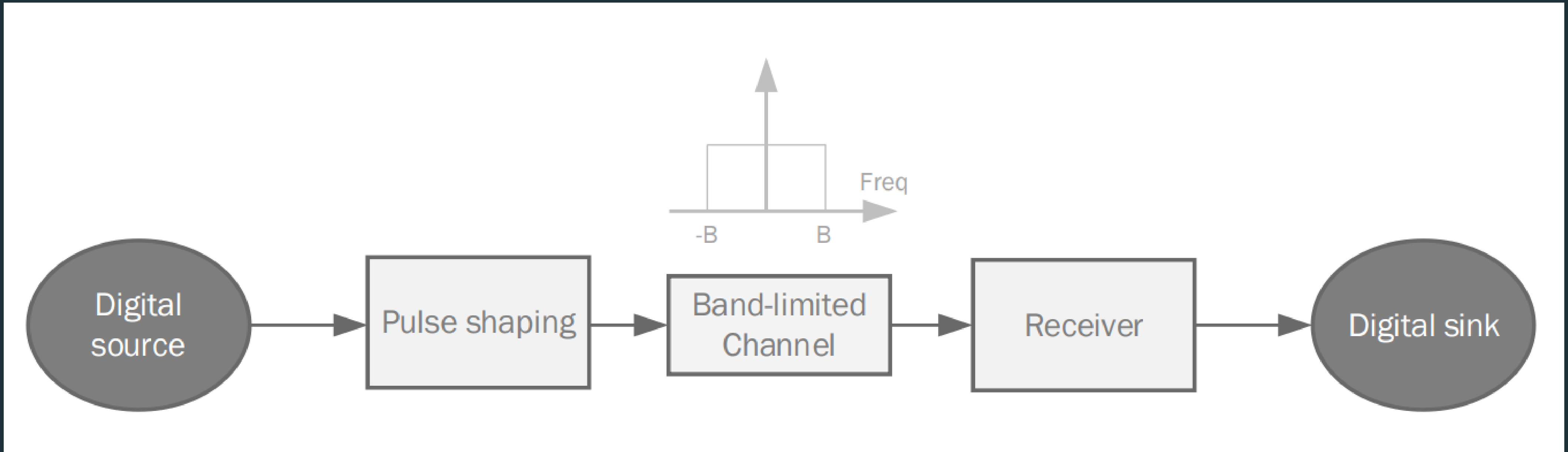
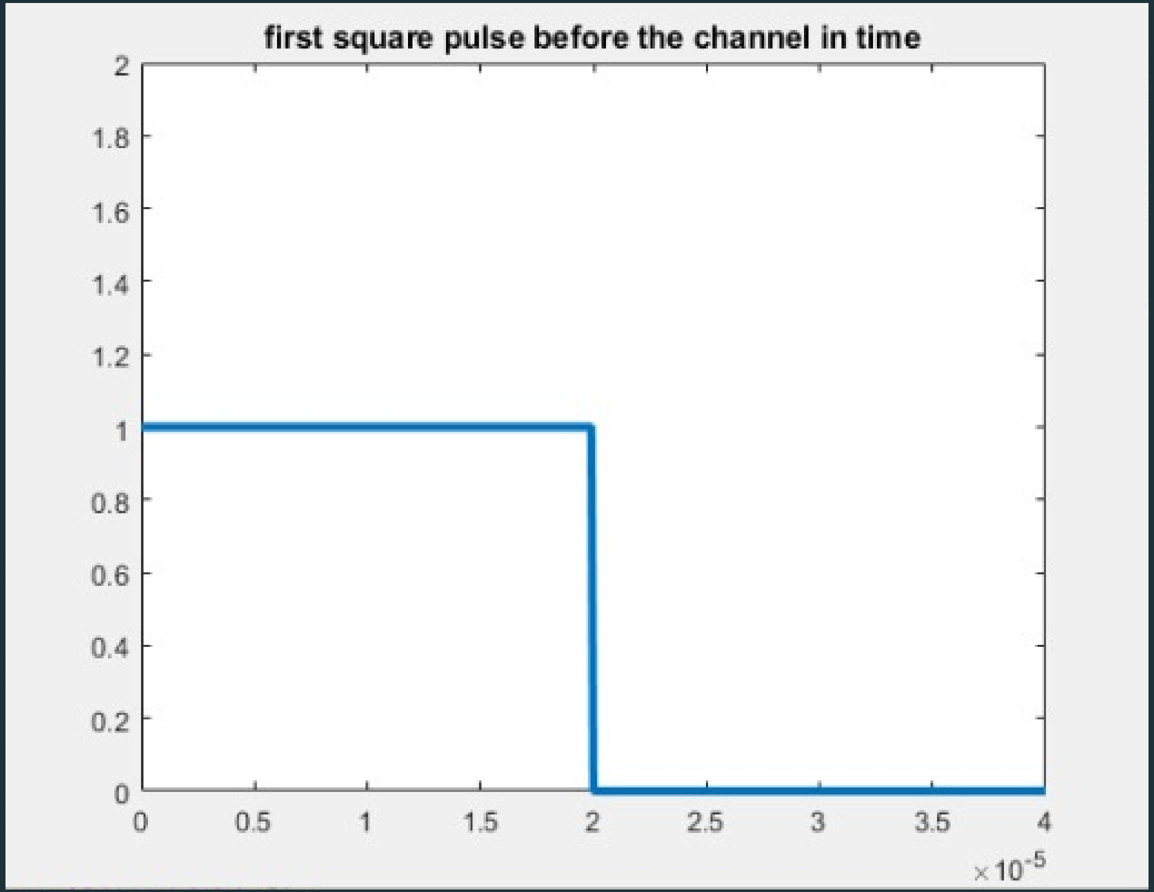
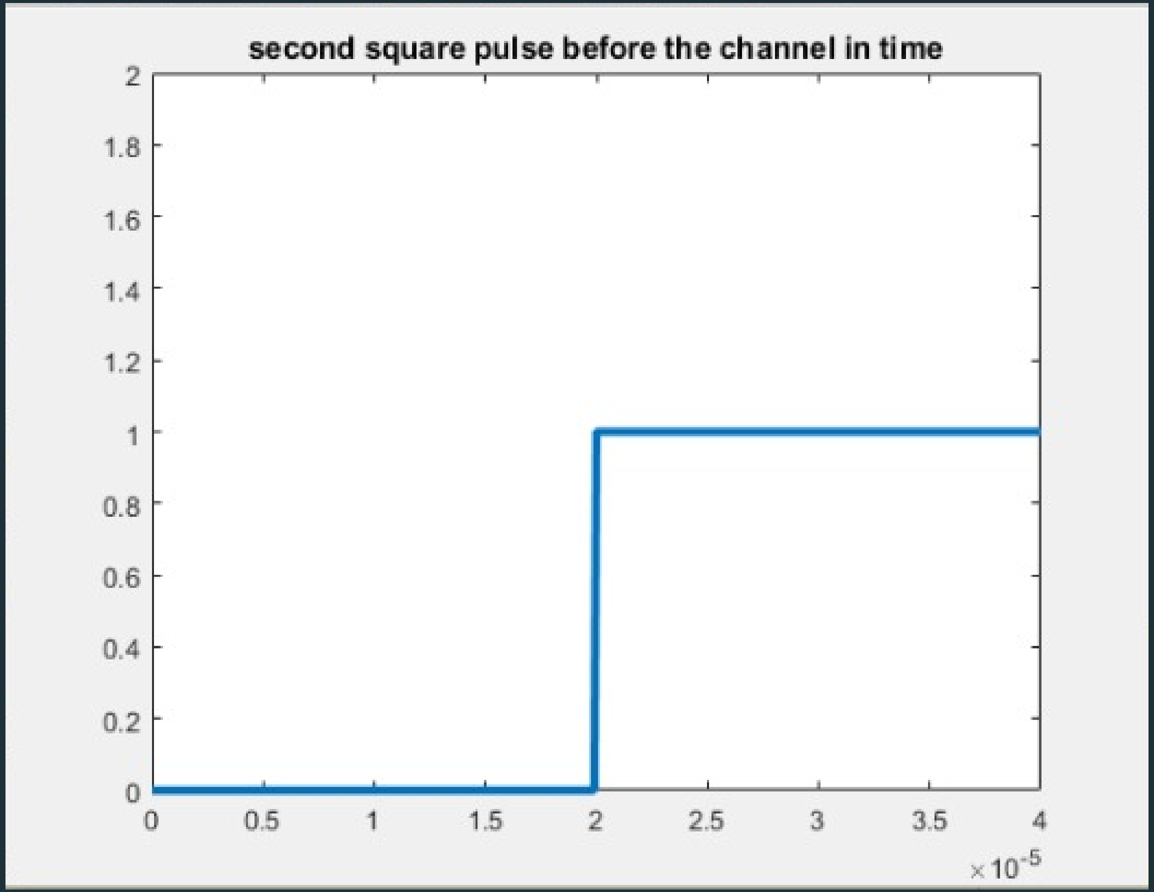

# INTER-SYMBOL INTERFERENCE DUE TO BAND-LIMITED CHANNELS

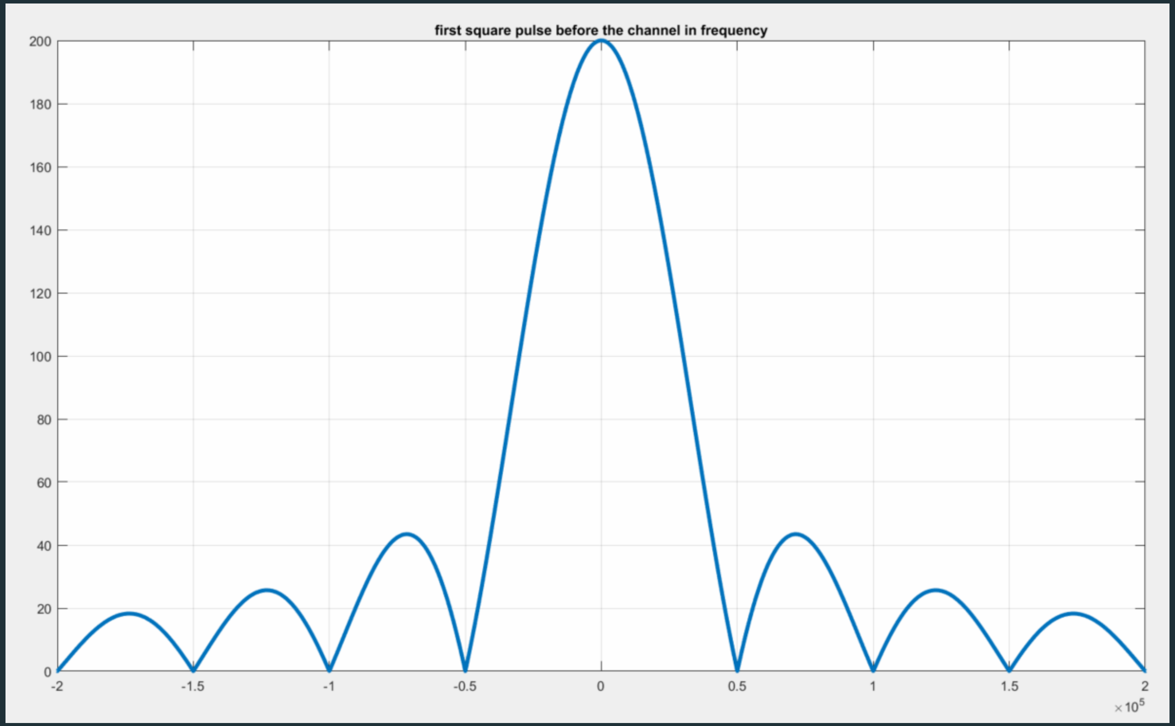
# GENERATING FIRST AND SECOND PULSE WITH PERIOD = 2/B IN TIME DOMAIN

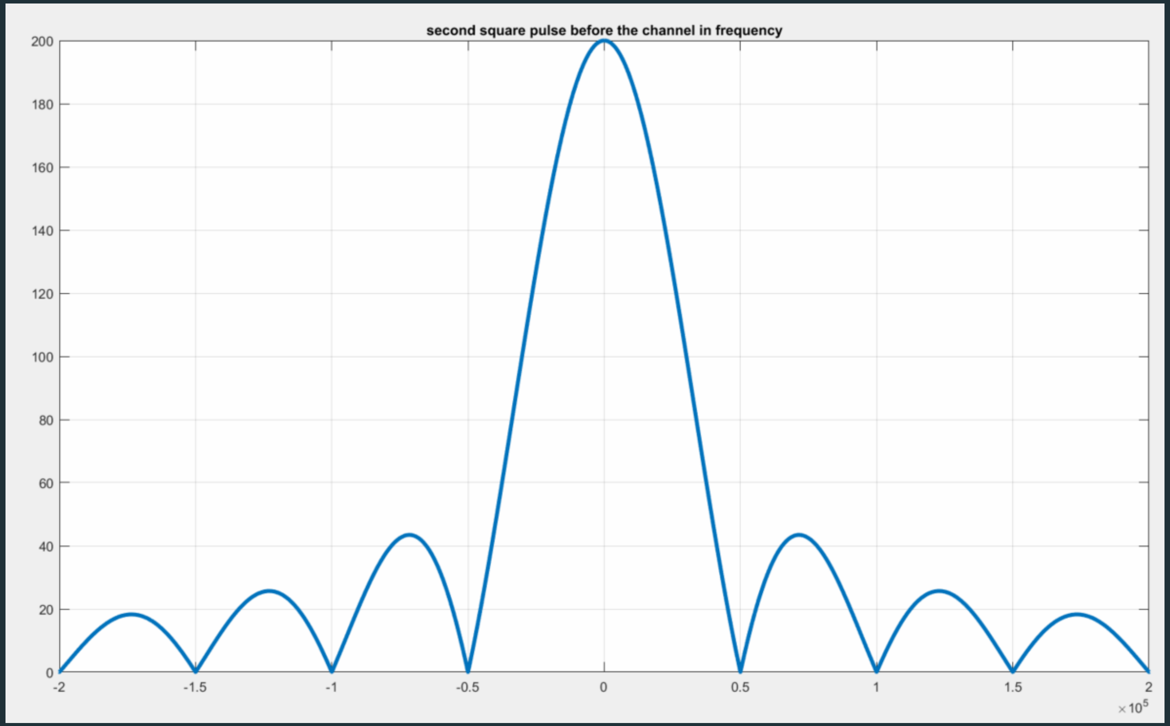



first square pulse before the channel in time
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
$\times 10^{-5}$


second square pulse before the channel in time
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
$\times 10^{-5}$

