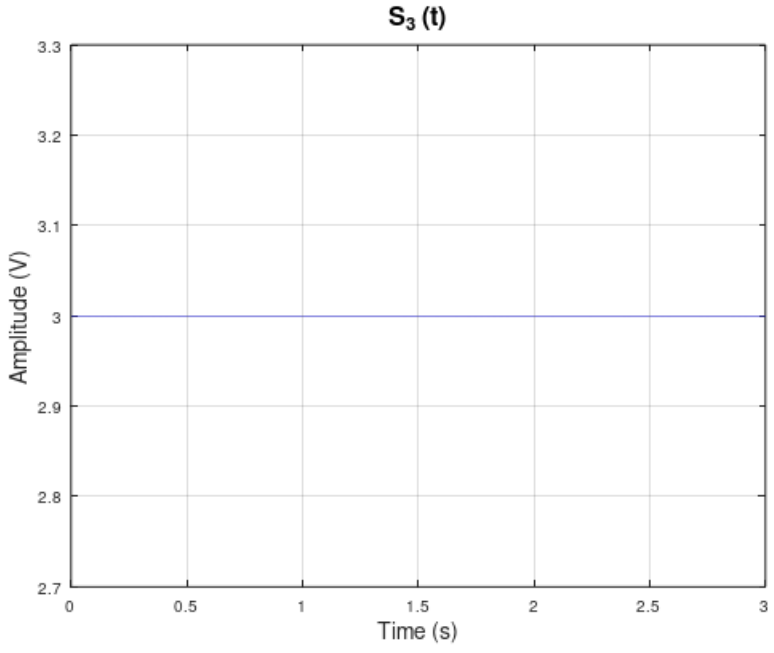
Signal 1



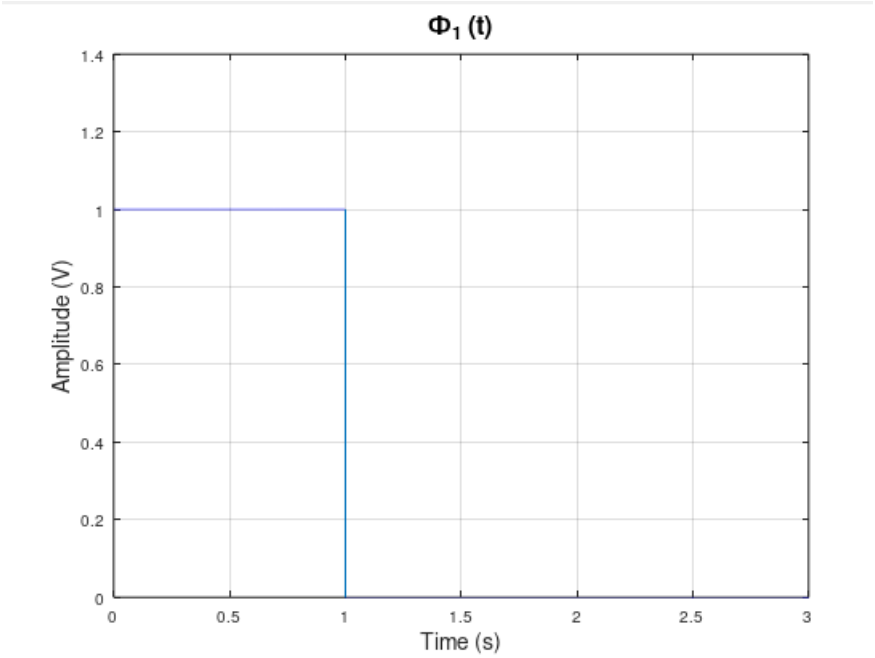
Signal 2



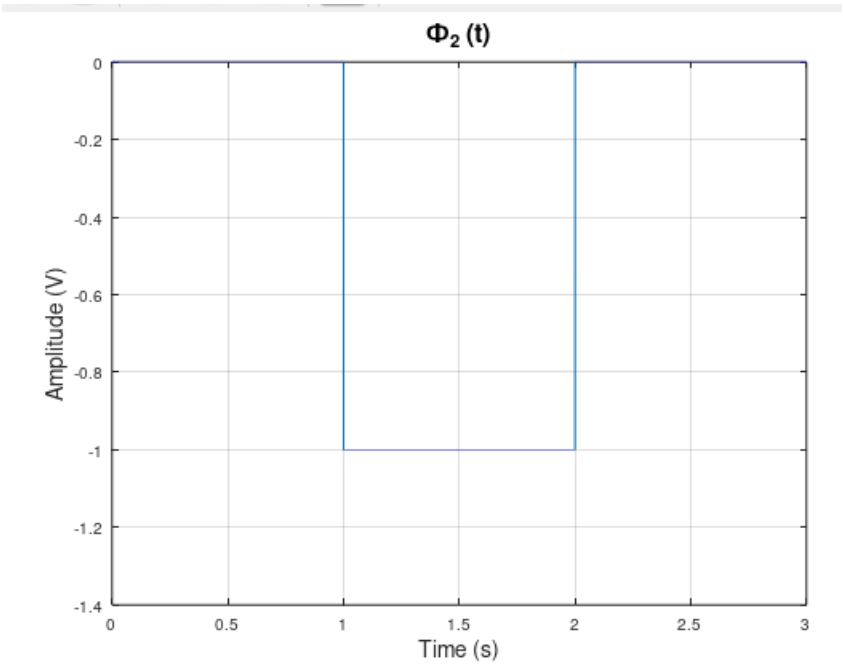
Signal 3



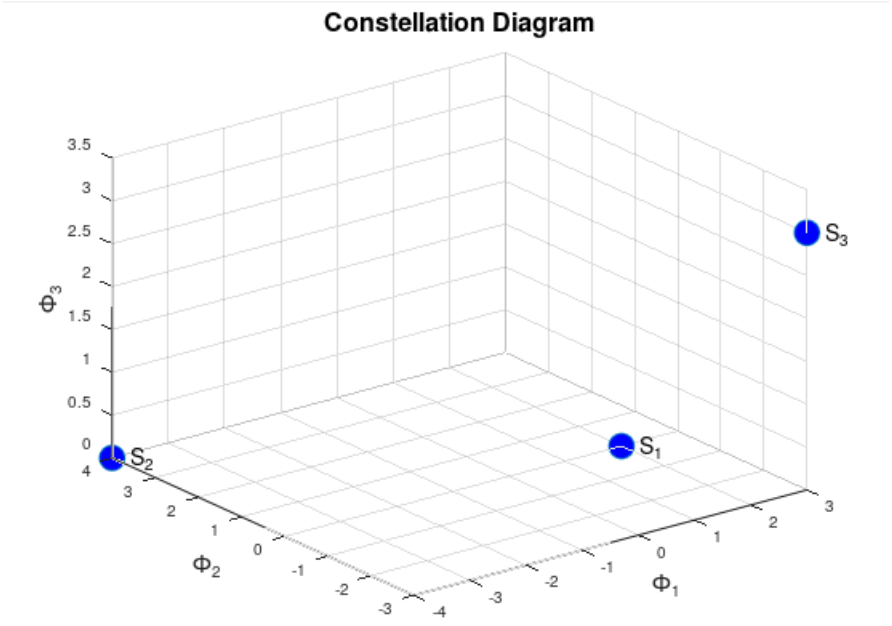
Phi 1


Φ1 (t)
Amplitude (V)
Time (s)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3

Phi 2


Φ2 (t)
Amplitude (V)
Time (s)
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
0.5
1
1.5
2
2.5
3