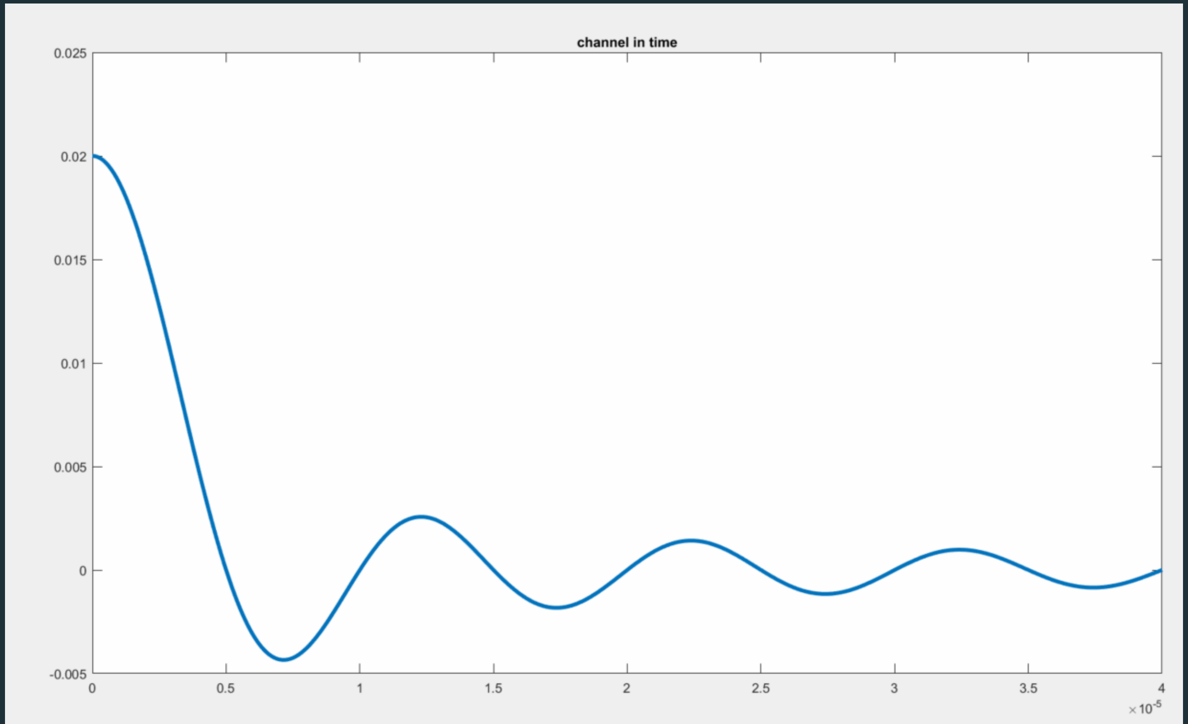
# GENERATING FIRST AND SECOND PULSE WITH PERIOD = 2/B IN FREQUENCY DOMAIN



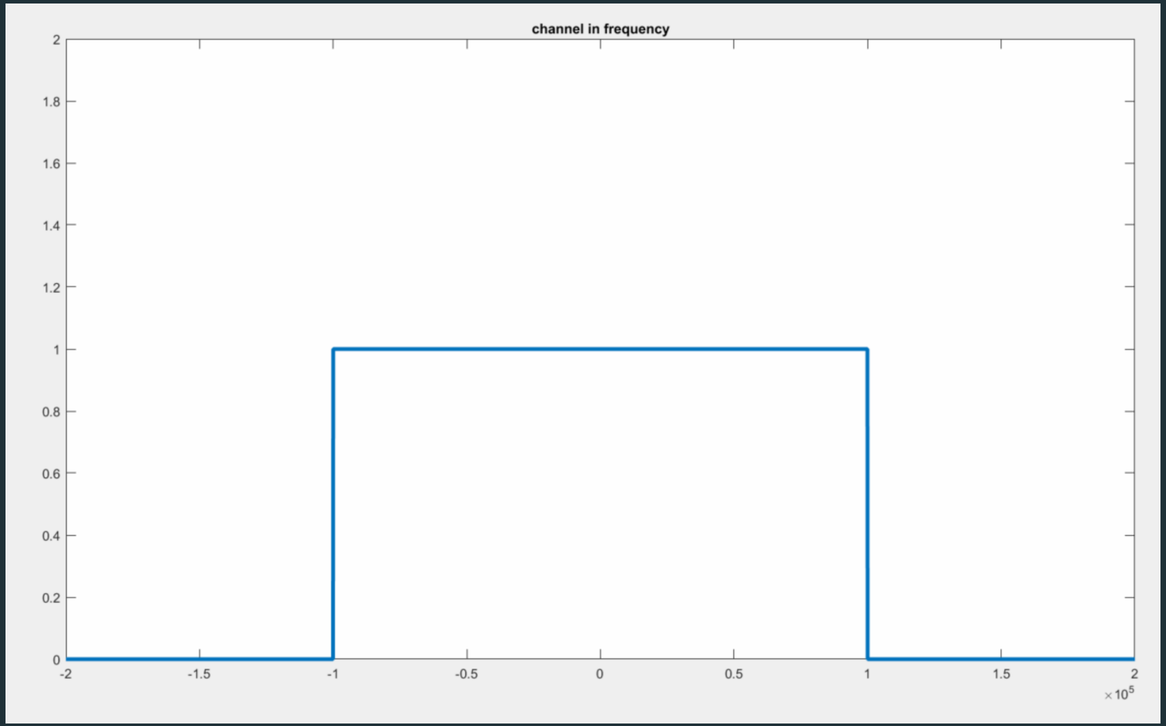




NRZ INPUT NULL TO NULL BANDWIDTH IS $1/T_b$ = 50KHZ

# BAND-LIMITED CHANNEL WITH BANDWIDTH B = 100 KHZ.

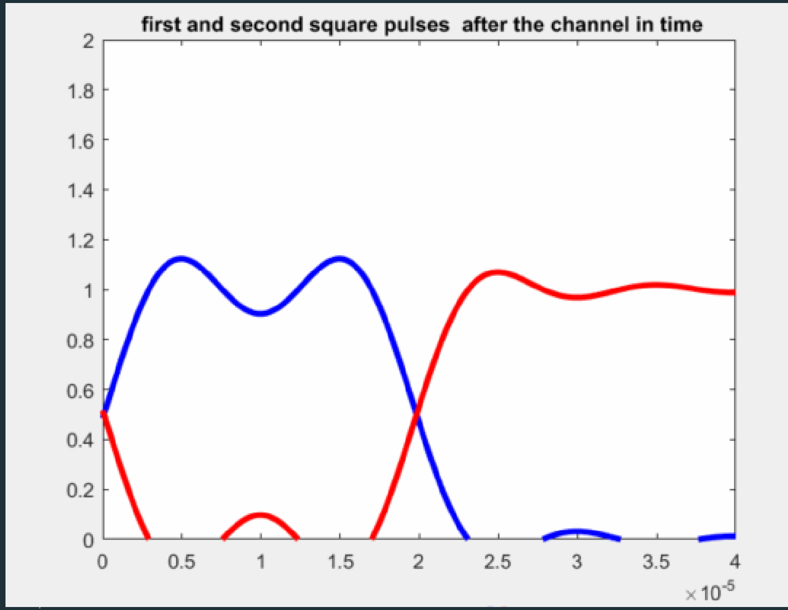


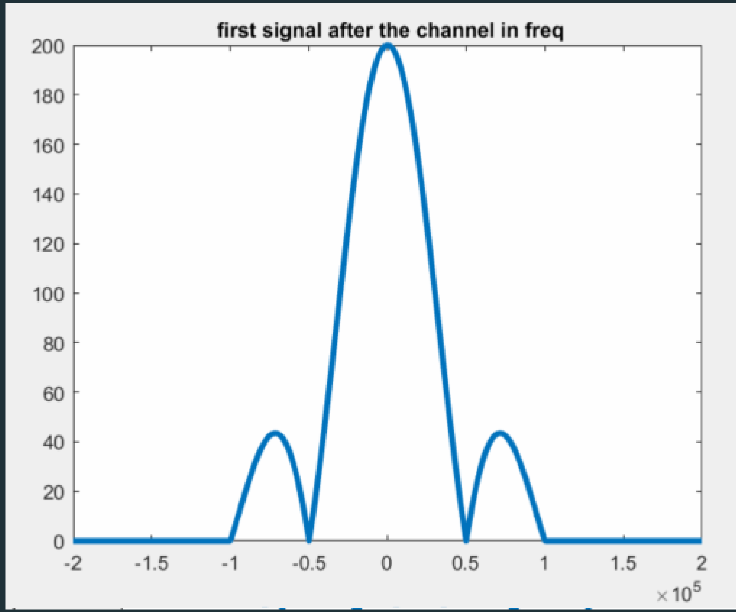

In time domain

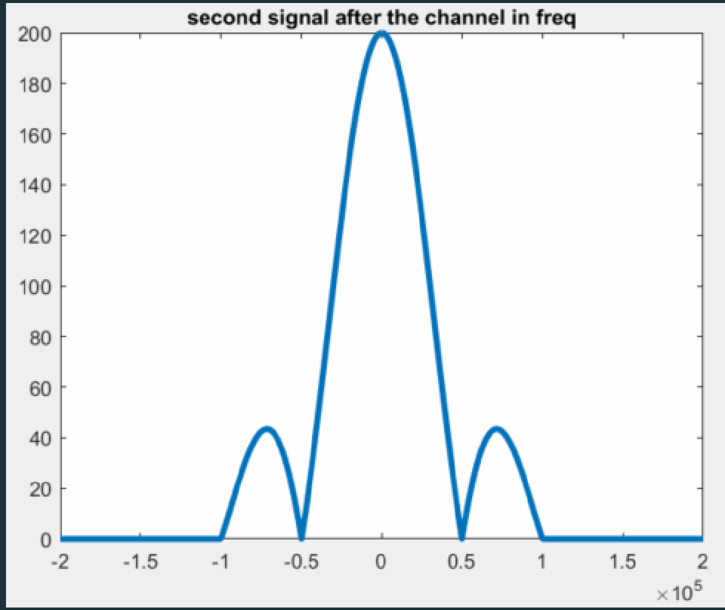



In frequency domain

# FIRST AND SECOND SQUARE AFTER THE CHANNEL IN TIME AND FREQUENCY DOMAIN



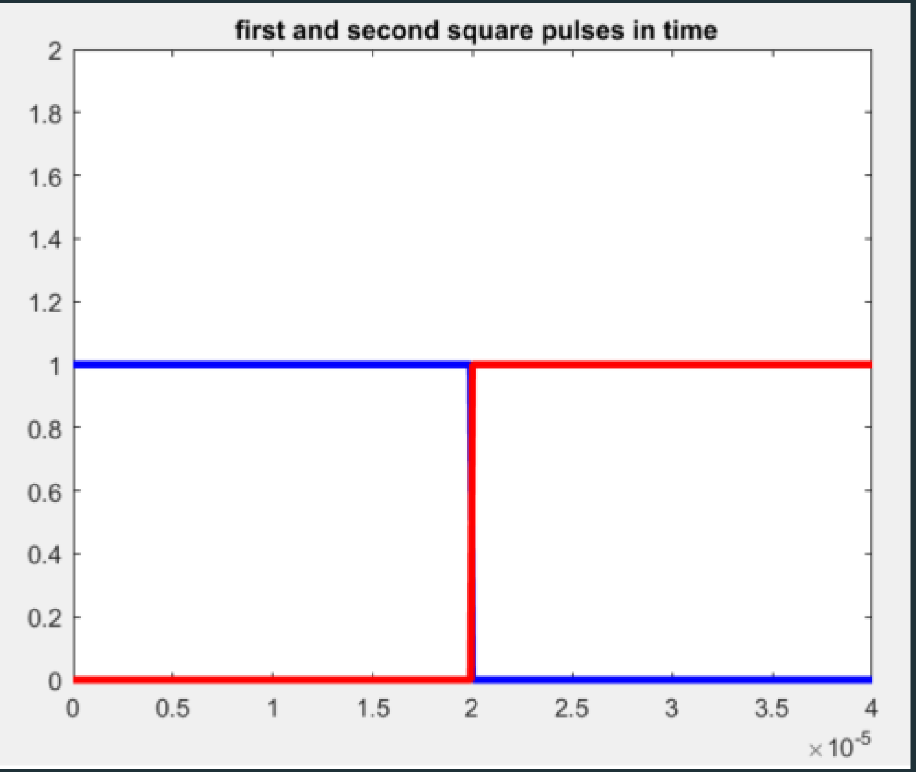