Constellation Diagram



Symbol Energy

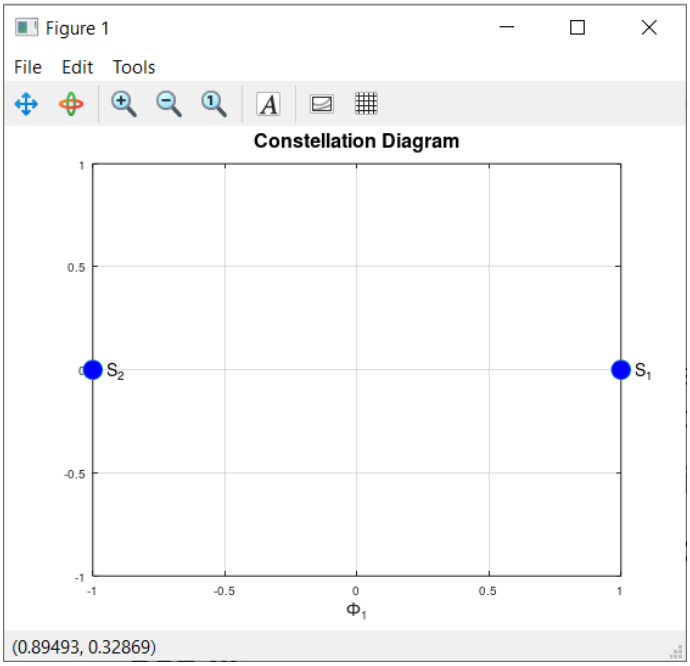
Command Window

```
How many signals do you want to input?
3
Input Signal period
3
Input Signal matrix
[1 3; 2 0]
Input Signal matrix
[2 3; -4 0]
Input Signal matrix
[3;3]
symbol_energy =

    4
   32
   27
```

Part 2

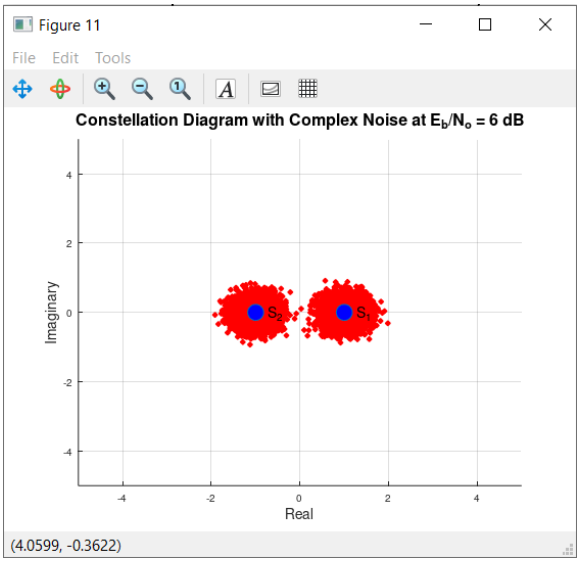
Polar NRZ

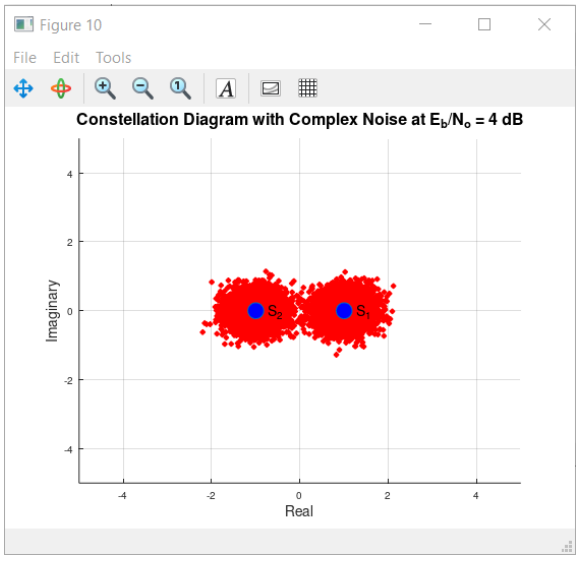
Constellation Diagram Without Noise



Note: In the following diagram, bit rate = 1 bit/s just to clarify the concept. However, in the next part bit rate = 1000 bits/s, and it could be varied from the code if necessary.