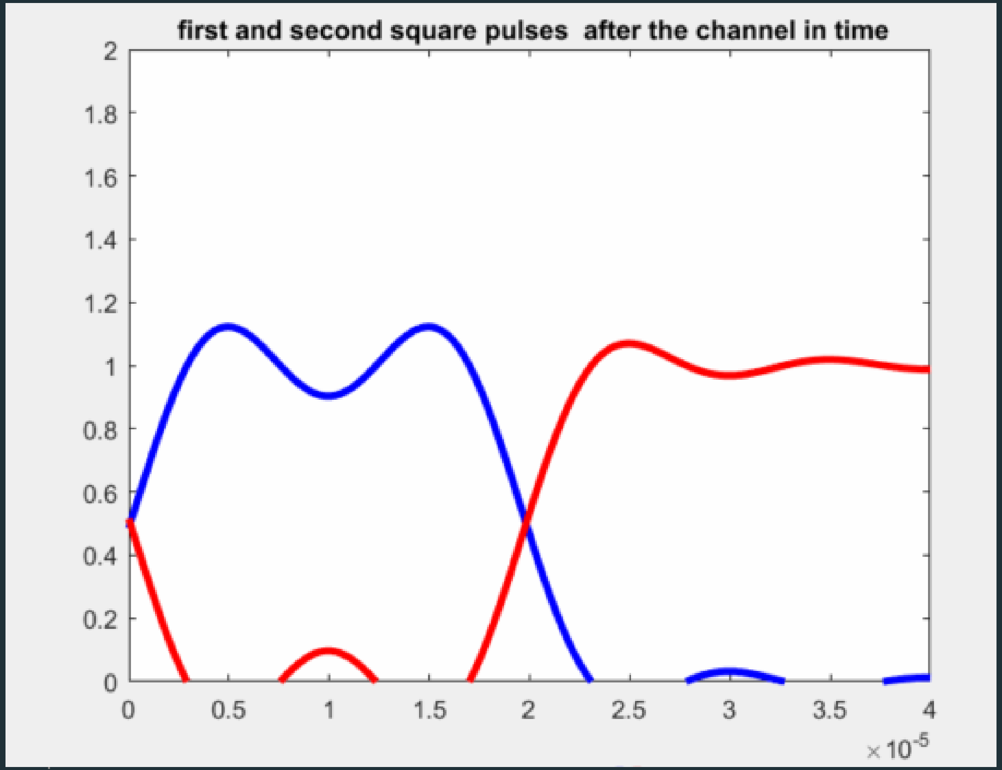

In time domain

In frequency domain

# SHOWING THE TWO PLOTS THE FIRST SQUARE PULSE BEFORE IT PASSES THROUGH THE CHANNEL, AND ONE AFTER IN TIME DOMAIN.

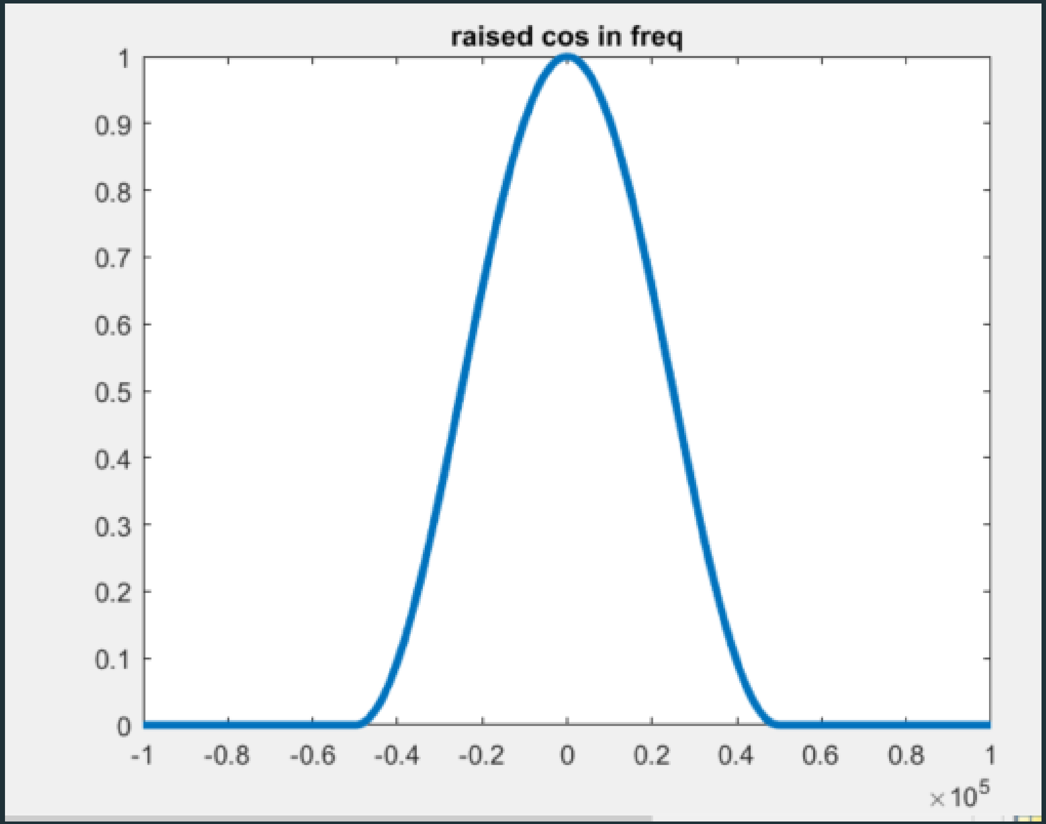


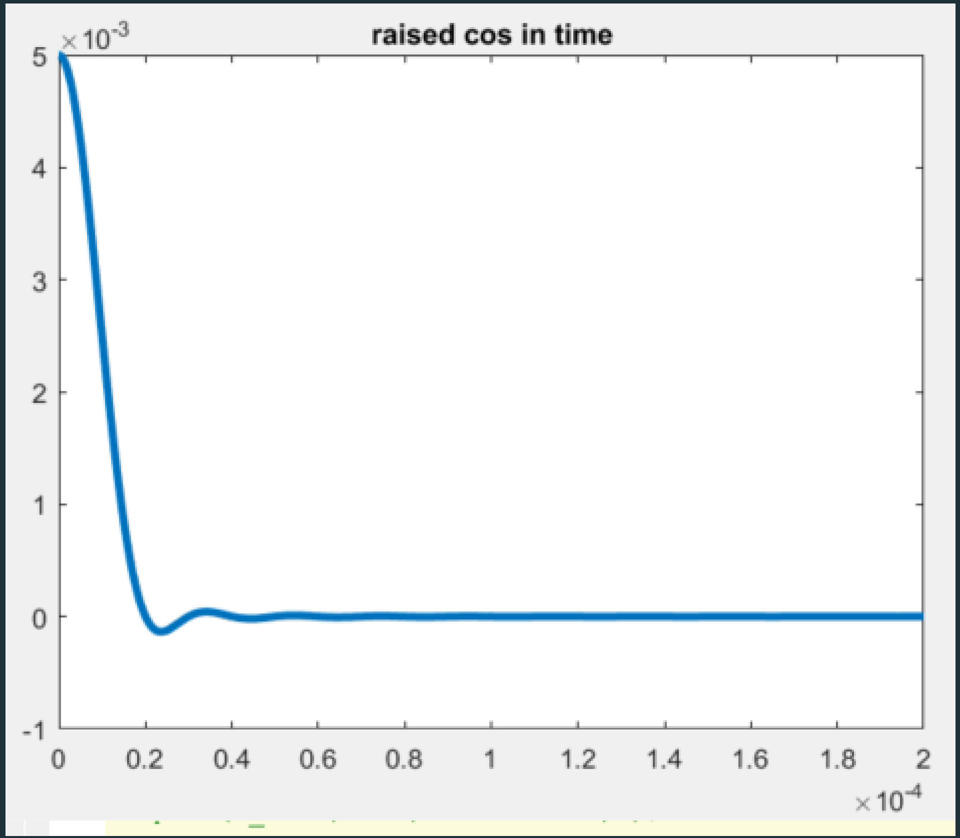

Before the channel



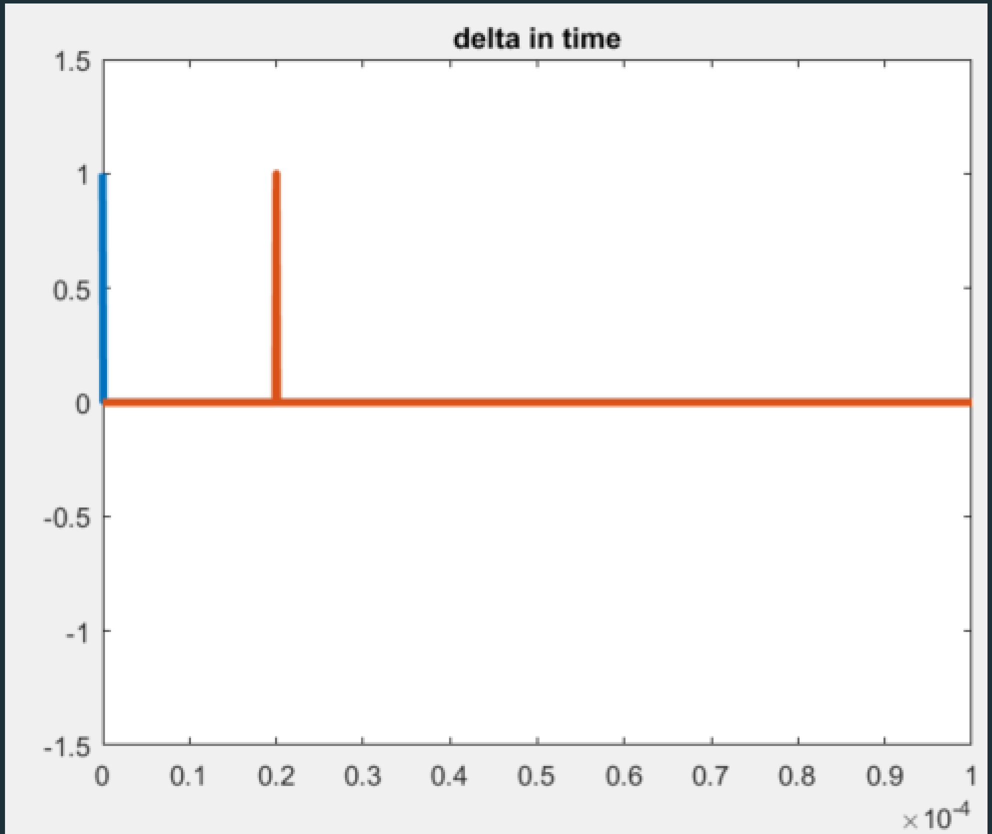

After the channel

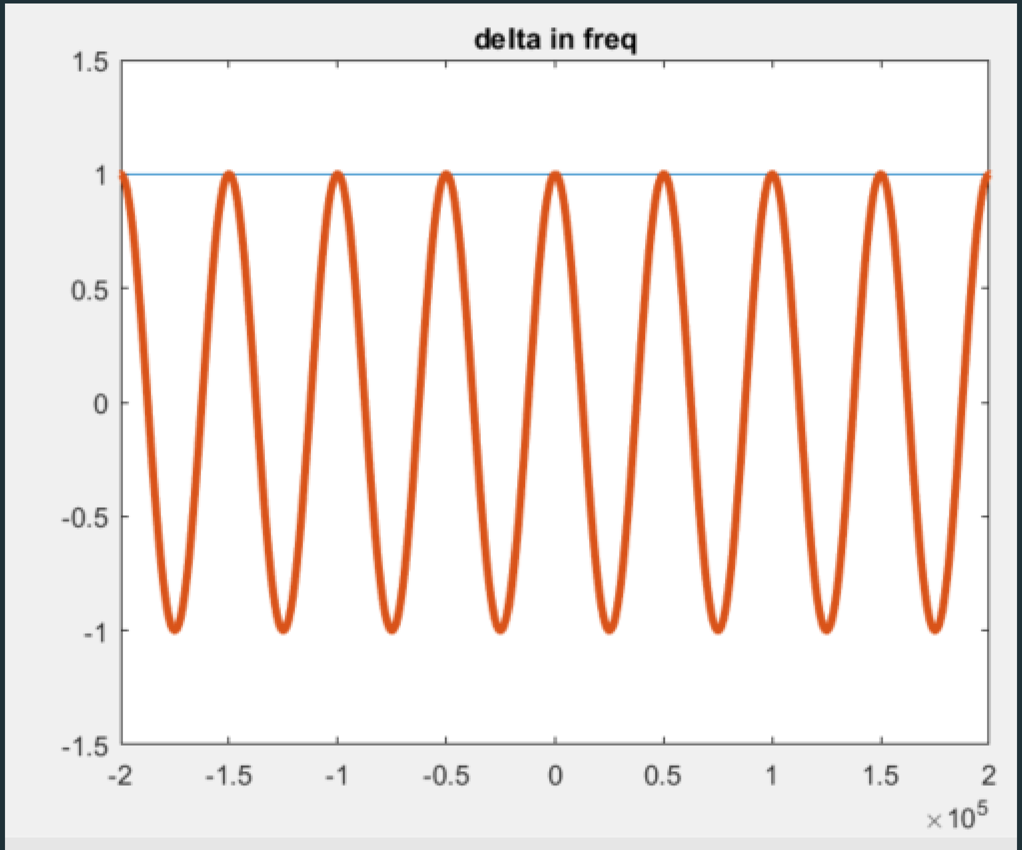
# RAISED COSINE: LIMITED IN FREQUENCY AND UNLIMITED IN TIME (ß = 1).