Constellation Diagram with Complex Noise





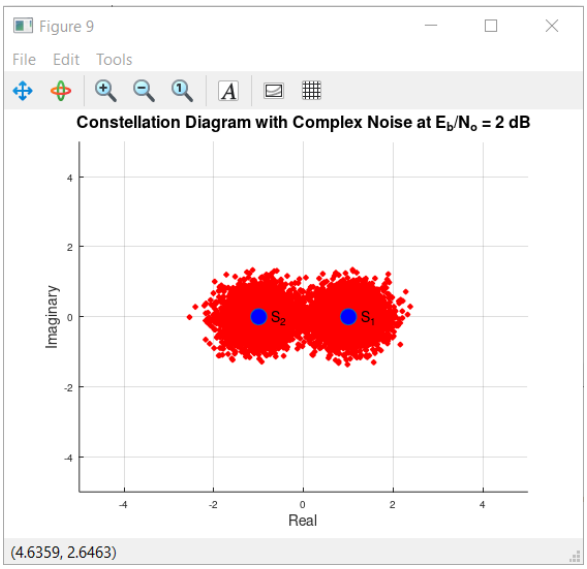


Figure 9
File Edit Tools
Constellation Diagram with Complex Noise at E_b/N_o = 2 dB
Imaginary
Real
S_2
S_1
(4.6359, 2.6463)

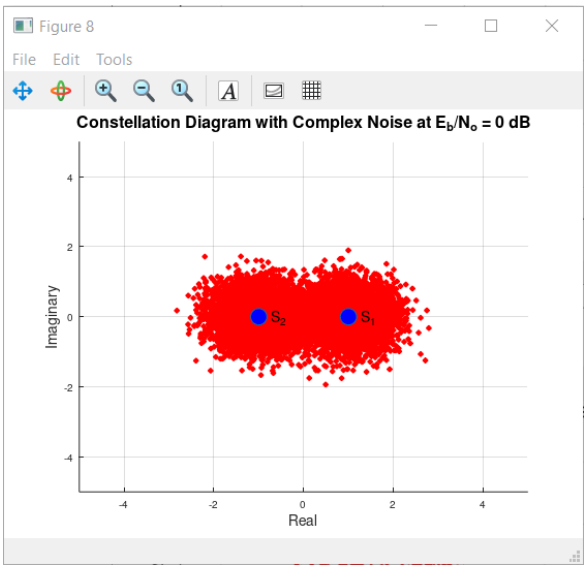


Figure 8
File Edit Tools
Constellation Diagram with Complex Noise at E_b/N_o = 0 dB
Imaginary
Real
S_2
S_1

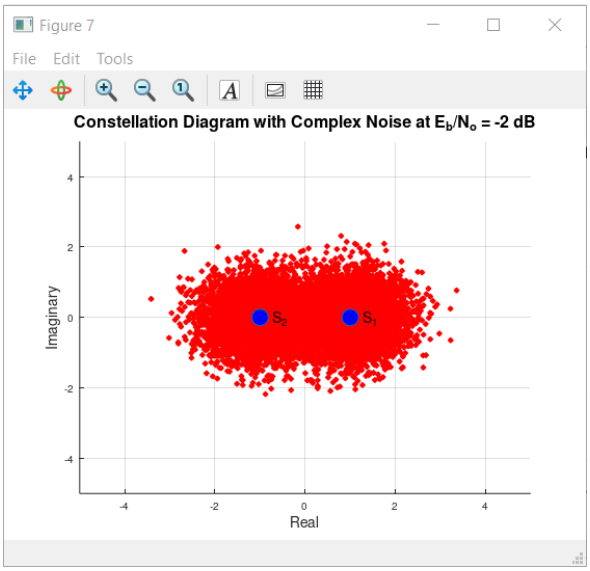


Figure 7
File Edit Tools
Constellation Diagram with Complex Noise at E_b/N_o = -2 dB
Imaginary
Real
S_2
S_1

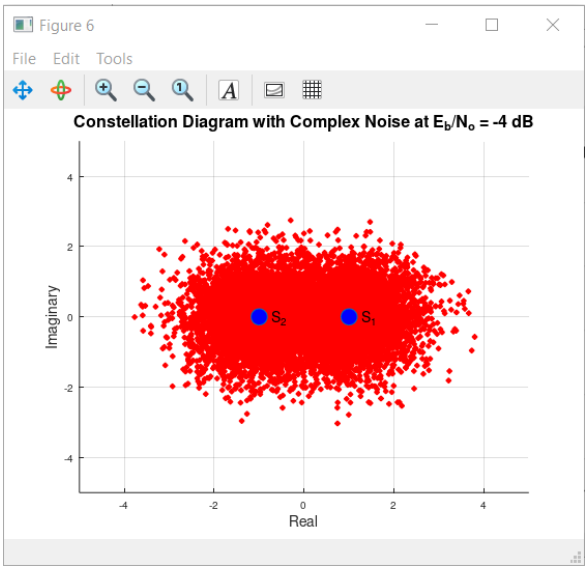


Figure 6
File Edit Tools
Constellation Diagram with Complex Noise at E_b/N_o = -4 dB
Imaginary
Real
S_2
S_1

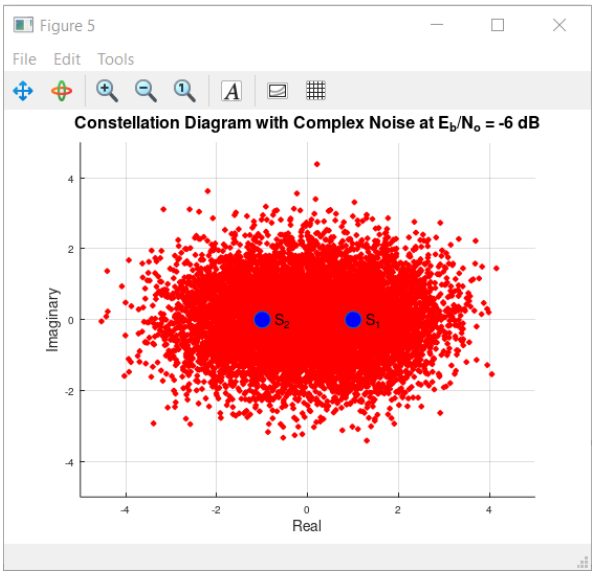


Figure 5
File Edit Tools
Constellation Diagram with Complex Noise at E_b/N_o = -6 dB
Imaginary
Real
S_2
S_1

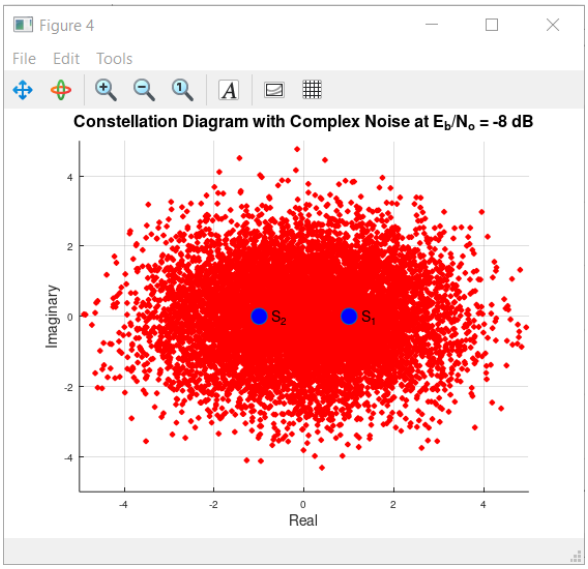
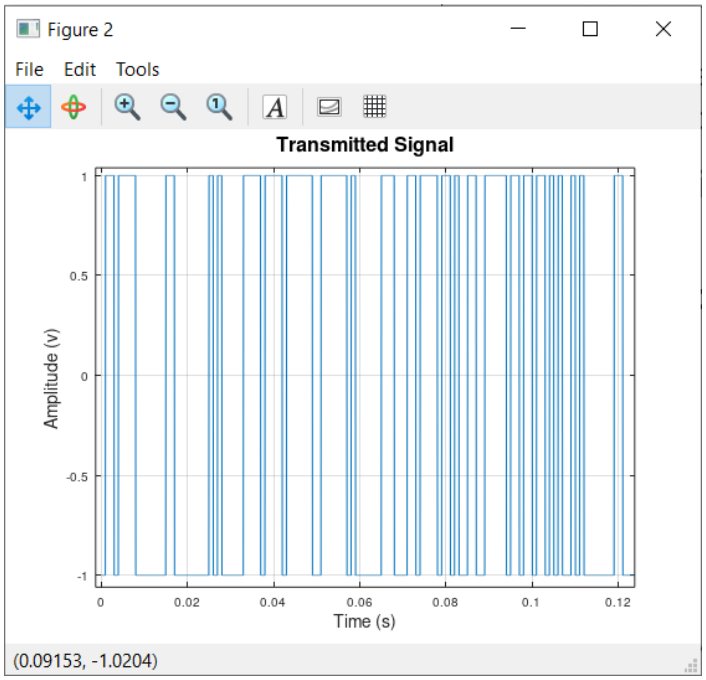