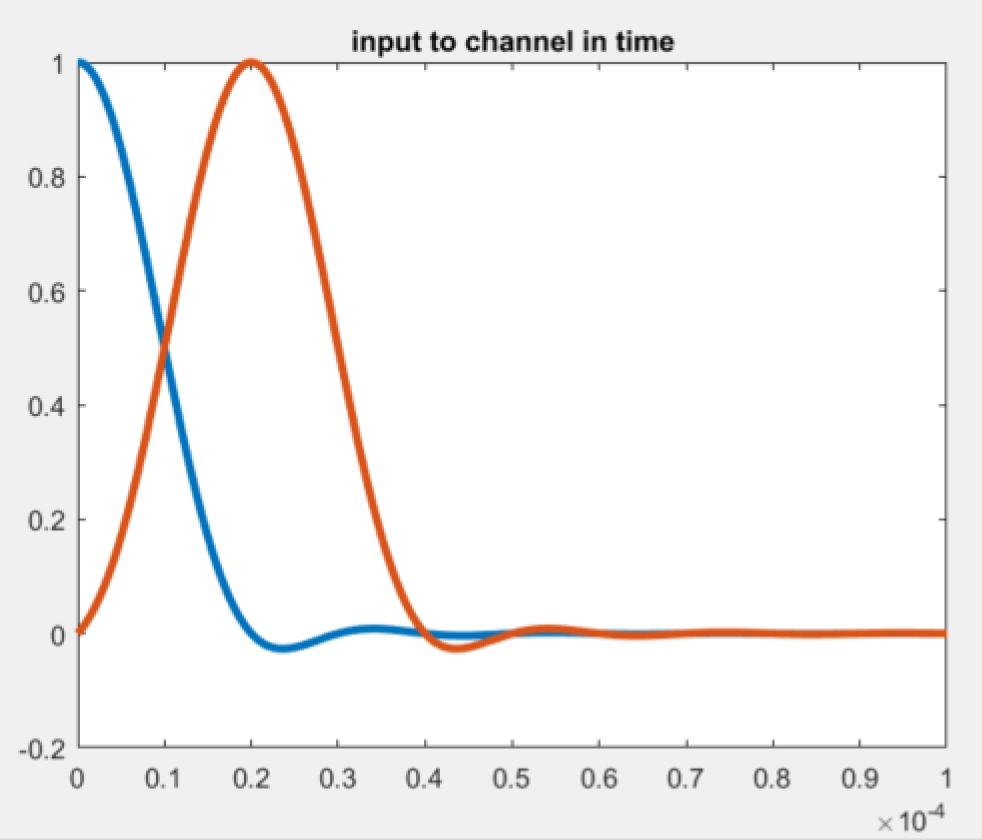



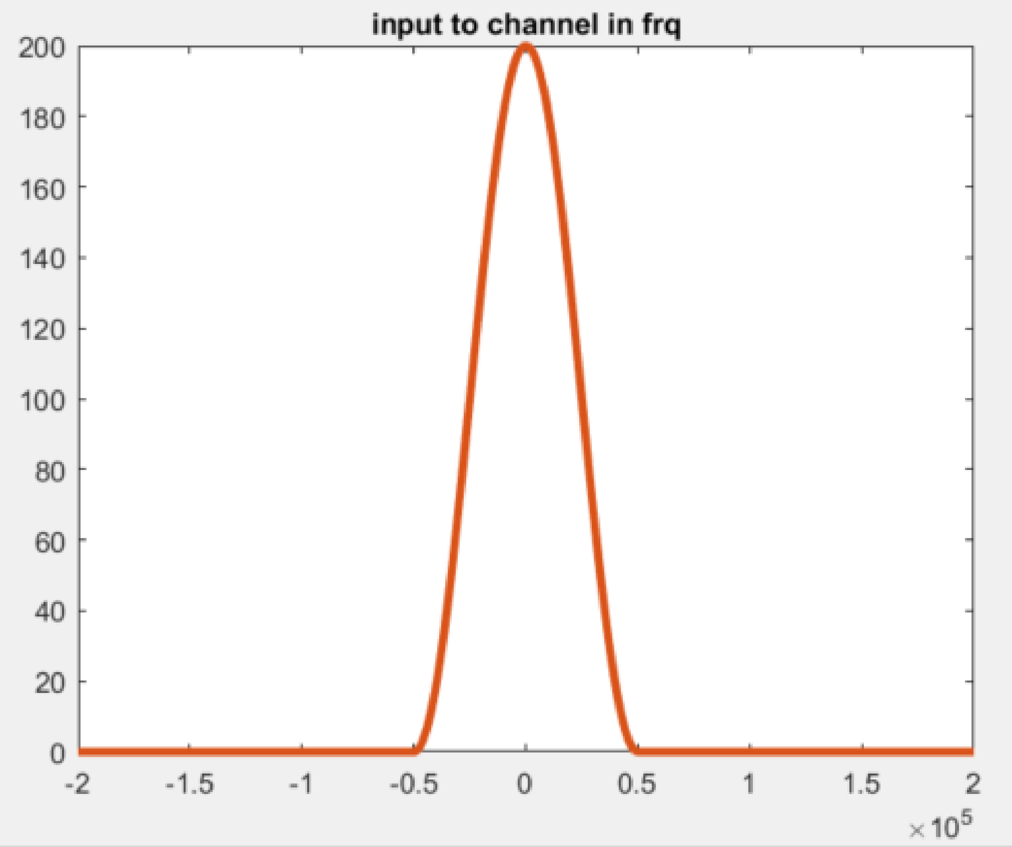
# GENERATING DELTA FOR SHIFTING THE SIGNAL



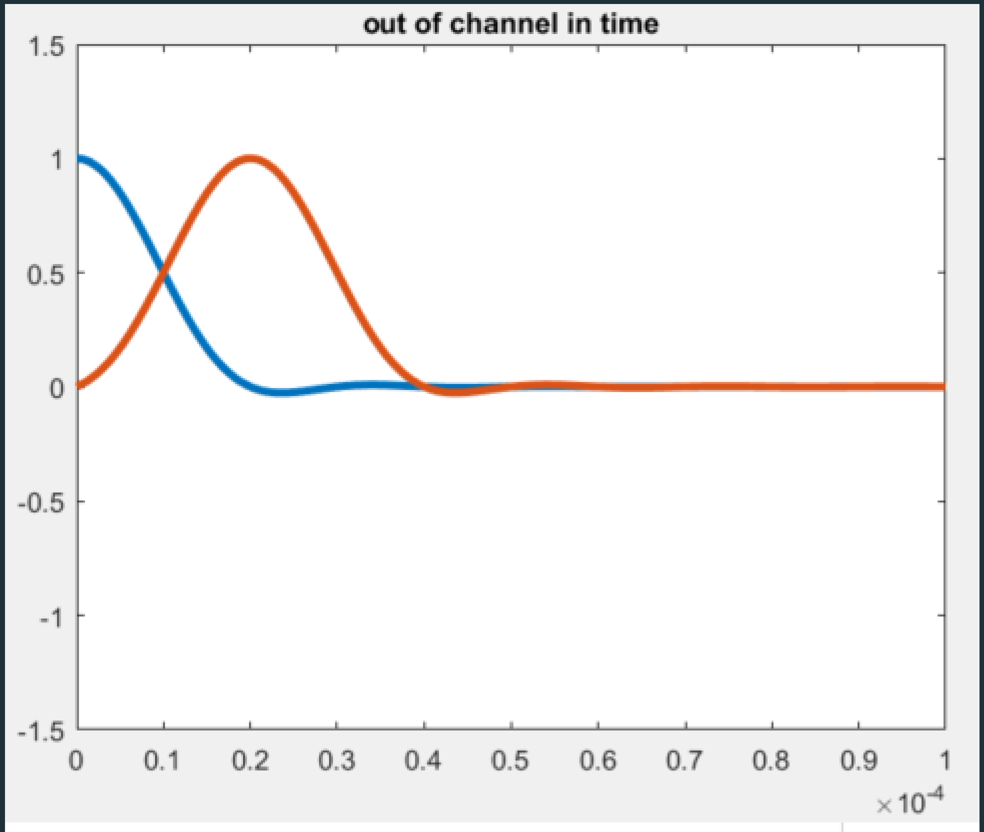



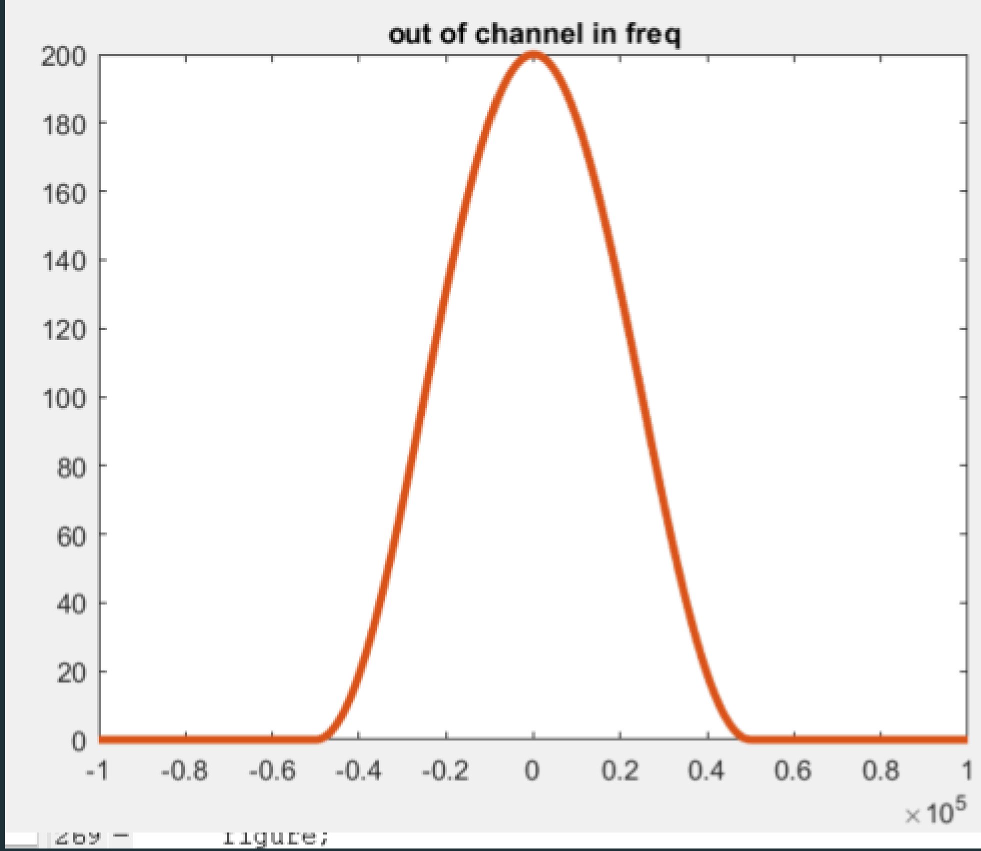
# SHIFTING


input to channel in time
1
0.8
0.6
0.4
0.2
0
-0.2
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
×10-4


input to channel in frq
200
180
160
140
120
100
80
60
40
20
0
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2
×105

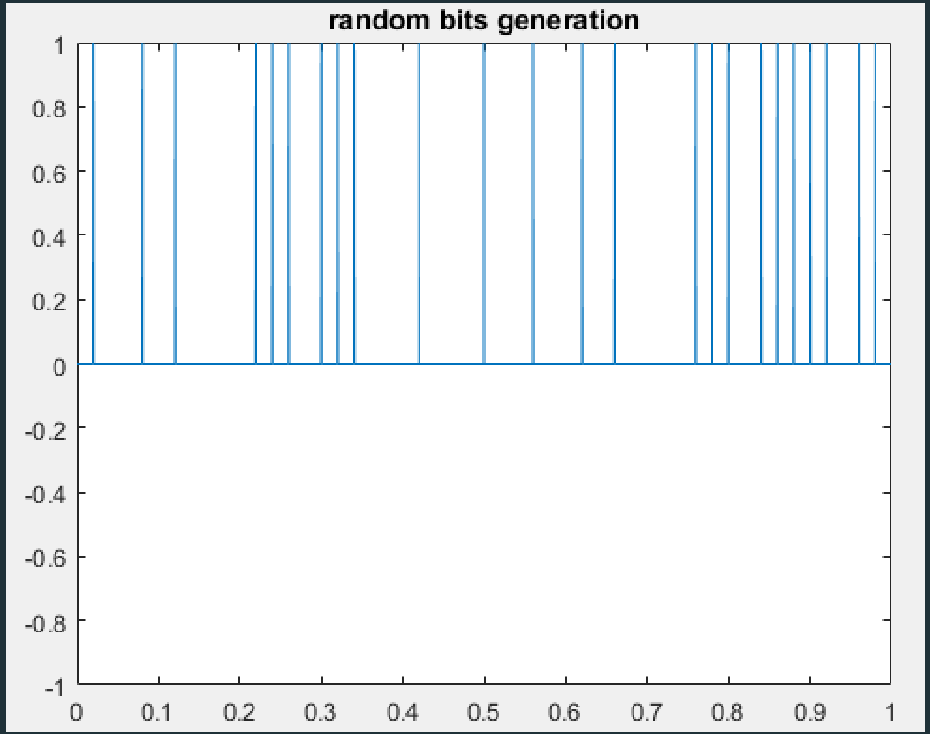
# OUTPUT FROM THE CHANNEL



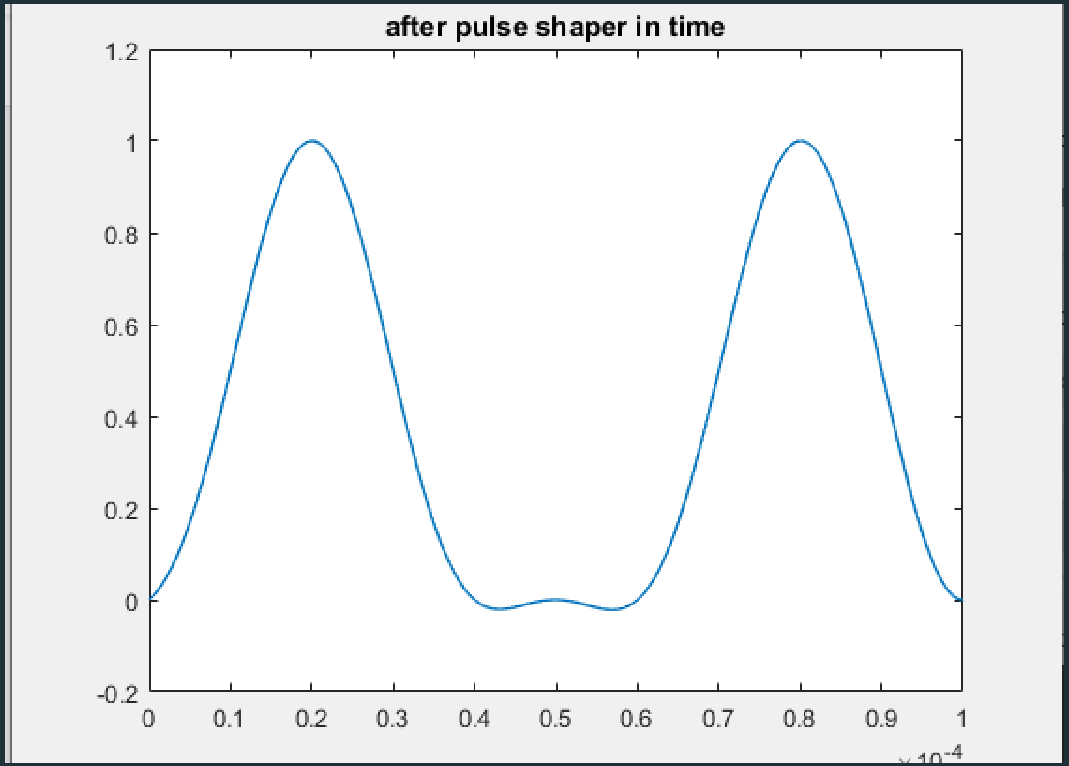



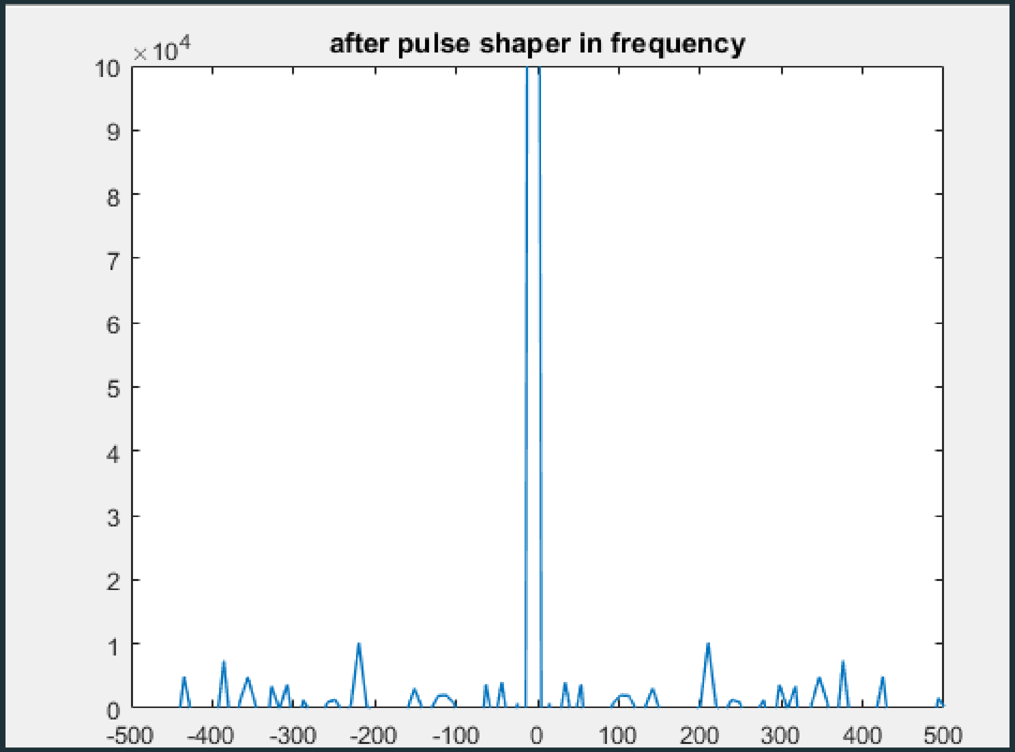

Channel has no effect

# GENERATING RANDOM BITS

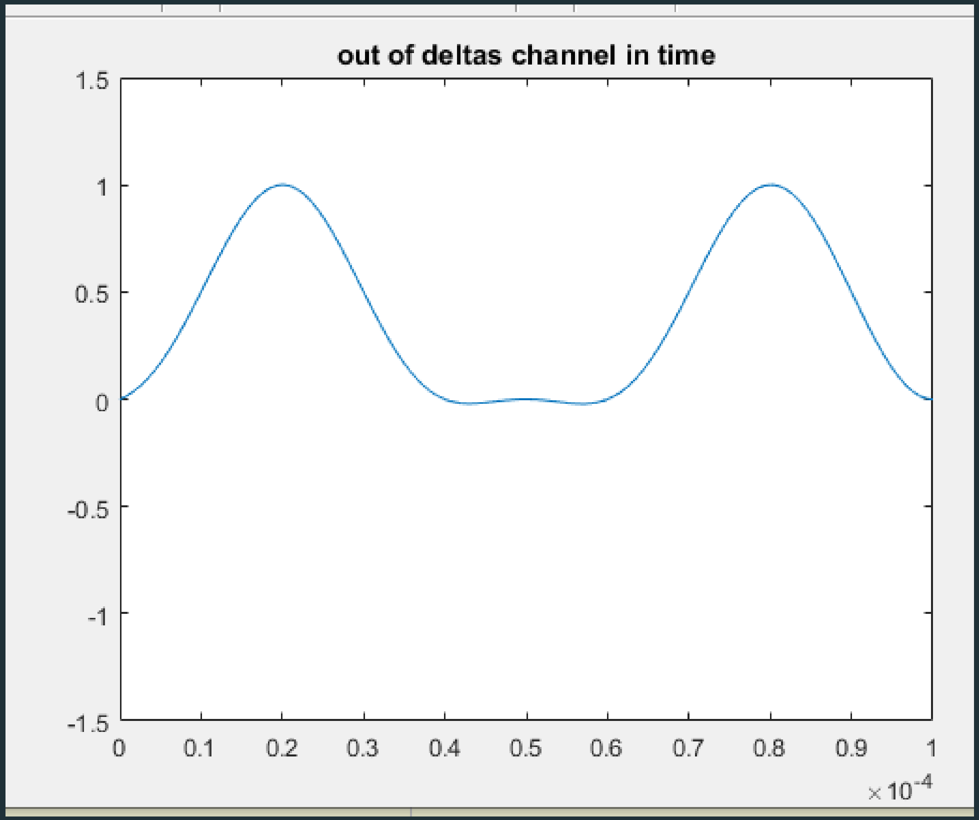


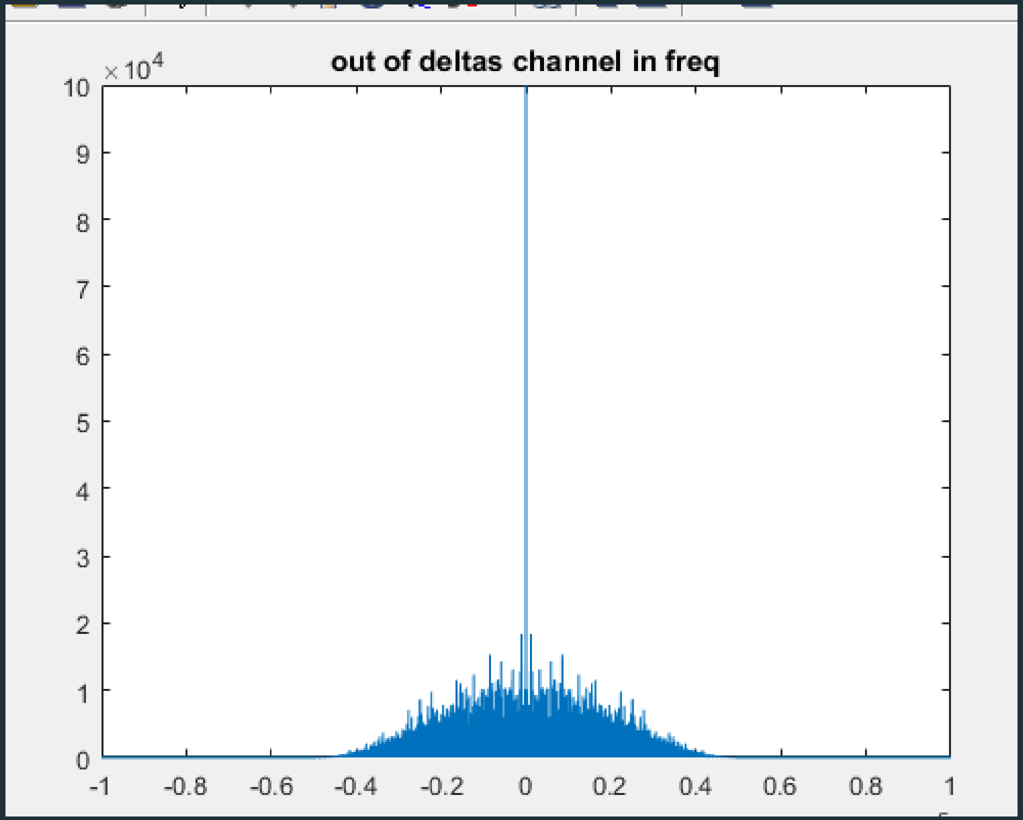
# AFTER PULSE SHAPER IN TIME AND FREQUENCY DOMAIN