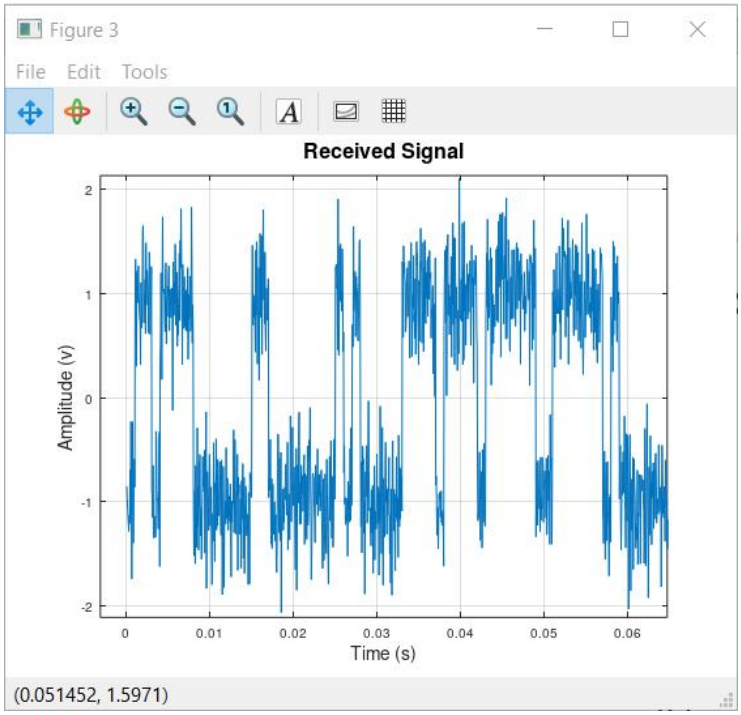
Figure 4
File Edit Tools
Constellation Diagram with Complex Noise at E_b/N_o = -8 dB
Imaginary
Real
S_2
S_1

Transmitter Encoded Signal (Time Domain)