# OUTPUT FROM CHANNEL

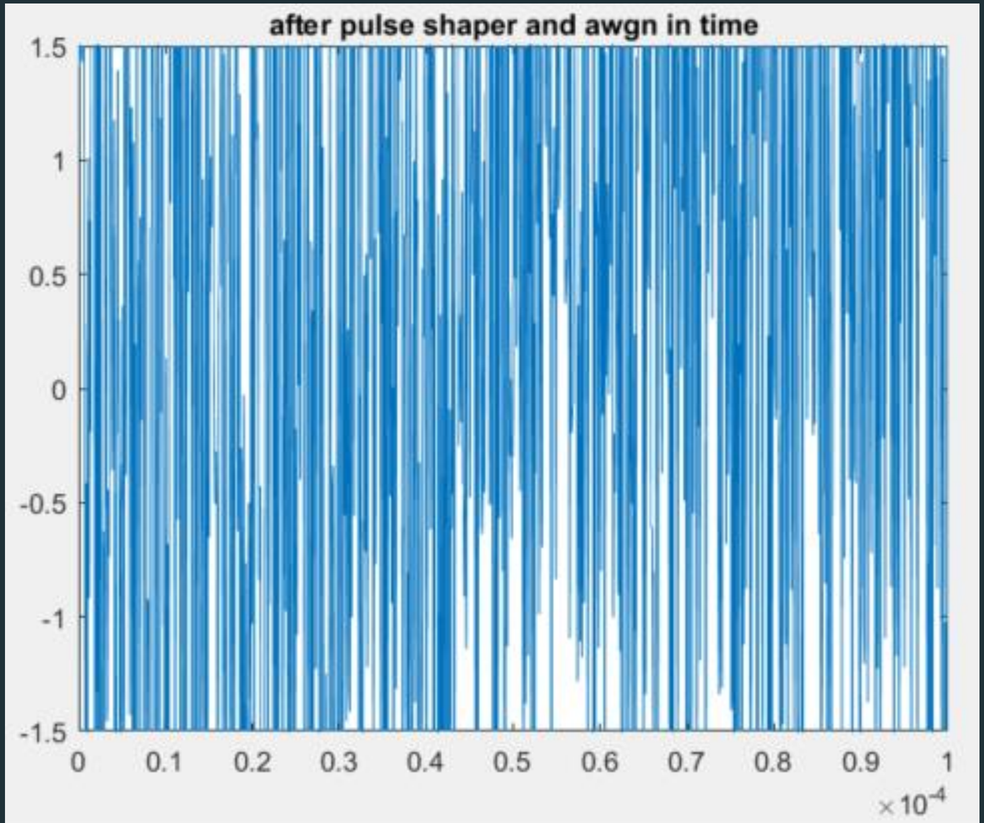


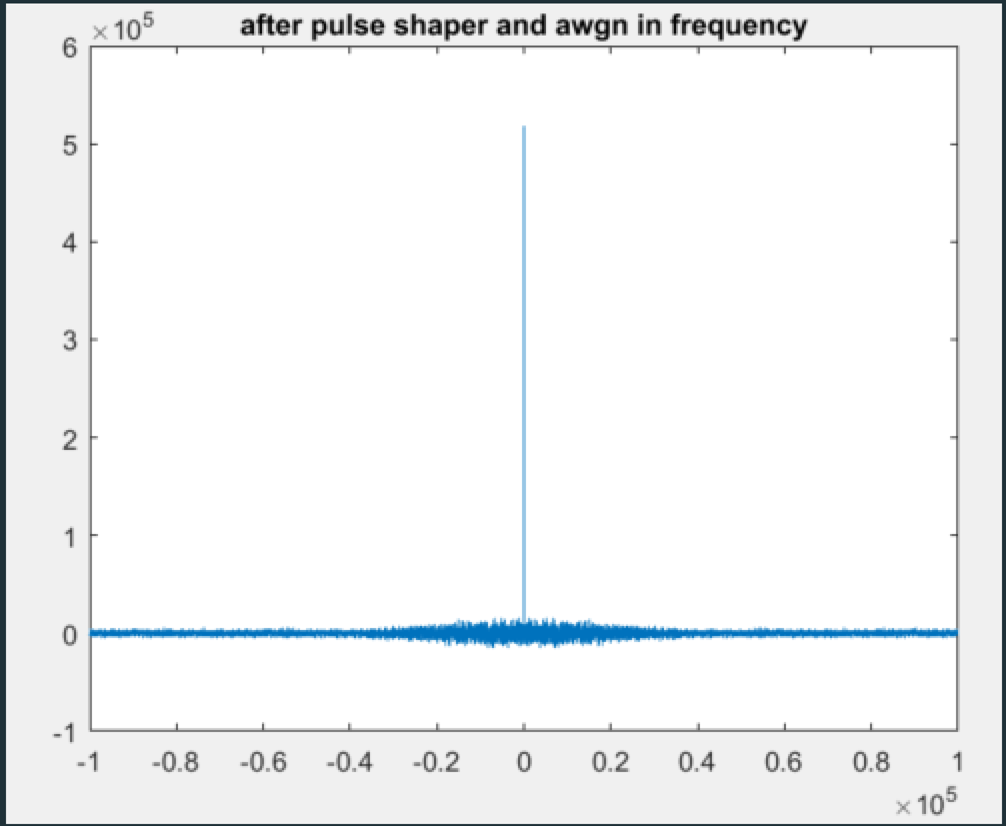



# COMPUTE BER

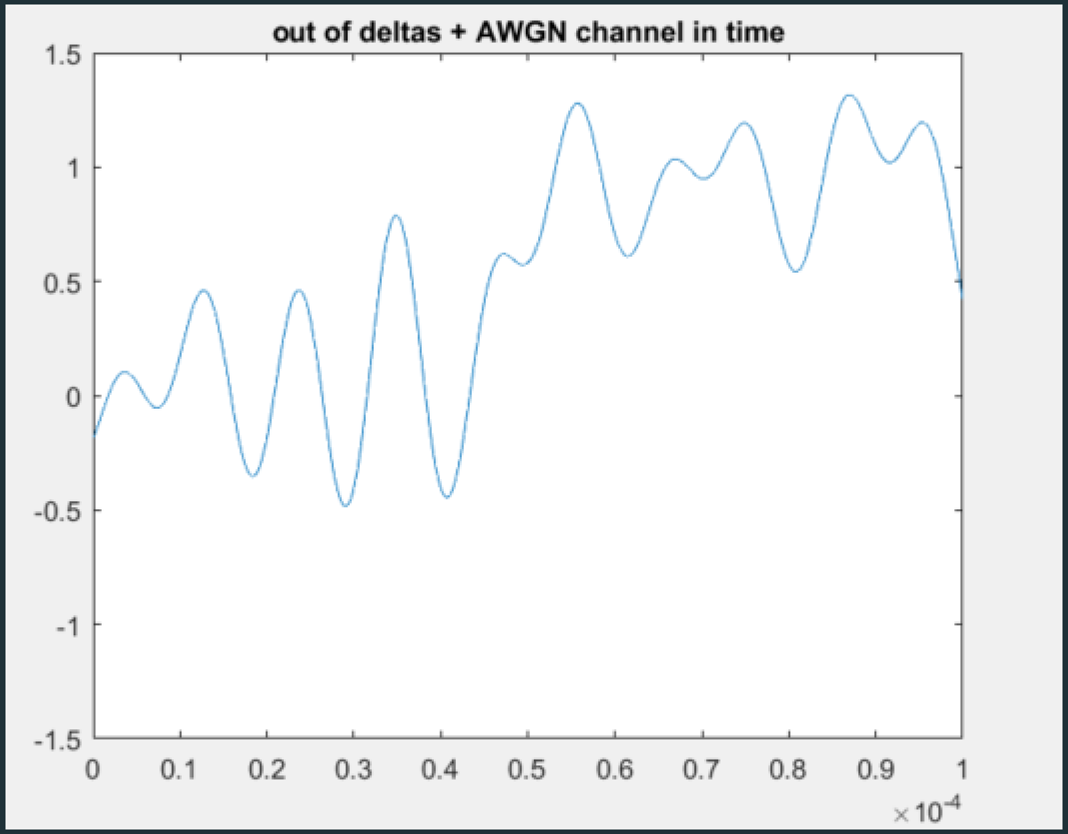
```
BER = 0.000000
```

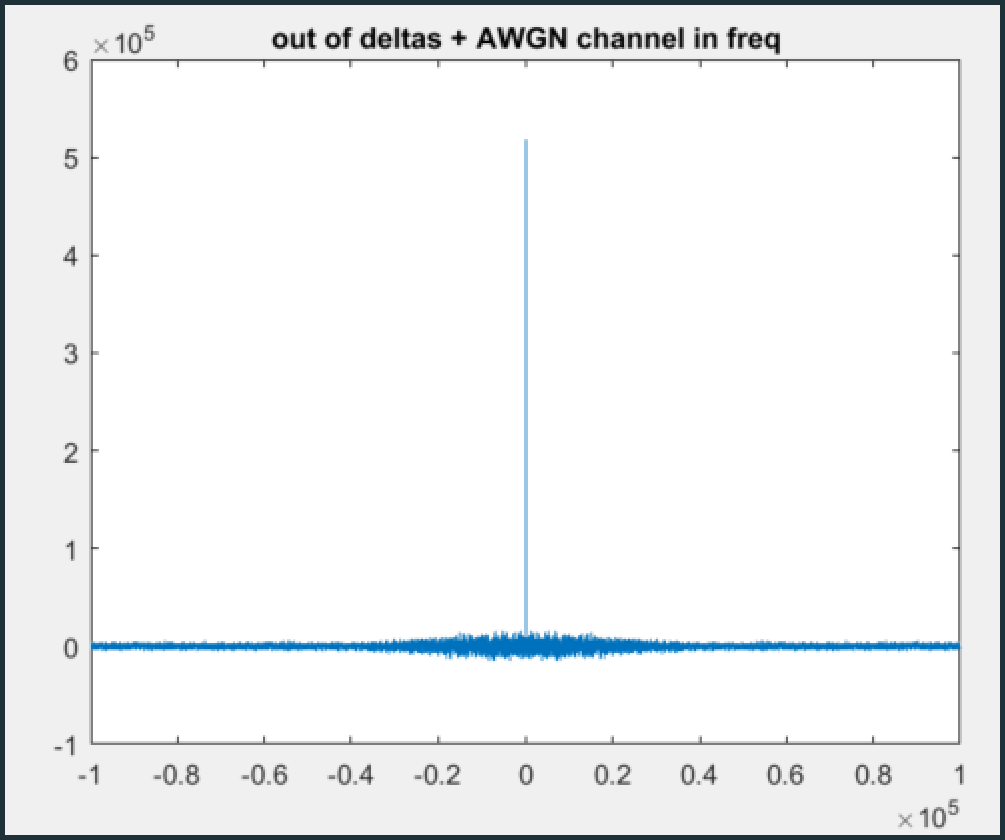
# ADDING AWGN ($N_o$ = 10)



# OUT OF DELTAS + AWGN CHANNEL



# COMPUTE BER WITH AWGN

BER = 0.060168

AT $N_0 = 10$

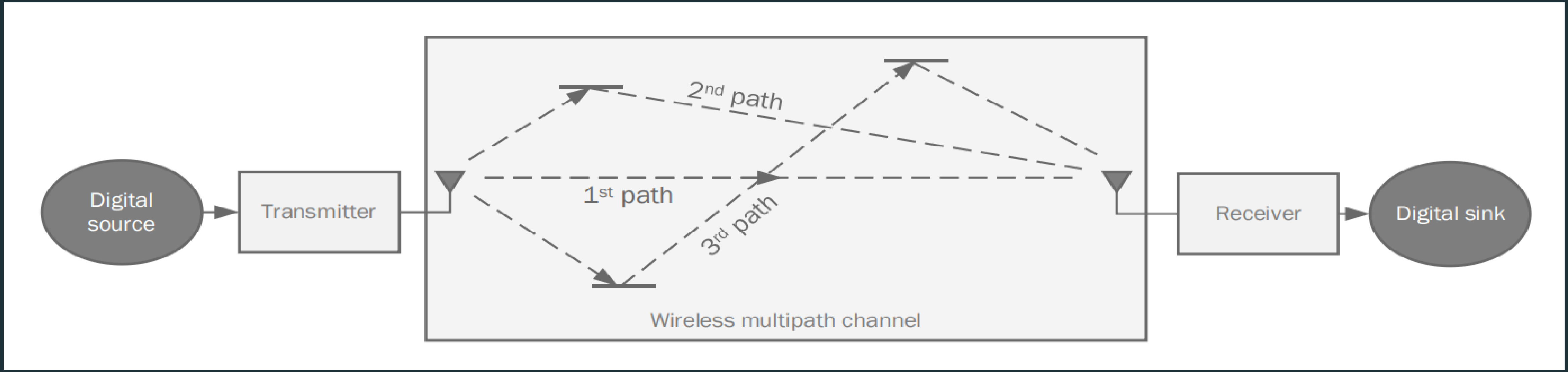
BER = 0.438172

AT $N_0 = 1000$


# INTER-SYMBOL INTERFERENCE DUE TO MULTI-PATH CHANNELS

# STEPS OF PROCESS

I. Generate transmitted symbols(X).
II. Generate channel coefficients (H).
III. Add effect of AWGN channel (N).
IV. Get Received signal Y=HX+N.
V. Estimate transmitted signal.
VI. Calculate BER vs Eb/No



# GENERATE TRANSMITTED SYMBOLS

- Generate random signal of 1's and -1's with length L.

# GENERATE CHANNEL COEFFICIENTS

- Arrange H matrix as shown:

$$\underbrace{\begin{bmatrix} h_0 & & & & & & \\ h_1 & h_0 & & & & & \\ h_2 & h_1 & h_0 & & & & \\ \vdots & & & \ddots & h_1 & h_0 & \\ h_{L-1} & h_{L-2} & h_{L-3} & \cdots & h_2 & h_1 & h_0 \end{bmatrix}}_{H}$$

- The next slide shows a part of result in MATLAB

**Result in MATLAB:**
For L=4000 :

| | 1 |
|---|---|
| 1 | 1 |
| 2 | 1 |
| 3 | 1 |
| 4 | 1 |
| 5 | 1 |
| 6 | -1 |
| 7 | 1 |
| 8 | -1 |
| 9 | -1 |
| 10 | 1 |
| 11 | 1 |
| 12 | 1 |
| 13 | -1 |
| 14 | -1 |
| 15 | -1 |
| 16 | 1 |
| 17 | 1 |
| 18 | 1 |
| 19 | -1 |
| 20 | 1 |
| 21 | -1 |
| 22 | -1 |
| 23 | -1 |
| 24 | 1 |
| ⋮ | |
| 4000 | 1 |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 | 0 |
| 11 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 | 0 |
| 12 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 | 0 |
| 13 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 | 0 |
| 14 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 | 1.5288 |
| 15 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 | 0.8038 |
| 16 | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 | 0.7523 |
| 17 | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 | 0.2557 |
| 18 | 3.5935e-... | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 | 0.1994 |
| 19 | 7.8799e-... | 3.5935e-... | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 | 0.2707 |
| 20 | 1.5967e-... | 7.8799e-... | 3.5935e-... | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 | 0.1044 |
| 21 | 7.5317e-... | 1.5967e-... | 7.8799e-... | 3.5935e-... | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 | 0.0426 |
| 22 | 5.0013e-... | 7.5317e-... | 1.5967e-... | 7.8799e-... | 3.5935e-... | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 | 0.0261 |
| 23 | 1.6571e-... | 5.0013e-... | 7.5317e-... | 1.5967e-... | 7.8799e-... | 3.5935e-... | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 | 0.0132 |
| 24 | 1.3804e-... | 1.6571e-... | 5.0013e-... | 7.5317e-... | 1.5967e-... | 7.8799e-... | 3.5935e-... | 6.7266e-... | 0.0011 | 0.0014 | 0.0024 | 0.0027 | 0.0037 | 0.0034 |

# ADD EFFECT OF AWGN CHANNEL

- Generate random noise with zero mean and one variance.

Result in MATLAB:

| | 1 |
|---|---|
| 1 | 0.4117 |
| 2 | -0.4186 |
| 3 | 0.6624 |
| 4 | -0.4599 |
| 5 | -0.5680 |
| 6 | -0.1180 |
| 7 | -0.4343 |
| 8 | -1.3030 |
| 9 | -0.1754 |
| 10 | 0.9302 |
| 11 | -1.7471 |
| 12 | 0.1420 |
| 13 | 0.7690 |
| 14 | -0.6486 |
| 15 | -0.0481 |
| 16 | -0.4305 |
| 17 | -0.3492 |
| 18 | 1.1565 |
| 19 | 1.1871 |
| 20 | 1.2258 |
| ⋮ | |
| 4000 | 0.4786 |

# GET RECEIVED SIGNAL

- Calculate received signal by this equation $Y=HX+N$.

Result in MATLAB:

| | 1 |
|---|---|
| 1 | 1.9405 |
| 2 | 1.9140 |
| 3 | 3.7473 |
| 4 | 2.8807 |
| 5 | 2.9720 |
| 6 | 0.6350 |
| 7 | 1.8730 |
| 8 | -1.9076 |
| 9 | -1.3683 |
| 10 | 1.4161 |
| 11 | -0.3039 |
| 12 | 3.0271 |
| 13 | 0.6929 |
| 14 | -2.1071 |
| 15 | -2.5277 |
| 16 | -0.1869 |
| 17 | 1.1623 |
| 18 | 3.6791 |
| 19 | 0.9743 |
| 20 | 2.7804 |
| ⋮ | |
| 4000 | 3.9351 |

# ESTIMATE TRANSMITTED SIGNAL

- Equalize channel effect by multiply the received signal by inverse of channel matrix.
- Make decision for each bit using threshold voltage equals (0) to get estimated (transmitted) signal

# CALCULATE BER VS EB/NO

- Change value of Eb/No from -15 to 0 .
- Calculate BER for each change .

Values of BER

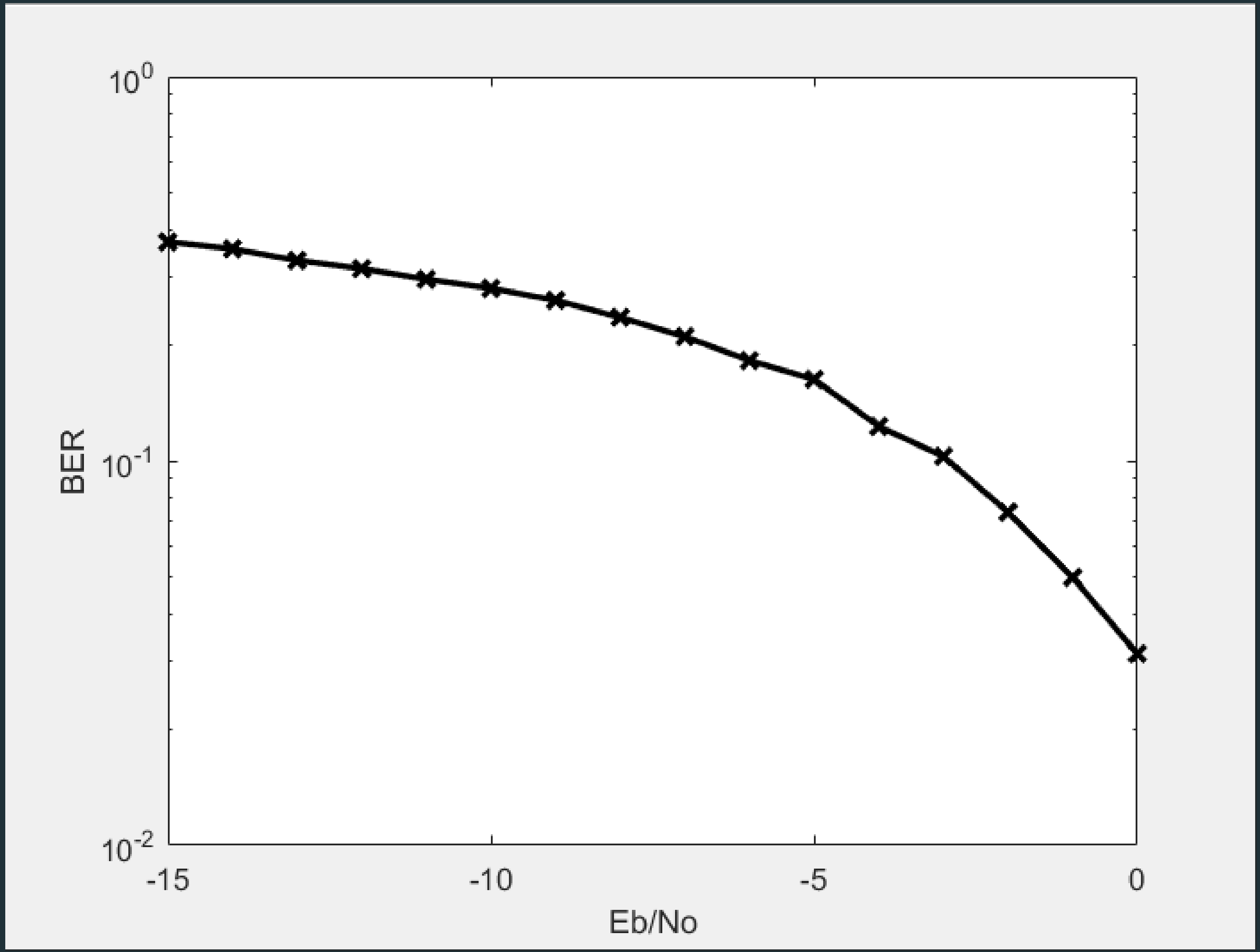
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.3715 | 0.3563 | 0.3325 | 0.3165 | 0.2970 | 0.2813 | 0.2618 | 0.2363 | 0.2105 | 0.1825 | 0.1630 | 0.1230 | 0.1028 | 0.0735 | 0.0498 | 0.0315 |

Result in MATLAB:

| | 1 |
|---|---|
| 1 | 1 |
| 2 | 1 |
| 3 | 1 |
| 4 | 1 |
| 5 | 1 |
| 6 | -1 |
| 7 | 1 |
| 8 | -1 |
| 9 | -1 |
| 10 | 1 |
| 11 | -1 |
| 12 | 1 |
| 13 | -1 |
| 14 | -1 |
| 15 | -1 |
| 16 | 1 |
| 17 | 1 |
| 18 | 1 |
| 19 | -1 |
| 20 | 1 |
| 21 | -1 |
| 22 | -1 |
| 23 | -1 |
| 24 | 1 |
| ⋮ | |
| 4000 | 1 |

- Draw relation between BER and Eb/No.

- The value of BER decrease as Eb/No increase.




# REPETITION CODE

# STEPS OF PROCESS

I. Generate information (transmitted) bits with length N.

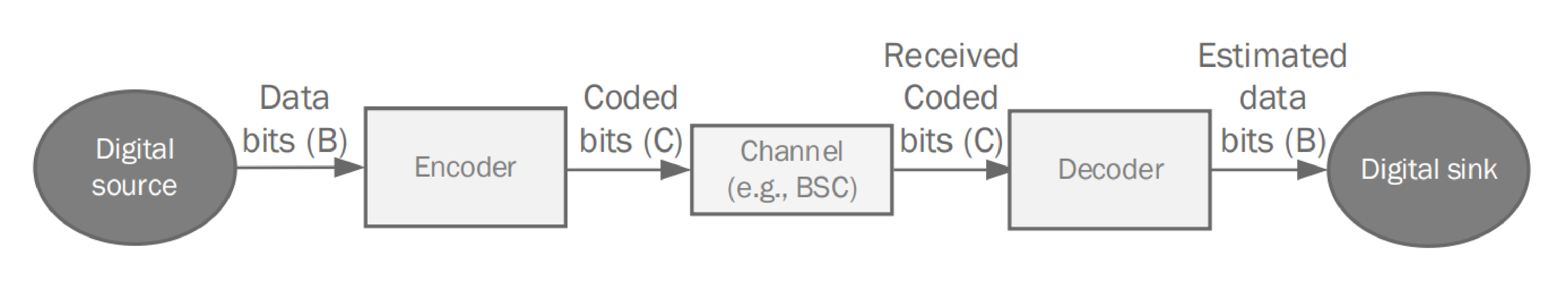
II. Repeat information bits L times.

III. See effect of BSC channel.

IV. Make decision for each bit to get received bits.

V. Compute BER.

VI. See effect of bit flipping probability on BER.




b ➔ block length

c ➔ coded length

# GENERATE INFORMATION (TRANSMITTED) BITS

- Generate a sequence of bits which consists of 0's and 1's.

**Result in MATLAB:**

For N=1000

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | . . . | 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | | 1 |

# REPEAT INFORMATION BITS L TIMES

- Calculate coding rate of repetition code ( $r=\frac{N}{C}$ ).
- Repeat each bit L times ( $L=\frac{1}{r}$ ) to get sequence of samples.

**Result in MATLAB:**

For C=5000

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | . . . | 4996 | 4997 | 4998 | 4999 | 5000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | | 1 | 1 | 1 | 1 | 1 |

# SEE EFFECT OF BSC CHANNEL

- Pass Sequence of sample through BSC channel .
- generates the output sample sequence based on the Independent channel and parameter.

## Result in MATLAB:

Channel effect:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | . . . | 4999 | 5000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | | 0 | 0 |

Output sample sequence:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | . . . | 4999 | 5000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | | 1 | 1 |

# MAKE DECISION FOR EACH BIT TO GET RECEIVED BITS

- Make decision for each L bits using threshold voltage equals (L/2) to get received bits .

## Result in MATLAB:

Received bits

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | . . . | 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | | 1 |

Compute BER for p=0.5

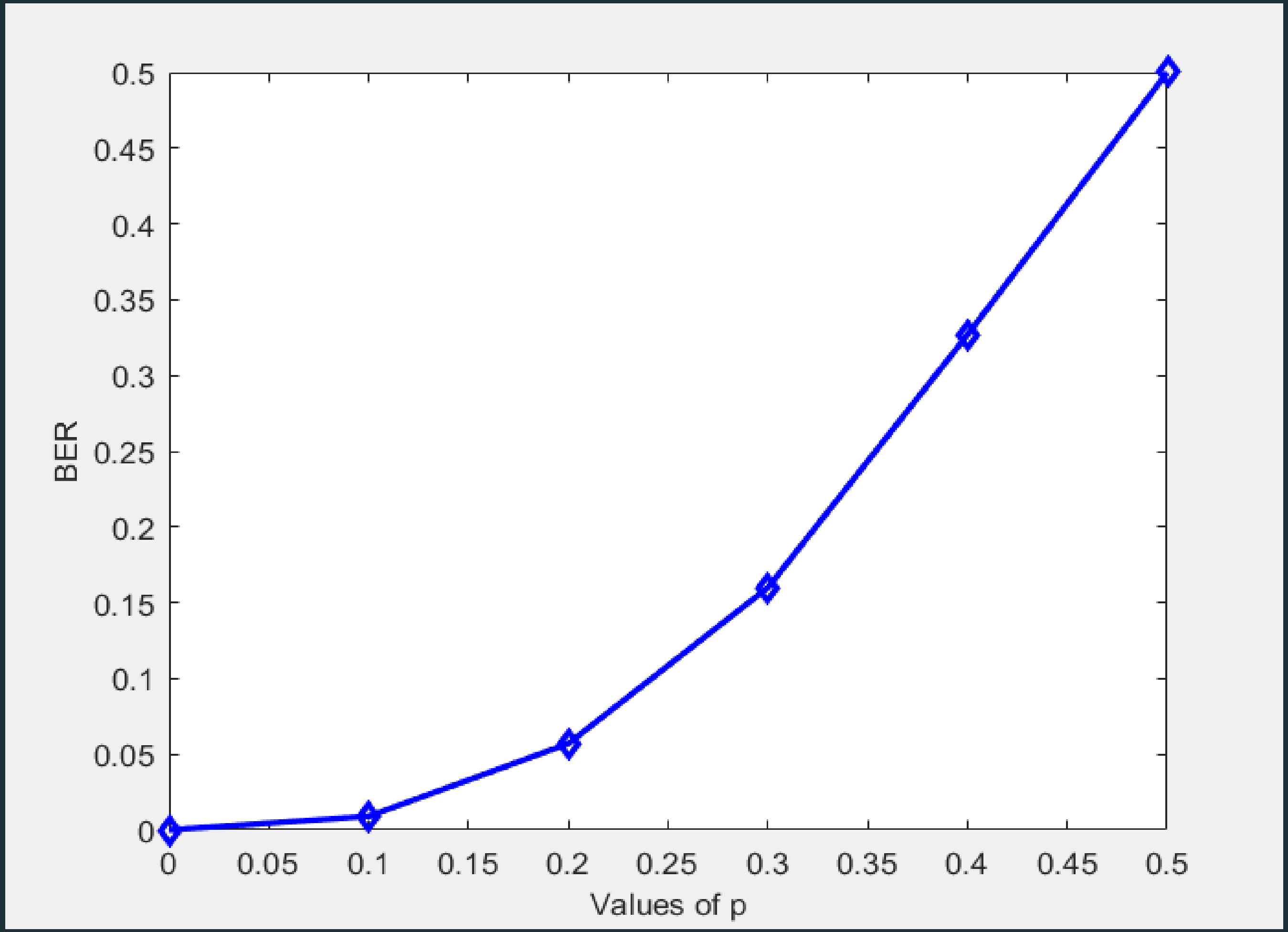
| | |
|---|---|
| BER | 0.4730 |

# SEE EFFECT OF BIT FLIPPING PROBABILITY ON BER

- Change the channel parameter from 0 to 0.5 .
- Calculate BER for each change .