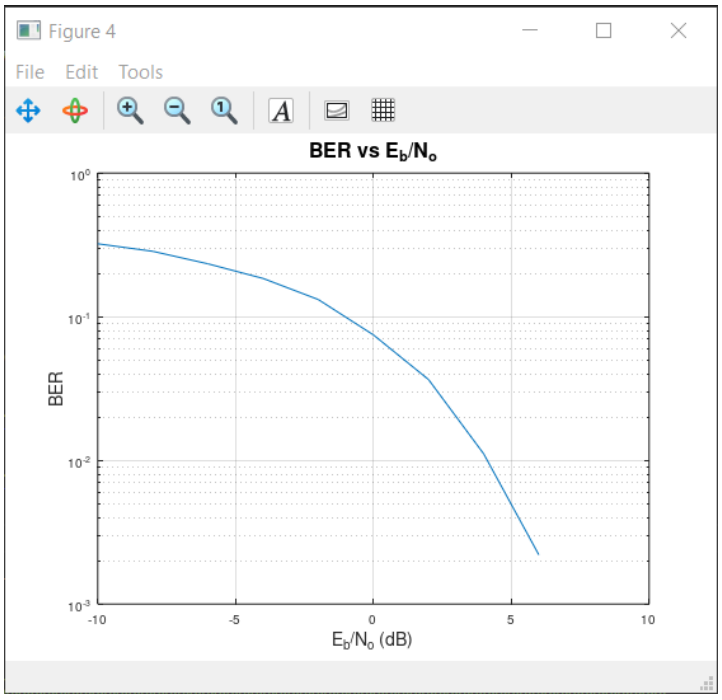


Received Noisy Signal (Time Domain)

Note: Eb/No = 6 dB for this graph.



BER vs $\frac{E_b}{N_o}$



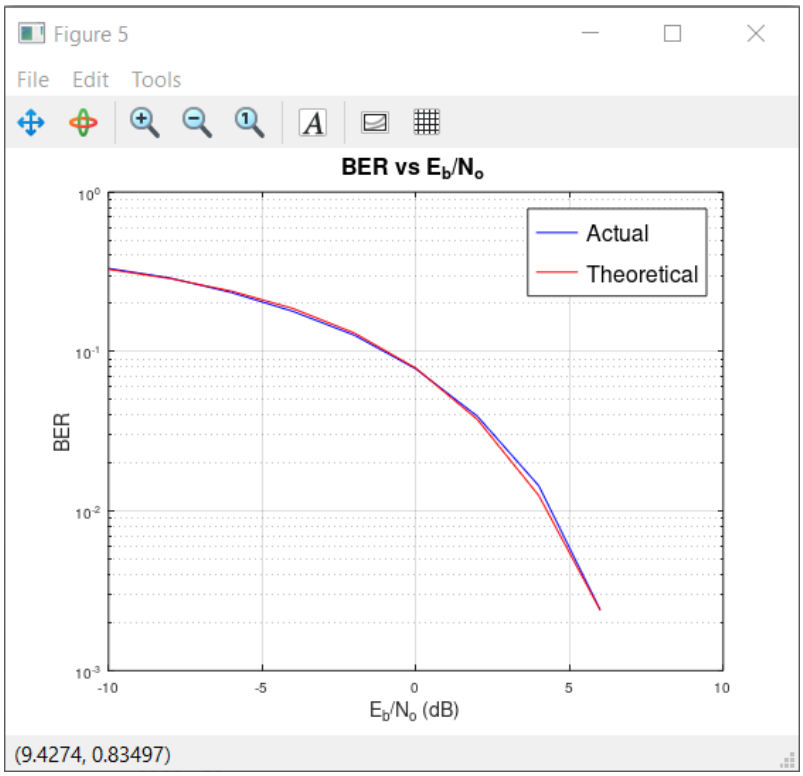
Theoretical Results

Theoretical Analysis

$$P_e(symbol) = Q\left(\frac{S_{21} - S_{11}}{\sqrt{2No}}\right)$$

- In BPSK each bit is represented in one symbol, so BER = $P_e(symbol)$
- From the constellation diagram shown at the beginning of Part 2:
- $S_{21} - S_{11} = 2\sqrt{Eb}$
- Therefore, BER = $Q\left(\sqrt{\frac{2\times Eb}{No}}\right)$

BER vs $\frac{E_b}{N_o}$



BER Values

```
Command Window
>> BER_s
BER_s =

   3.3190e-01   2.8910e-01   2.3420e-01   1.7850e-01   1.2650e-01   7.7800e-02   3.9300e-02   1.4400e-02   2.4000e-03

>> BER_t
BER_t =

   3.2736e-01   2.8671e-01   2.3923e-01   1.8611e-01   1.3064e-01   7.8650e-02   3.7506e-02   1.2501e-02   2.3883e-03
```

Comments

- The BER decreases with increasing Eb/No, as predicted by the theoretical expression.
- The actual BER curve deviates slightly from the theoretical curve.
- Overall, the results demonstrate that polar NRZ can achieve good BER performance in AWGN channels.