Result in MATLAB:

- Draw relation between BER and P.
- BER increases as channel parameter increases because when p is large value , random numbers which equal or smaller than p are large so there are large number of ones XOR with signal so there is high effect of flipping on signal.




# CONVOLUTIONAL CODE

# STEPS OF PROCESS

I. Generate input bits .

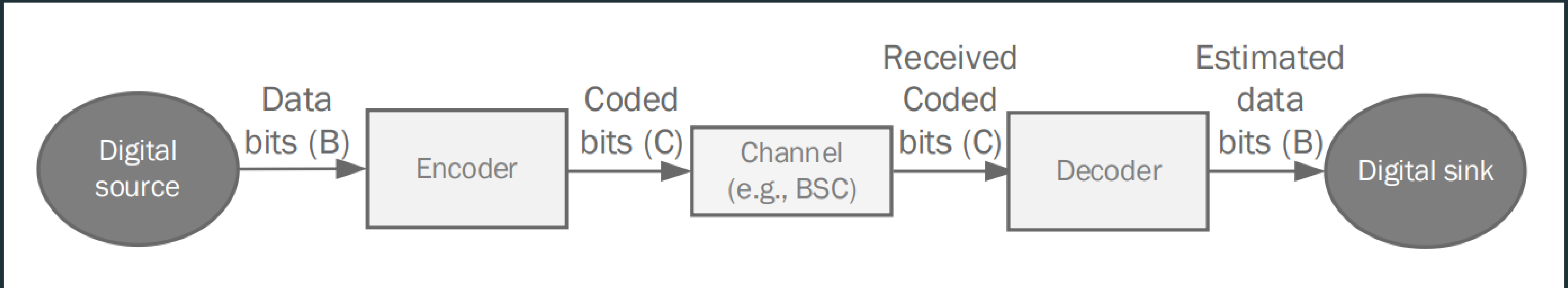
II. Encode information bits based on a given Generator polynomial.

III. See effect of BSC channel .

IV. Decode received coded bits into estimated data bits by Viterbi algorithm.

V. Compute BER.

VI. See effect of bit flipping probability on BER.



# GENERATE INPUT BITS

- Generate a sequence of bits which consists of 0′s and 1′s.

Result in MATLAB:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | . . . | 4000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | | 1 |

# ENCODE INFORMATION BITS

- Pass input bits through m shift registers.
- Number of encoded bits = m* length of msg .

Result in MATLAB:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | . . . | 11996 | 11997 | 11998 | 11999 | 12000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | | 0 | 0 | 1 | 1 | 1 |

## SEE EFFECT OF BSC CHANNEL

- Pass Sequence of sample through BSC channel .
- generates the output sample sequence based on the Independent channel and parameter.

Result in MATLAB:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | . . . | 11999 | 12000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | 1 | 1 |

## DECODE RECEIVED CODED BITS INTO ESTIMATED DATA BITS

- Decode received bits using vitdec function .

Result in MATLAB:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | . . . | 3999 | 4000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | | 1 | 1 |

# COMPUTE BER

Compute BER for p=0.5

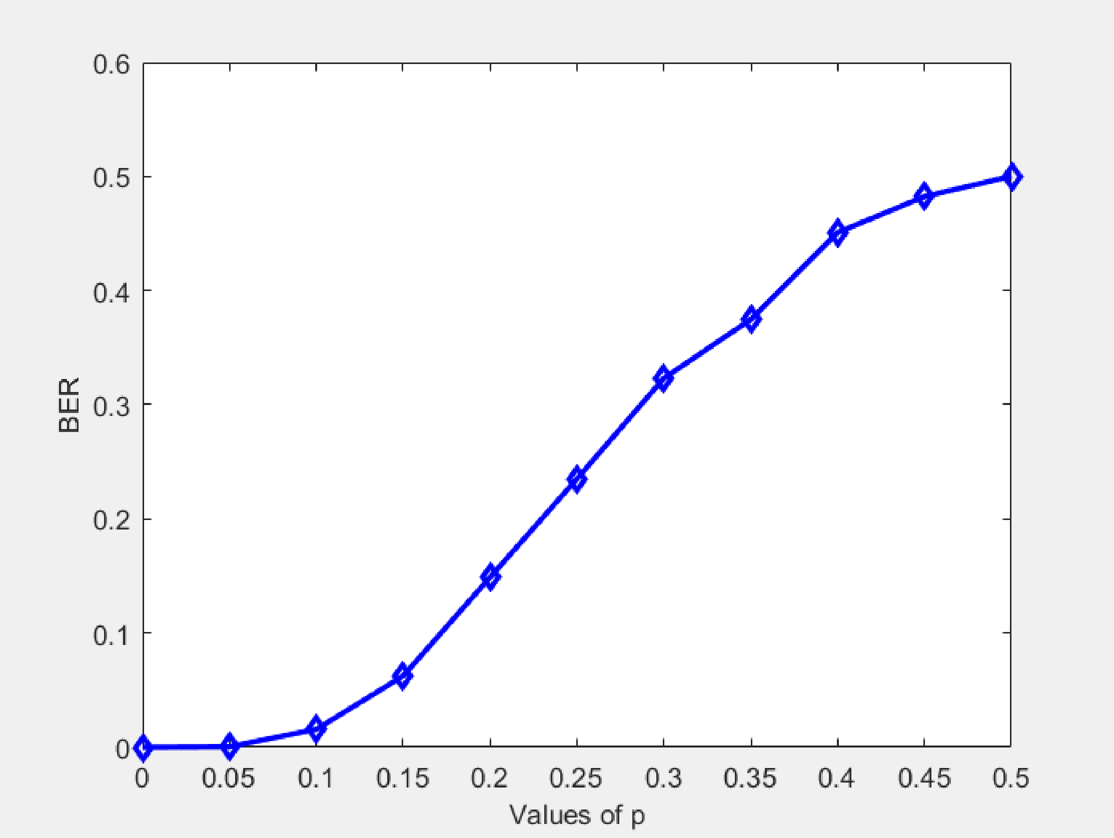
| | |
|---|---|
| BER | 0.5053 |

# SEE EFFECT OF BIT FLIPPING PROBABILITY ON BER

- Change the channel parameter from 0 to 0.5 .
- Calculate BER for each change .

Result in MATLAB:

- BER increases as channel parameter increases because when p is large value , random numbers which equal or smaller than p are large so there are large number of ones XOR with signal so there is high effect of flipping on signal.




150.01
145.58
173.16
101.09
144.99
145.58
115.49
144.22
106.99
160.18
153.63
145.74

# POLAR CODE

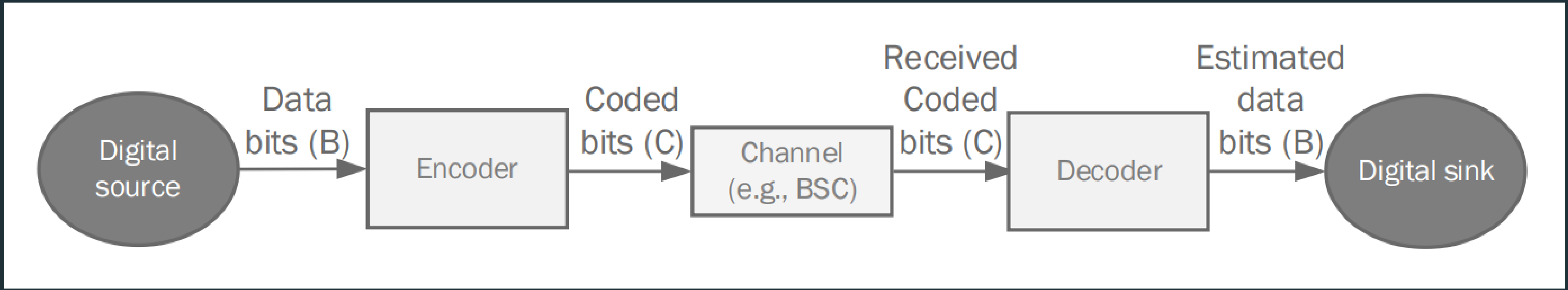
# STEPS OF PROCESS

I. Generate input bits .

II. Encode information bits by polarization transformation.

III. See effect of BSC channel .

IV. Decode received coded bits into estimated data bits by Successive Cancellation.



# GENERATE INPUT BITS

- N=2^n
- Message : m of length K bits
- Form a vector U of length N bits as follows:
  - Find N-K least reliable (worst) channels from reliability sequence
  - Set Ui for those N-K channels to zero (called frozen positions)
  - m:remaining K bits of U (called message positions)

## Example on reliability sequence for N=16

(16,10)

- 1 2 3 5 9 4 6 10 7 11 13 8 12 14 15 16
  - Frozen: 1 2 3 5 9 4
  - Message: 6 10 7 11 13 8 12 14 15 16

## Result in MATLAB:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |

Message bits

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

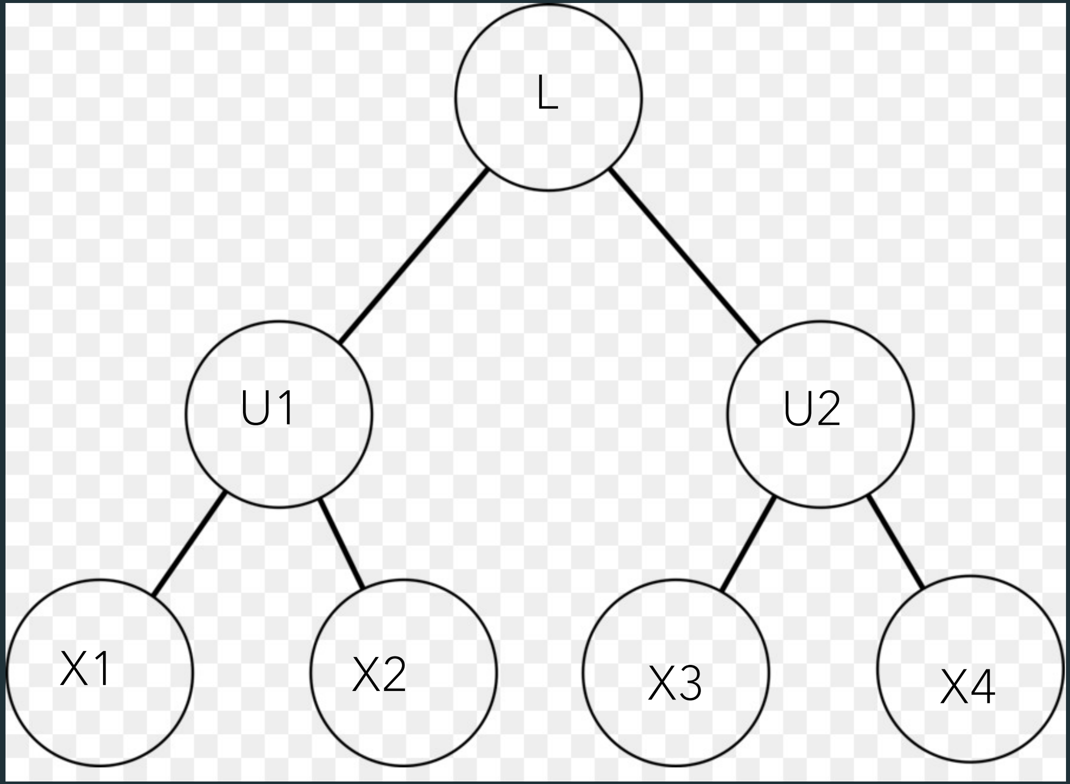
Input bits

# ENCODER

- Binary tree representation

  Depth n

- U1 = [X1+X2   X2]
- U2 = [X3+X4   X4]
- L = [U1 U2]
- L= [X1+X2+X3+X4   X2+X4   X3+X4   X4]



# ENCODER

- $G_N$ : N*N matrix , Kronecker product of 2*2 kernel.
- Binary tree representation
  - Depth n
  - $U^{(N)}$= U * $G_N$ : evaluated on tree with u at bottom and $U^{(N)}$ at top

$$G_{2^n} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}^{\otimes n}$$

**Result in MATLAB:**

Generator Matrix

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 12 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 13 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 14 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 15 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 16 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Encoded bits

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

# BSC CHANNEL

- take the sample sequence passing through the channel.
- generates the output sample sequence based on the Independent channel and parameter.

**Result in MATLAB :**

for p =0.5 :

Channel Effect

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |

Received bits

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |