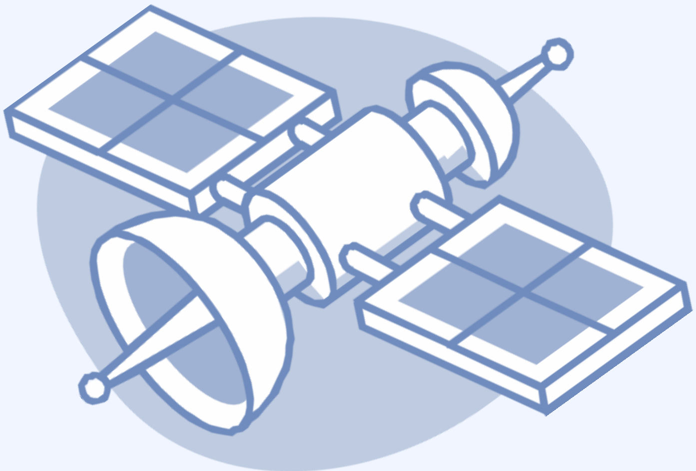
ECE252s

Fundamentals of communication systems project.

Line coding system & BPSK transmitter and Receiver using octave simulator.



Spring 2023

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Part1: Line coding system:

Transmitter:

Step 1 : Generate stream of random bits:

Code:

<u>Used functions:</u>

File: generate_random_bits.m

```
function bit_stream = generate_random_bits( noOfBits )
   % generate random sequence of binary data zeros and ones
   bit_stream = randi( [ 0 , 1 ] , 1 , noOfBits );
end
```

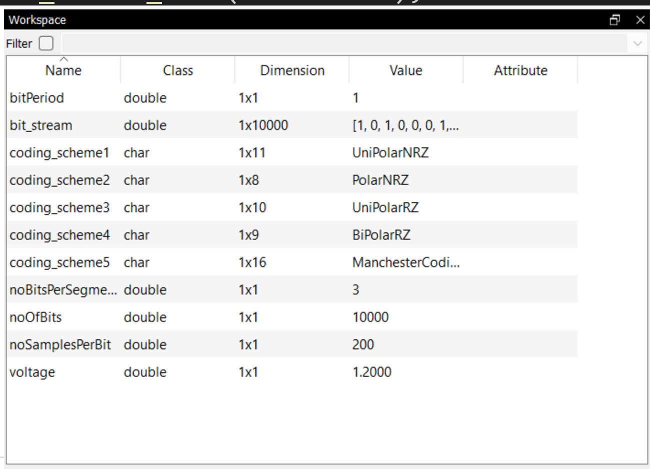
<u>Script:</u>

File: part1.m

```
% Clear all variables and close all figures
clear all;
close all;

%set values
voltage=1.2;

noOfBits=10000;
bitPeriod=1;
noSamplesPerBit=200;
noBitsPerSegments=3;

coding_scheme1='UniPolarNRZ';
coding_scheme2='PolarNRZ';
coding_scheme3='UniPolarRZ';
coding_scheme4='BiPolarRZ';
coding_scheme5='ManchesterCoding';


% generate bit_stream
bit_stream = generate_random_bits( noOfBits );
```

Snapshots:

Workspace:



Name	Class	Dimension	Value	Attribute
bitPeriod	double	1x1	1	
bit_stream	double	1x10000	[1, 0, 1, 0, 0, 0, 1,...	
coding_scheme1	char	1x11	UniPolarNRZ	
coding_scheme2	char	1x8	PolarNRZ	
coding_scheme3	char	1x10	UniPolarRZ	
coding_scheme4	char	1x9	BiPolarRZ	
coding_scheme5	char	1x16	ManchesterCodi...	
noBitsPerSegme...	double	1x1	3	
noOfBits	double	1x1	10000	
noSamplesPerBit	double	1x1	200	
voltage	double	1x1	1.2000	

Step 2: Line code the stream of bits:

Note: this part is containing all the line codes required in step 7 (Uni-polar non return to zero, Polar non return to zero, Uni-polar return to zero, Bipolar return to zero and Manchester coding).

Code:

Function:

File: line_coding.m

```
function [lineCodeVec,timeVec]=line_coding(bit_stream,coding_scheme,voltage,bitPeriod,noSamplesPerBit,fc )
    switch nargin
        %choose according to number of input arguments
        case 5
            %belong to part 1
            [lineCodeVec,timeVec]=Baseband_communication(bit_stream,coding_scheme,voltage,bitPeriod,noSamplesPerBit);
        case 6
            %belong to part 2
            [lineCodeVec,timeVec]=Passband_communication(bit_stream,coding_scheme,voltage,bitPeriod,noSamplesPerBit,fc);
    end
end


%% skip to the needed function in part1
function lineCodeVec = polarNRZ(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = unipolarNRZ(bit_stream , voltage , timeVec , noSamplesPerBit);
    %same as unipolarNRZ but change all the zeros into -ve voltage
    lineCodeVec(lineCodeVec == 0) = -1 * voltage;
end
function lineCodeVec = unipolarRZ(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = zeros(1 , length(timeVec));
    for i = 1 : length(bit_stream)
        if bit_stream(i) == 1
            %+ve voltage for the first half cycle of the bits
            lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = voltage;
            % 0 voltage for the other half cycle of the bit
            lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = 0;
        end
    end
end
function lineCodeVec = bipolarRZ(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = zeros(1 , length(timeVec));
    flag = 0; % to indicate whether the voltage to be +ve or -ve
    for i = 1 : length(bit_stream)
        if bit_stream(i) == 1
```

```
            if (flag == 0)
                %+ve voltage for the first half cycle of the bits
                lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = voltage;
                % 0 voltage for the other half cycle of the bit
                lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = 0;
                flag = 1; %update the flag
            elseif(flag == 1)
                %-ve voltage for the first half cycle of the bits
                lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = -voltage;
                % 0 voltage for the other half cycle of the bit
                lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = 0;
                flag = 0; %update the flag
            end
        end
    end
end
function lineCodeVec = manchesterCoding(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = zeros(1 , length(timeVec));
    for i = 1 : length(bit_stream)
        if bit_stream(i) == 1
            %+ve voltage for the first half cycle of the bits
            lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = voltage;
            %-ve voltage for the other half cycle of the bit
            lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = -1* voltage;
        else
            %-ve voltage for the first half cycle of the bits
            lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = -1 * voltage;
            %+ve voltage for the other half cycle of the bit
            lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = voltage;
        end
    end
end
```

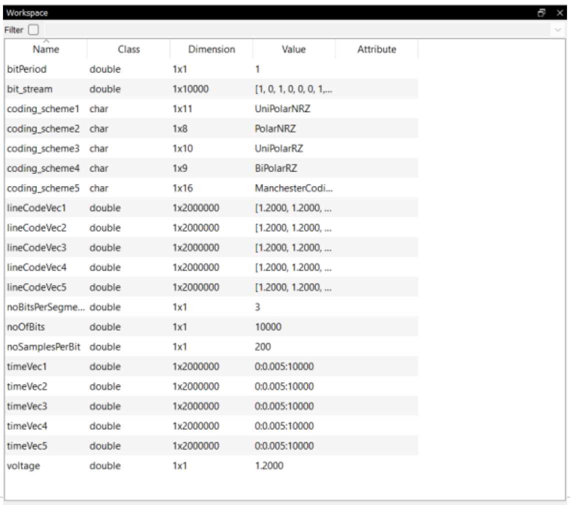
<u>Script:</u>

File: part1.m

```
[lineCodeVec1, timeVec1] = line_coding(bit_stream, coding_scheme1, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec2, timeVec2] = line_coding(bit_stream, coding_scheme2, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec3, timeVec3] = line_coding(bit_stream, coding_scheme3, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec4, timeVec4] = line_coding(bit_stream, coding_scheme4, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec5, timeVec5] = line_coding(bit_stream, coding_scheme5, voltage, bitPeriod, noSamplesPerBit);

%% plot 5 line coding in time domain
% UniPolarNRZ line coding
figure(1);
plot(timeVec1, lineCodeVec1, 'color', [0.4940 0.1840 0.5560], 'LineWidth', 2);
axis([0 timeVec1(end) 0 - voltage/2 voltage*3/2]);
title("UniPolarNRZ line coding");
legend('UniPolarNRZ');

% Zoomed
figure(2);
plot(timeVec1, lineCodeVec1, 'color', [0.4940 0.1840 0.5560], 'LineWidth', 2);
axis([0 100*bitPeriod 0 - voltage/2 voltage*3/2]);
title("UniPolarNRZ line coding (zoomed to first 100 bits)");
legend('UniPolarNRZ');
grid on;

% PolarNRZ line coding
figure(3);
plot(timeVec2, lineCodeVec2, 'color', [1 0 0], 'LineWidth', 2);
axis([0 timeVec2(end) -3*voltage/2 3*voltage/2]);
title("PolarNRZ line coding");
legend('PolarNRZ');

% Zoomed
figure(4);
plot(timeVec2, lineCodeVec2, 'color', [1 0 0], 'LineWidth', 2);
axis([0 100*bitPeriod -3*voltage/2 3*voltage/2]);
title("PolarNRZ line coding (zoomed to first 100 bits)");
legend('PolarNRZ');
grid on;

% UniPolarRZ line coding
figure(5);
plot(timeVec3, lineCodeVec3, 'color', [0.8500 0.3250 0.0980], 'LineWidth', 2);
axis([0 timeVec3(end) 0 - voltage/2 voltage*3/2]);
title("UniPolarRZ line coding");
legend('UniPolarRZ');
```

```
% Zoomed
figure(6);
plot(timeVec3, lineCodeVec3, 'color', [0.8500 0.3250 0.0980], 'LineWidth', 2);
axis([0 100*bitPeriod 0 - voltage/2 voltage*3/2]);
title("UniPolarRZ line coding (zoomed to first 100 bits)");
legend('UniPolarRZ');

% BiPolarRZ line coding
figure(7);
plot(timeVec4, lineCodeVec4, 'color', [0 0.4470 0.7410], 'LineWidth', 2);
axis([0 timeVec4(end) -3*voltage/2 3*voltage/2]);
title("BiPolarRZ line coding");
legend('BiPolarRZ');

% Zoomed
figure(8);
plot(timeVec4, lineCodeVec4, 'color', [0 0.4470 0.7410], 'LineWidth', 2);
axis([0 100*bitPeriod -3*voltage/2 3*voltage/2]);
title("BiPolarRZ line coding (zoomed to first 100 bits)");
legend('BiPolarRZ');
grid on;

% ManchesterCoding line coding
figure(9);
plot(timeVec5, lineCodeVec5, 'color', [0.6350 0.0780 0.1840], 'LineWidth', 2);
axis([0 timeVec5(end) -3*voltage/2 3*voltage/2]);
title("ManchesterCoding line coding");
legend('ManchesterCoding');

% Zoomed
figure(10);
plot(timeVec5, lineCodeVec5, 'color', [0.6350 0.0780 0.1840], 'LineWidth', 2);
axis([0 100*bitPeriod -3*voltage/2 3*voltage/2]);
title("ManchesterCoding line coding (zoomed to first 100 bits)");
legend('ManchesterCoding');
grid on;
```

Snapshots:
Workspace:



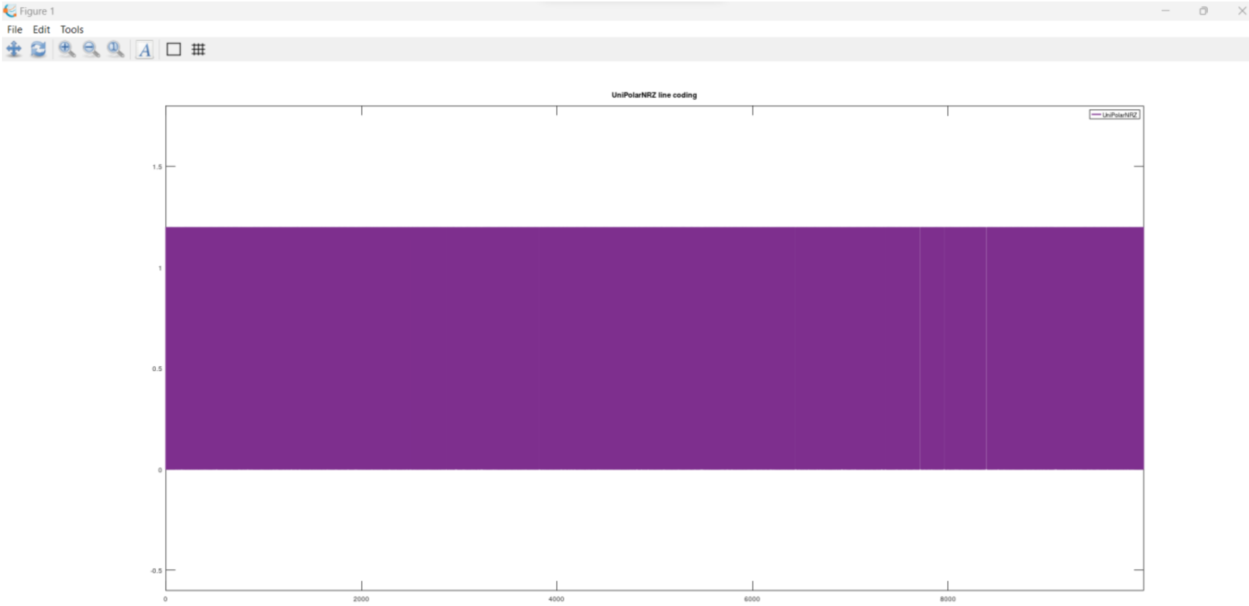
Workspace

Filter

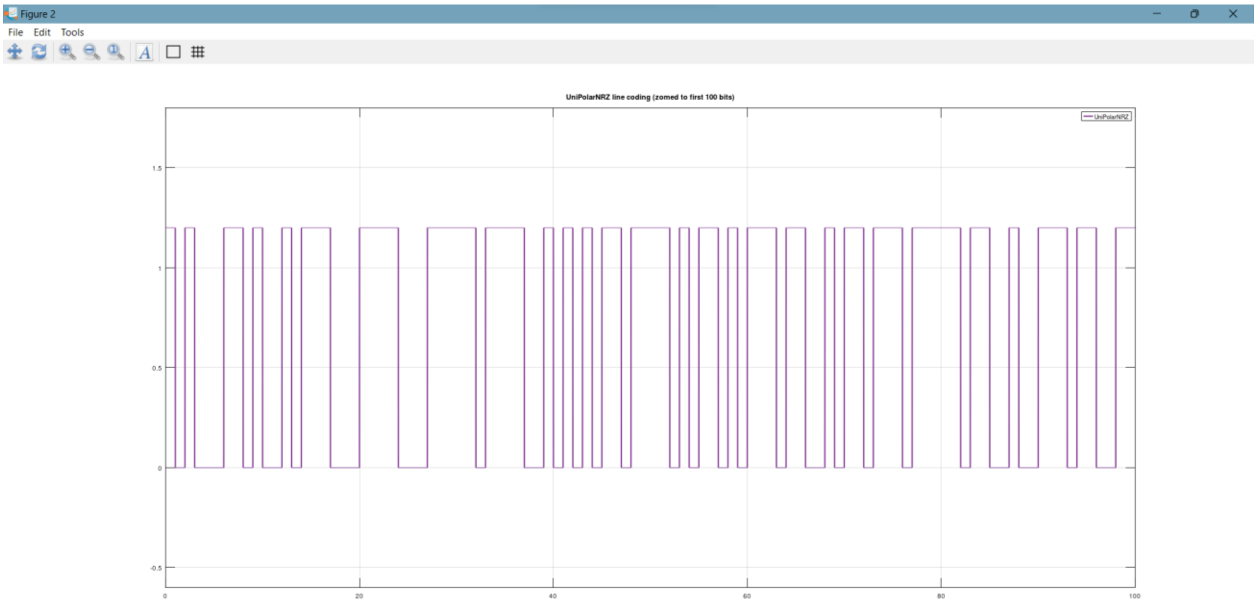
Name	Class	Dimension	Value	Attribute
bitPeriod	double	1x1	1	
bit_stream	double	1x10000	[1, 0, 1, 0, 0, 0, 1,...	
coding_scheme1	char	1x11	UniPolarNRZ	
coding_scheme2	char	1x8	PolarNRZ	
coding_scheme3	char	1x10	UniPolarRZ	
coding_scheme4	char	1x9	BiPolarRZ	
coding_scheme5	char	1x16	ManchesterCodi...	
lineCodeVec1	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec2	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec3	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec4	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec5	double	1x2000000	[1.2000, 1.2000, ...	
noBitsPerSegme...	double	1x1	3	
noOfBits	double	1x1	10000	
noSamplesPerBit	double	1x1	200	
timeVec1	double	1x2000000	0:0.005:10000	
timeVec2	double	1x2000000	0:0.005:10000	
timeVec3	double	1x2000000	0:0.005:10000	
timeVec4	double	1x2000000	0:0.005:10000	
timeVec5	double	1x2000000	0:0.005:10000	
voltage	double	1x1	1.2000	

<u>Time domain plot of UniPolar NRZ signal:</u>

Before zoom:

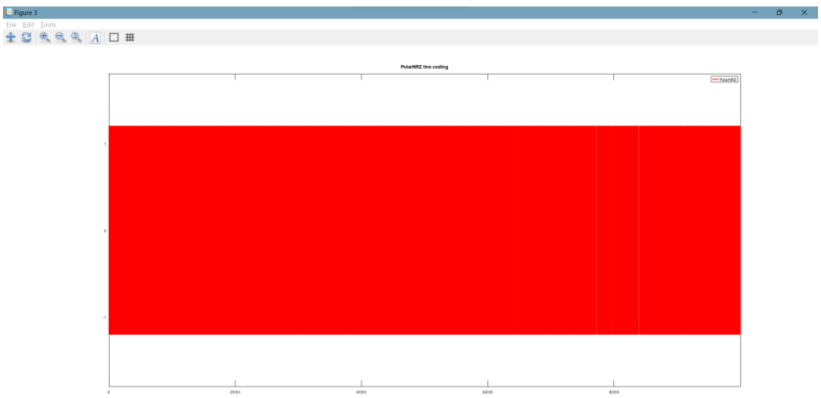


After zoom:

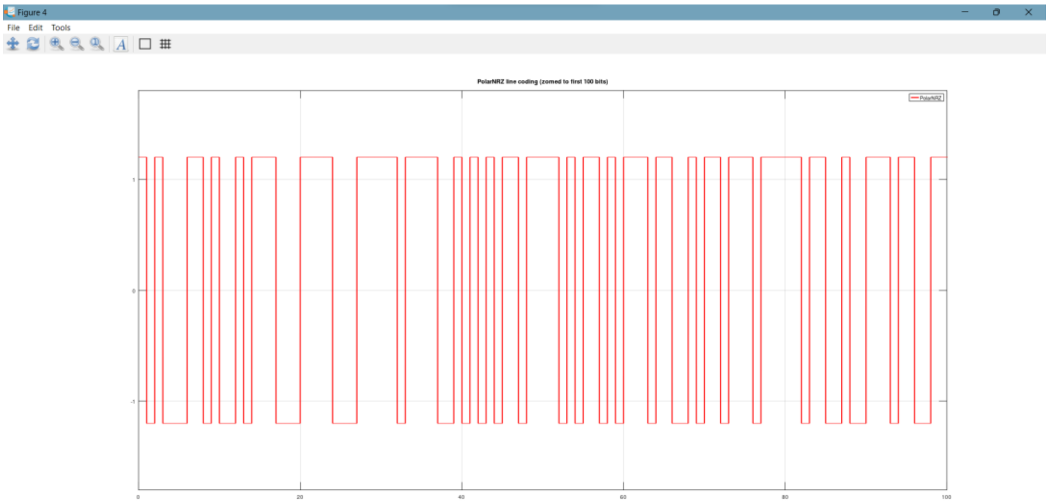


<u>Time domain plot of Polar NRZ signal:</u>

Before zoom:

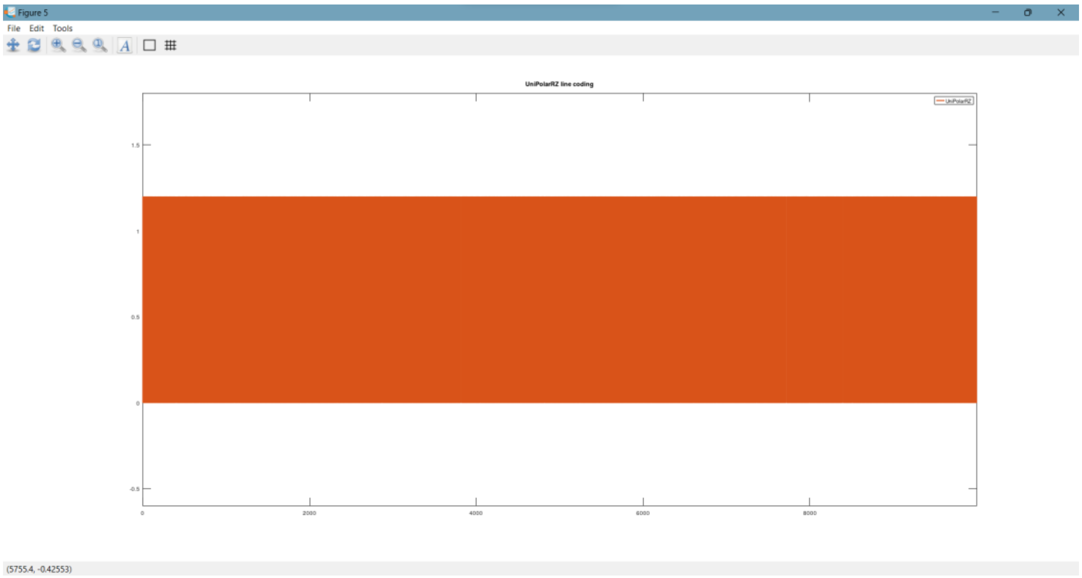


After zoom:

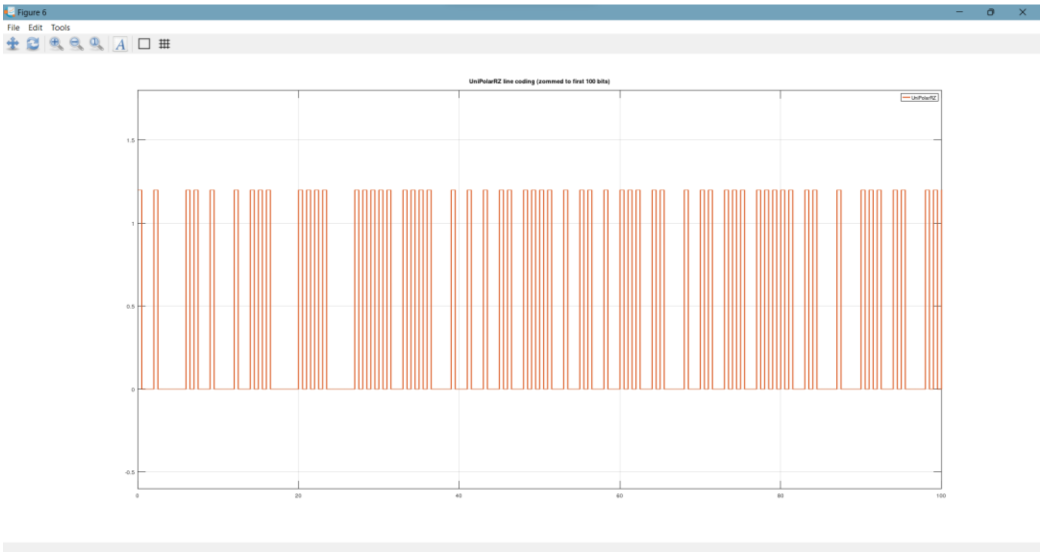


Time domain plot of UniPolar RZ signal:

Before zoom:

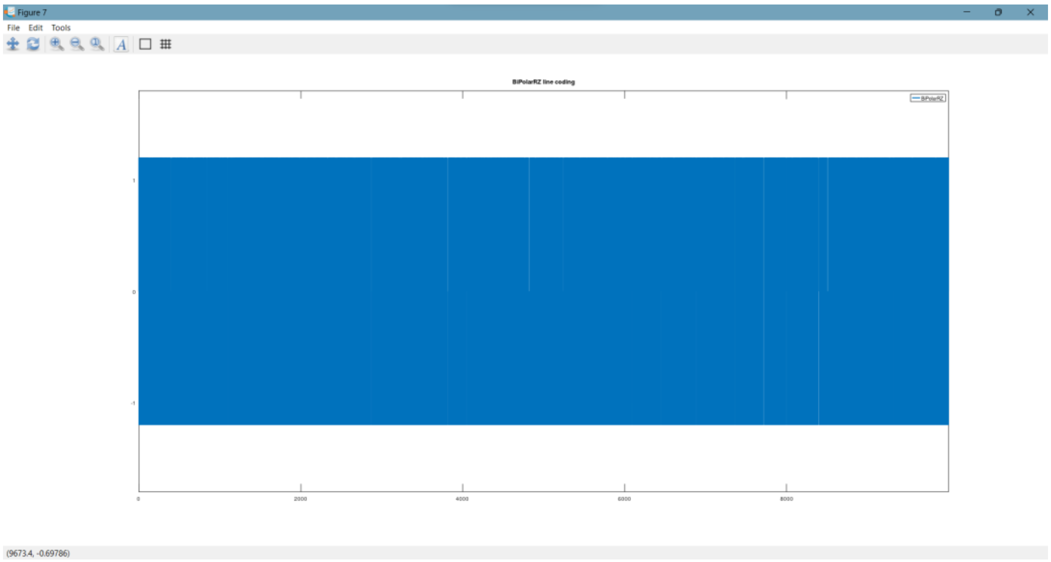


After zoom:

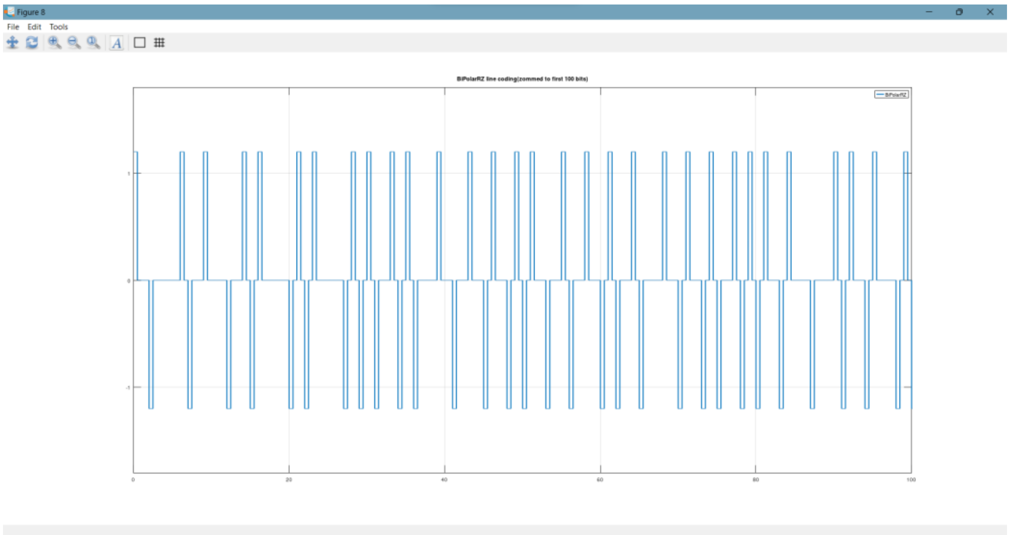


<u>Time domain plot of BiPolar RZ signal:</u>

Before zoom:

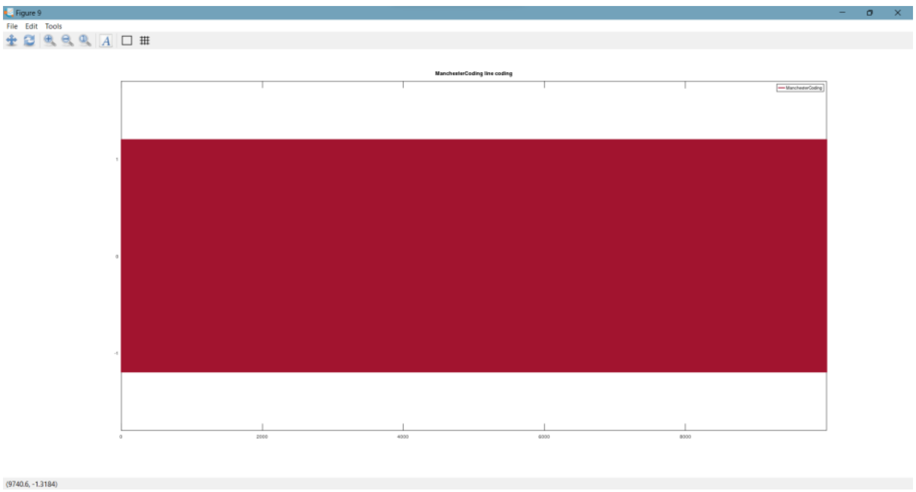


After zoom:



<u>Time domain plot of Manchester signal:</u>

Before zoom:



After zoom:

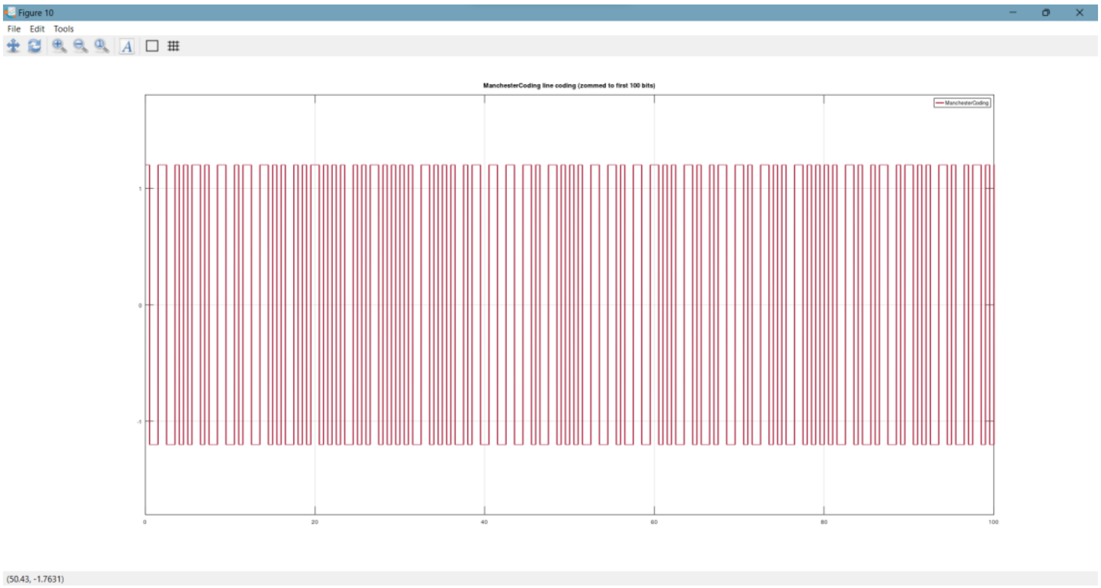


Figure 10
File Edit Tools
ManchesterCoding line coding (zommed to first 100 bits)
ManchesterCoding
1
0
-1
0
20
40
60
80
100
(50.43, -1.7631)

Step 3: Plot the Eye diagram.:

<u>Note:</u> this part is containing all the line codes required in step 7 (Uni-polar non return to zero, Polar non return to zero, Uni-polar return to zero, Bipolar return to zero and Manchester coding).

Code:

<u>Functions:</u>

File: plot_eye_diagram.m

```matlab
function plot_eye_diagram(noBitsPerSegments , noSamplePerBit , lineCodeVec , bitPeriod)
    % segment is a collection of bits we need to shift them to create the eye diagram
    % segmentLength: total samples in a segment
    segmentLength = noSamplePerBit * noBitsPerSegments;
    % periodic time of the samples
    samplePeriod = bitPeriod / noSamplePerBit;
    % time vector is created with a step of samplePeriod, and the end is the total time a segment
    % could be calculated using noBitsPerSegments and bitPeriod, with a step = samplePeriod
    timeVec = (0 : segmentLength - 1) * samplePeriod;
    % to center the zero in the mid
    timeVec = timeVec - (noBitsPerSegments * bitPeriod / 2);
    % total number of segment layers to place on top of each other
    % segmentLayers = total number of samples in line code / total number of samples in the segment
    % it's rounded down to the nearest integer, as we need to keep the size of the segment
    % equal to the size of the time vector in terms of the samples
    segmentLayers = floor(length(lineCodeVec) / segmentLength);
    for i = 1 : segmentLayers
        % find the start and end points of the segment in the line code
        % it's multiplied by the number of bits per segment
        segmentStart = (i - 1) * segmentLength + 1;
        segmentEnd = i * segmentLength;
        % x-axis is the time vector, and the y-axis is the amplitude of each bit
        plot(timeVec , lineCodeVec(segmentStart : segmentEnd),'LineWidth',2);
        % hold to plot all the segments on top of each other
        hold on;
    end
    axis([-1.5 1.5 -bitPeriod bitPeriod]);
end
```

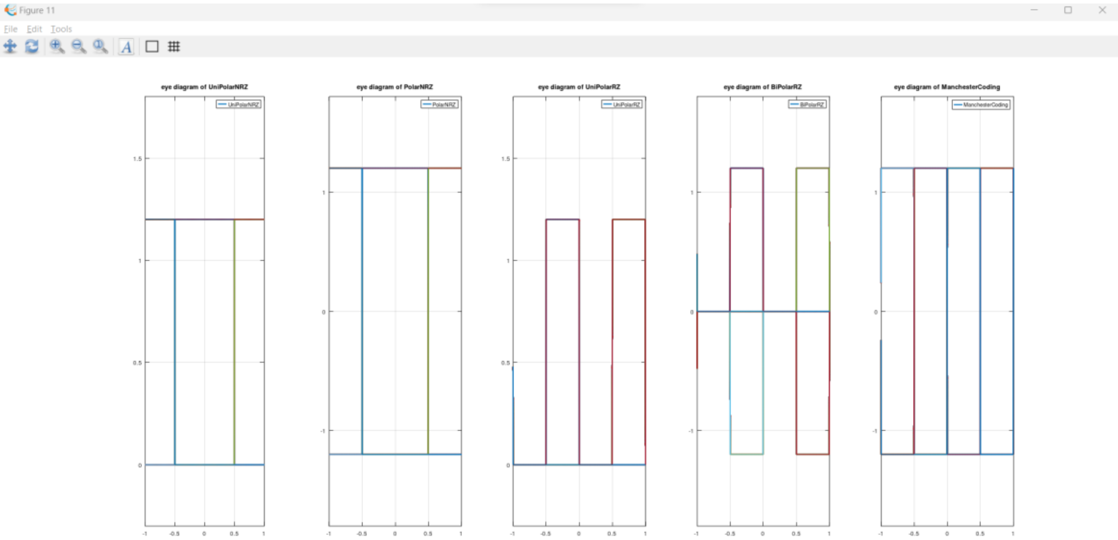
Script:

File: part1.m

```
%% plot eye diagram of line coding(transmitted signal)
% UniPolarNRZ
figure(11);
subplot(1,5,1);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec1 , bitPeriod);
title("eye diagram of UniPolarNRZ");
legend('UniPolarNRZ');
ylim([0-voltage/4 3*voltage/2]);
grid on;

% PolarNRZ
subplot(1,5,2);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec2 , bitPeriod);
title("eye diagram of PolarNRZ");
legend('PolarNRZ');
ylim([-3*voltage/2 3*voltage/2]);
grid on;

% UniPolarRZ
subplot(1,5,3);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec3 , bitPeriod);
title("eye diagram of UniPolarRZ");
legend('UniPolarRZ');
ylim([0-voltage/4 3*voltage/2]);
grid on;

% BiPolarRZ
subplot(1,5,4);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec4 , bitPeriod);
title("eye diagram of BiPolarRZ");
legend('BiPolarRZ');
ylim([-3*voltage/2 3*voltage/2]);
grid on;

% ManchesterCoding
subplot(1,5,5);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec5 , bitPeriod);
title("eye diagram of ManchesterCoding");
legend('ManchesterCoding');
ylim([-3*voltage/2 3*voltage/2]);
grid on;
```

Snapshots:

Eye-diagram of all line coding:



Step 4: Plot the spectral domains of the pulses :

Note: this part is containing all the line codes required in step 7 (Uni-polar non return to zero, Polar non return to zero, Uni-polar return to zero, Bipolar return to zero and Manchester coding).

Code:

Functions:

File: spectral_domain.m

```
function [spectral,f,BW,Spec_Original_line_coding]=spectral_domain(lineCodeVec,bit_stream,noSamplesPerBit,bitPeriod,fc)
    switch nargin
        %choose according to number of input arguments
        case 4
            [spectral,f]=Baseband_communication(lineCodeVec,bit_stream,noSamplesPerBit,bitPeriod);
        case 5
            [spectral,f,BW,Spec_Original_line_coding]=Passband_communication(lineCodeVec,bit_stream,noSamplesPerBit,bitPeriod,fc);
    end
end

%% skip into the needed function for part1

function [spectral,f]=Baseband_communication(lineCodeVec,noSamplesPerBit,bitPeriod,bit_stream)
    %calculation to generate frequency domain
    T = length(bit_stream)*bitPeriod; %simulation time
    df=1/T;  %frequency  step
    fs=noSamplesPerBit/bitPeriod; % sampling frequency
    N=noSamplesPerBit*length(bit_stream);
    %spectrum of Original Digital Signal
    Spec_Original_line_coding = (fftshift(fft(lineCodeVec)))/N;
    % frequency doomain
    if(rem(N,2)==0) %% even
        f = ((-(0.5*fs)): df : ((0.5*fs)-df));%% frequency vector if x/f even
    else %% odd
        f = (-(0.5*fs-0.5*df)) : df :(((0.5*fs)+1)-0.5*df); %% frequecy vector if X/f is odd
    end
    %power spectral of Original Digital Signal
    spectral =abs(Spec_Original_line_coding).^2;
end
```

Script:

File: part1.m

```
%% get power spectrum of line coding(transmitted signal)
[spectral_of_lineCodeVec1,f1]=spectral_domain(lineCodeVec1,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec2,f2]=spectral_domain(lineCodeVec2,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec3,f3]=spectral_domain(lineCodeVec3,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec4,f4]=spectral_domain(lineCodeVec4,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec5,f5]=spectral_domain(lineCodeVec5,noSamplesPerBit,bitPeriod,bit_stream);

%% plot power spectrum of any type of line coding
% UniPolarNRZ
figure(12);
plot(f1,spectral_of_lineCodeVec1,'color',[0.4940 0.1840 0.5560],'LineWidth',2);
title("power spectral of UniPolarNRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarNRZ');
grid on;

% Zoomed UniPolarNRZ
figure(13);
plot(f1,spectral_of_lineCodeVec1,'color',[0.4940 0.1840 0.5560],'LineWidth',2);
title("power spectral of UniPolarNRZ (zoomed)");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarNRZ');
axis([-3 3 0 0.0003]);
grid on;

% PolarNRZ
figure(14);
plot(f2,spectral_of_lineCodeVec2,'color',[1 0 0],'LineWidth',2);
title("power spectral of PolarNRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('PolarNRZ');
grid on;
axis([-5 5 0 0.0012]);

% UniPolarRZ
figure(15);
```

```
plot(f3,spectral_of_lineCodeVec3,'color',[0.8500 0.3250 0.0980],'LineWidth',2);
title("power spectral of UniPolarRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarRZ');
grid on;

% Zoomed UniPolarRZ
figure(16);
plot(f3,spectral_of_lineCodeVec3,'color',[0.8500 0.3250 0.0980],'LineWidth',2);
title("power spectral of UniPolarRZ (zoomed)");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarRZ');
grid on;
axis([-6 6 0 0.0001]);

% BiPolarRZ
figure(17);
plot(f4,spectral_of_lineCodeVec4,'color',[0 0.4470 0.7410],'LineWidth',2);
title("power spectral of BiPolarRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('BiPolarRZ');
axis([-15 15 0 0.00025]);
grid on;

% ManchesterCoding
figure(18);
plot(f5,spectral_of_lineCodeVec5,'color',[0.6350 0.0780 0.1840],'LineWidth',2);
title("power spectral of ManchesterCoding");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('ManchesterCoding');
axis([-10 10 0 0.0008]);
```

Snapshots:

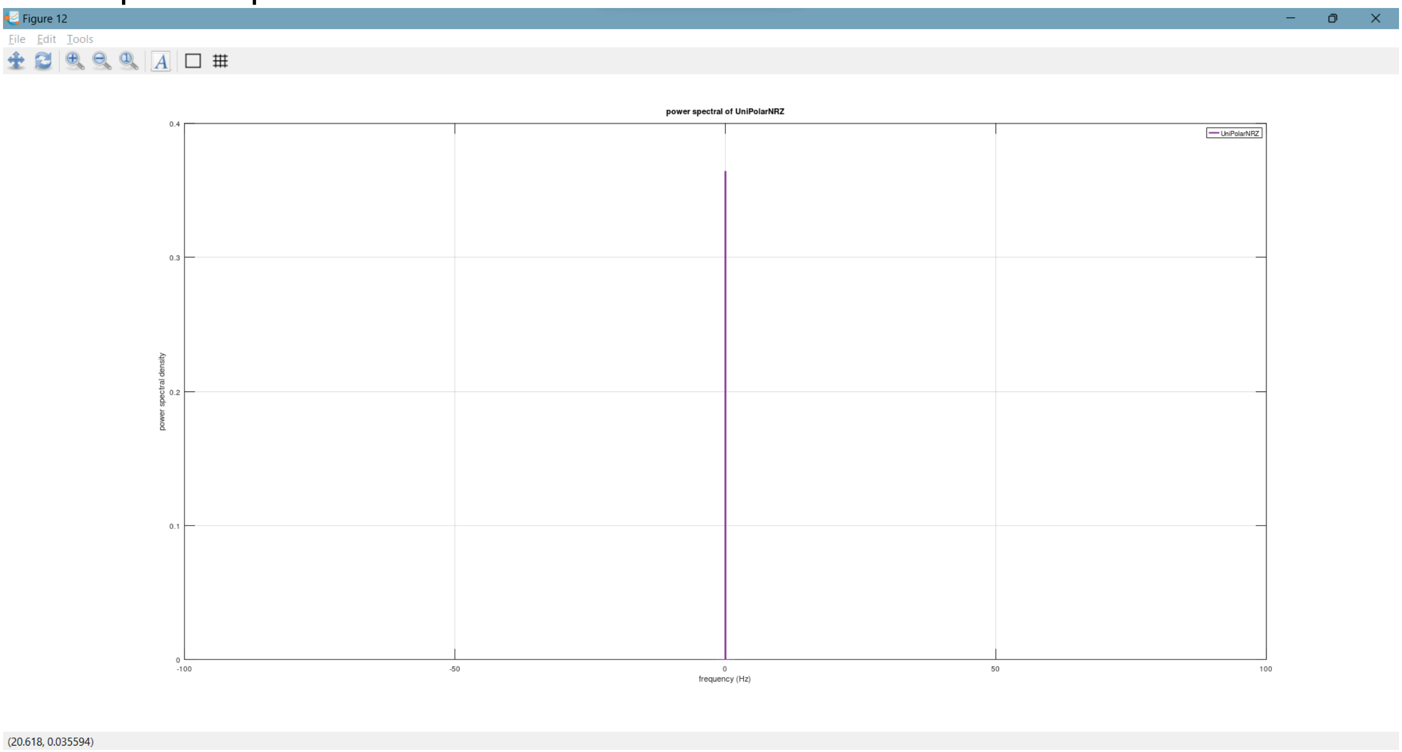
Workspace:

Workspace

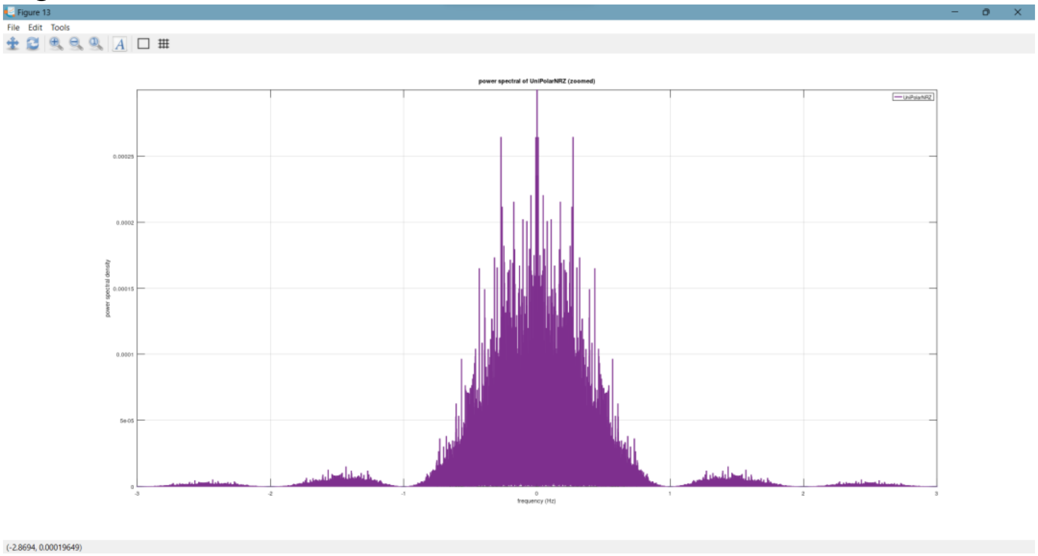
Filter

Name	Class	Dimension	Value	Attribute
bitPeriod	double	1x1	1	
bit_stream	double	1x10000	[1, 0, 1, 0, 0, 0, 1,...	
coding_scheme1	char	1x11	UniPolarNRZ	
coding_scheme2	char	1x8	PolarNRZ	
coding_scheme3	char	1x10	UniPolarRZ	
coding_scheme4	char	1x9	BiPolarRZ	
coding_scheme5	char	1x16	ManchesterCodi...	
f1	double	1x2000000	-100:0.0001:99.9...	
f2	double	1x2000000	-100:0.0001:99.9...	
f3	double	1x2000000	-100:0.0001:99.9...	
f4	double	1x2000000	-100:0.0001:99.9...	
f5	double	1x2000000	-100:0.0001:99.9...	
lineCodeVec1	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec2	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec3	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec4	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec5	double	1x2000000	[1.2000, 1.2000, ...	
noBitsPerSegme...	double	1x1	3	
noOfBits	double	1x1	10000	
noSamplesPerBit	double	1x1	200	
spectral_of_line...	double	1x2000000	[0, 4.6797e-17, ...	
spectral_of_line...	double	1x2000000	[0, 1.8719e-16, ...	
spectral_of_line...	double	1x2000000	[0, 1.1699e-17, ...	
spectral_of_line...	double	1x2000000	[0, 9.3060e-21, ...	
spectral_of_line...	double	1x2000000	[0, 4.6187e-24, ...	
timeVec1	double	1x2000000	0:0.005:10000	
timeVec2	double	1x2000000	0:0.005:10000	
timeVec3	double	1x2000000	0:0.005:10000	
timeVec4	double	1x2000000	0:0.005:10000	
timeVec5	double	1x2000000	0:0.005:10000	

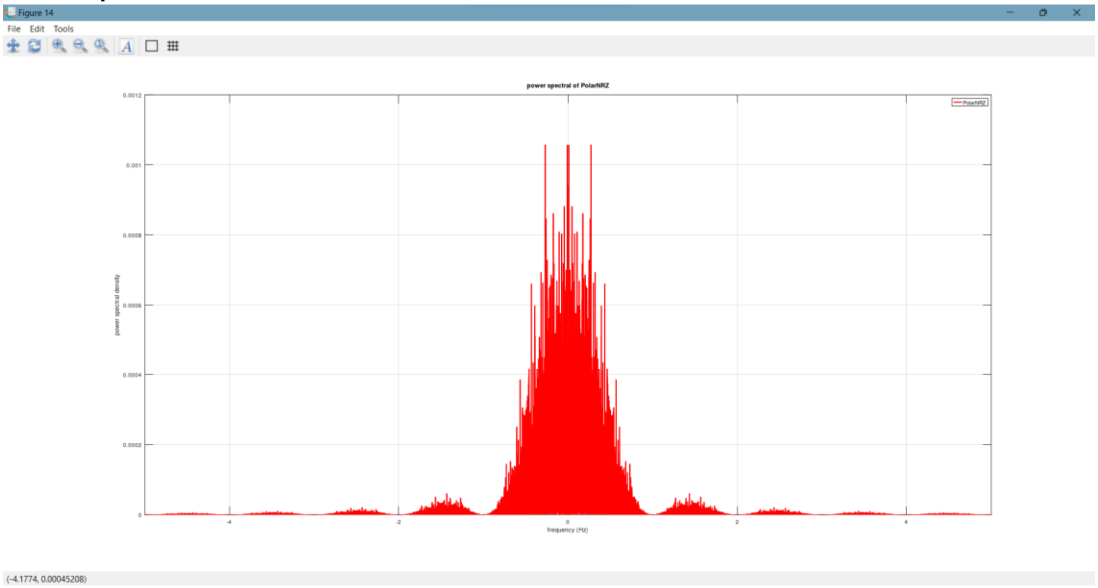
Plot of power spectral of UniPolar NRZ:



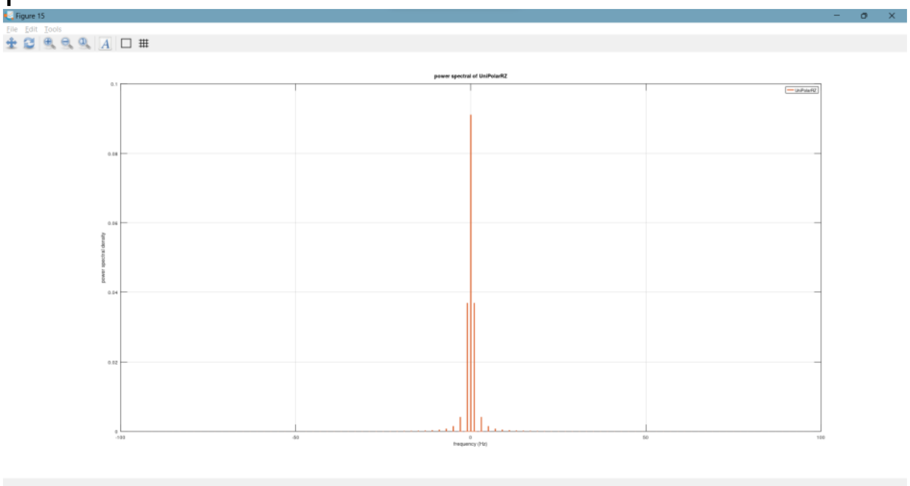
After zooming:



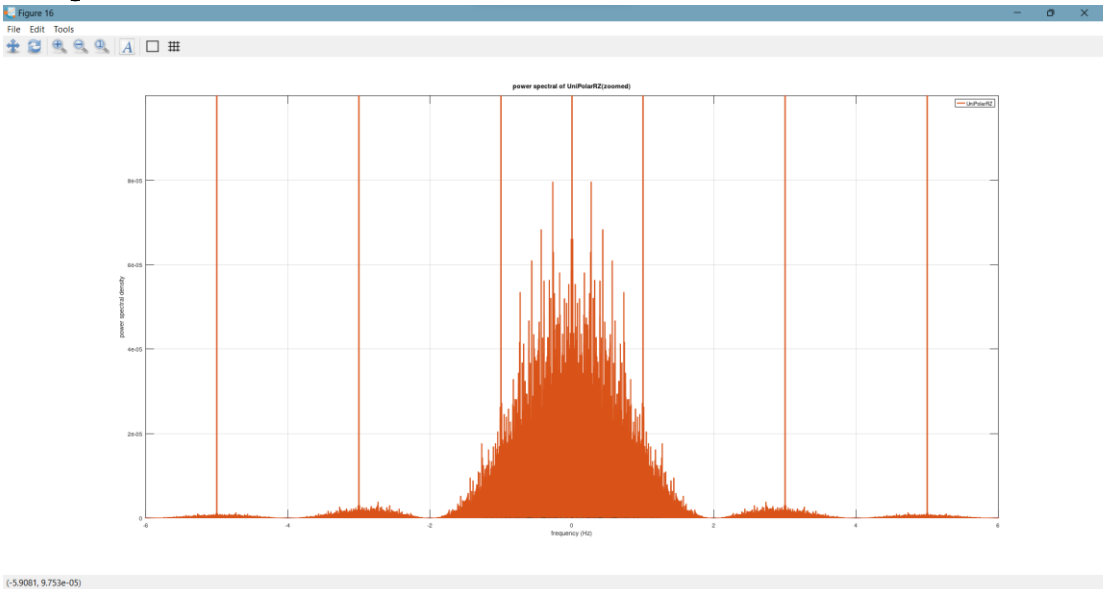
Plot of power spectral of Polar NRZ:



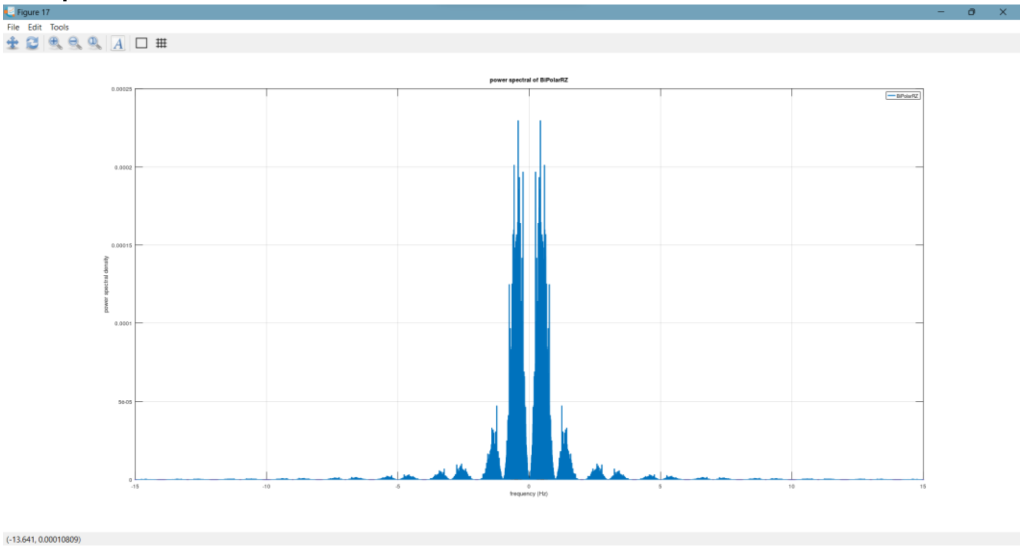
Plot of power spectral of UniPolar RZ:



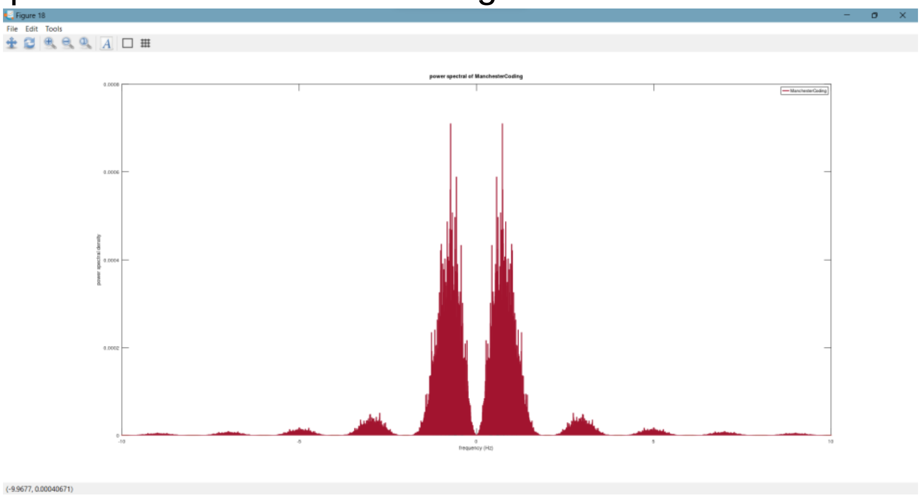
After zooming:



Plot of power spectral of BiPolar RZ:



Plot of power spectral of Manchester Coding:



Receiver:

Step 5-6-8-9-10: design the receiver and add noise to the received signal then calculate BER and error and plot BER verses sigma for each line code:

Code:

<u>Used functions:</u>

File: Sweep_on_value_of_sigma.m

```
function [BER_values, num_errors] = Sweep_on_value_of_sigma(lineCodeVec, voltage, timeVec, coding_scheme, noSamplesPerBit, noOfBits, bit_stream)
    % generate 10 ranges for sigma that range from 0 to the maximum supply voltage
    sigma_ranges = linspace(0, voltage, 10);

    % pre-allocate a vector to store the BER values & num_errors
    BER_values = zeros(1, 10);
    num_errors = zeros(1, 10);

    % loop choose each value of sigma by index i
    for i = 1:10
        % add noise to signal
        received_signal_with_noise = add_noise_to_linecoding(lineCodeVec, sigma_ranges(i), timeVec);

        % path signal through the decision device
        Reciever_output = decision_device(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits);

        % this loop is used to convert Reciever output into binary data
        binary_data = convert_into_Binary_data(Reciever_output, bit_stream, noSamplesPerBit);

        % calculate the BER & num_errors for this value of sigma
        [BER_values(i), num_errors(i)] = BER_device(binary_data, bit_stream); % insert your code for calculating BER & num_errors here
    end
end
```

File: add_noise_to_linecoding.m

```
function received_signal_with_noise = add_noise_to_linecoding(lineCode, sigma, Vectime)
    % this function simulates external noise from the communication channel (telephone line) or noise from the receiver added to the transmitted line coding

    % define your time vector
    t = Vectime;

    % noise
    n = sigma * randn(1, length(t));

     % add the noise to your received signal
     received_signal_with_noise = lineCode + n;
end
```

File: decision_device.m

```
function [Reciever_output] = decision_device(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits)
    % to select the type of line coding by coding scheme
    switch (coding_scheme)
        case 'UniPolarNRZ'
            Reciever_output = r_unipolarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'PolarNRZ'
            Reciever_output = r_polarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'UniPolarRZ'
            Reciever_output = r_unipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
         case 'BiPolarRZ'
             Reciever_output = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
         case 'ManchesterCoding'
             Reciever_output = r_manchesterCoding(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
     end
end

function [Reciever_output] = Master_source_and_comparator (received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold_1, threshold_2)
    % pre-allocate a vector to store the Reciever_output
    Reciever_output = zeros(1, length(timeVec));
    switch nargin
        case 8
            for i = 1:1:noOfBits
                if (received_signal_with_noise(L) < threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 0;
                    end
                elseif (received_signal_with_noise(L) > threshold_1)
                    for k = M:1:P
```

```
                        Reciever_output(k) = 1;
                    end
                end
                M = M + noSamplesPerBit;
                P = P + noSamplesPerBit;
                L = L + noSamplesPerBit;
            end
        case 9
            for i = 1:1:noOfBits
                if (received_signal_with_noise(L) < threshold_2)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                elseif (received_signal_with_noise(L) > threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                elseif (received_signal_with_noise(L) < threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 0;
                    end
                end
                M = M + noSamplesPerBit;
                P = P + noSamplesPerBit;
                L = L + noSamplesPerBit;
            end
    end
end

function [Reciever_output] = r_unipolarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = voltage / 2;
    L = noSamplesPerBit / 2;
    M = 1;
    P = noSamplesPerBit;
    [Reciever_output] = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end

function [Reciever_output] = r_polarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = (voltage + (-1 * (voltage))) / 2;
    L = noSamplesPerBit / 2;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
```

```
end

function [Reciever_output] = r_unipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = voltage / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end

function [Reciever_output] = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold_1 = voltage / 2;
    threshold_2 = (-1 * (voltage)) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold_1, threshold_2);
end

function [Reciever_output] = r_manchesterCoding(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = (voltage + (-1 * (voltage))) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end
```

File: convert_into_Binary_data.m

```
function [binary_data] = convert_into_Binary_data(Reciever_output, bit_stream, noSamplesPerBit)
    % pre-allocate a vector to store the binary_data
    binary_data = zeros(1, length(bit_stream));

    L = noSamplesPerBit / 2;

    for P = 1:1:length(bit_stream)
        if (Reciever_output(L) == 0)
            binary_data(P) = 0;
        elseif (Reciever_output(L) == 1)
             binary_data(P) = 1;
        end

         L = L + noSamplesPerBit;
     end
end
```

File: BER_device.m

```
function [BER, num_errors] = BER_device(Reciever_output, bit_stream)
    % count the number of errors & calculate BER
    num_errors = sum(Reciever_output ~= bit_stream);
    BER = num_errors / length(bit_stream);
end
```

<u>Script:</u>

File: part1.m

```
figure(19);
sigma_ranges = linspace(0, voltage, 10);
[BER_values1, num_errors1] = Sweep_on_value_of_sigma(lineCodeVec1, voltage, timeVec1, coding_scheme1, noSamplesPerBit, noOfBits, bit_stream);
[BER_values2, num_errors2] = Sweep_on_value_of_sigma(lineCodeVec2, voltage, timeVec2, coding_scheme2, noSamplesPerBit, noOfBits, bit_stream);
[BER_values3, num_errors3] = Sweep_on_value_of_sigma(lineCodeVec3, voltage, timeVec3, coding_scheme3, noSamplesPerBit, noOfBits, bit_stream);
[BER_values4, num_errors4] = Sweep_on_value_of_sigma(lineCodeVec4, voltage, timeVec4, coding_scheme4, noSamplesPerBit, noOfBits, bit_stream);
[BER_values5, num_errors5] = Sweep_on_value_of_sigma(lineCodeVec5, voltage, timeVec5, coding_scheme5, noSamplesPerBit, noOfBits, bit_stream);

semilogy(sigma_ranges, BER_values1, sigma_ranges, BER_values2, sigma_ranges, BER_values3, sigma_ranges, BER_values4, sigma_ranges, BER_values5, 'LineWidth', 2);

grid on;
xlabel('Sigma');
ylabel('BER');
legend({'UniPolarNRZ', 'PolarNRZ', 'UniPolarRZ', 'BiPolarRZ', 'ManchesterCoding'});
```

Snapshots:

Workspace:

Workspace

Workspace

Filter

Name	Class	Dimension	Value	Attribute
BER_values1	double	1x10	[0, 0, 0.010900, ...	
BER_values2	double	1x10	[0, 0, 0, 1.3000e-...	
BER_values3	double	1x10	[0, 0, 0.012900, ...	
BER_values4	double	1x10	[0, 0, 0.018600, ...	
BER_values5	double	1x10	[0, 0, 0, 1.0000e-...	
bitPeriod	double	1x1	1	
bit_stream	double	1x10000	[1, 0, 1, 0, 0, 0, 1,...	
coding_scheme1	char	1x11	UniPolarNRZ	
coding_scheme2	char	1x8	PolarNRZ	
coding_scheme3	char	1x10	UniPolarRZ	
coding_scheme4	char	1x9	BiPolarRZ	
coding_scheme5	char	1x16	ManchesterCodi...	
f1	double	1x2000000	-100:0.0001:99.9...	
f2	double	1x2000000	-100:0.0001:99.9...	
f3	double	1x2000000	-100:0.0001:99.9...	
f4	double	1x2000000	-100:0.0001:99.9...	
f5	double	1x2000000	-100:0.0001:99.9...	
lineCodeVec1	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec2	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec3	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec4	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec5	double	1x2000000	[1.2000, 1.2000, ...	
noBitsPerSegme...	double	1x1	3	
noOfBits	double	1x1	10000	
noSamplesPerBit	double	1x1	200	
num_errors1	double	1x10	[0, 0, 109, 657, 1...	
num_errors2	double	1x10	[0, 0, 0, 13, 113, ...	
num_errors3	double	1x10	[0, 0, 129, 646, 1...	
num_errors4	double	1x10	[0, 0, 186, 999, 1...	
num_errors5	double	1x10	[0, 0, 0, 10, 121, ...	
sigma_ranges	double	1x10	[0, 0.1333, 0.266...	
spectral_of_line...	double	1x2000000	[0, 4.6797e-17, ...	
spectral_of_line...	double	1x2000000	[0, 1.8719e-16, ...	
spectral_of_line...	double	1x2000000	[0, 1.1699e-17, ...	
spectral_of_line...	double	1x2000000	[0, 9.3060e-21, ...	
spectral_of_line...	double	1x2000000	[0, 4.6187e-24, ...	
timeVec1	double	1x2000000	0:0.005:10000	
timeVec2	double	1x2000000	0:0.005:10000	
timeVec3	double	1x2000000	0:0.005:10000	
timeVec4	double	1x2000000	0:0.005:10000	
timeVec5	double	1x2000000	0:0.005:10000	
voltage	double	1x1	1.2000	

num_errors vectors:

num_errors1 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	109	657	1331	1870	2268	2546	2891	3095	
2											

num_errors2 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	13	113	357	652	997	1324	1544	
2											

num_errors3 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	129	646	1266	1850	2258	2647	2833	3099	

num_errors4 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	186	999	1918	2734	3320	3794	4121	4355	

num_errors5 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	10	121	383	659	979	1308	1574	
2											

Editor | Command Window | Documentation | Variable Editor

sigame_ranges and BER_values vectors:

sigma_ranges [1x10 double]

	1	2	3	4	5	6	7	8	9	10
1	0	0.13333	0.26667	0.4	0.53333	0.66667	0.8	0.93333	1.0667	1.2

BER_values1 [1x10 double]

	1	2	3	4	5	6	7	8	9	10
1	0	0	0.0109	0.0657	0.1331	0.187	0.2268	0.2546	0.2891	0.3095

BER_values2 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	0.0013	0.0113	0.0357	0.0652	0.0997	0.1324	0.1544	

BER_values3 [1x10 double]

	1	2	3	4	5	6	7	8	9	10
1	0	0	0.0129	0.0646	0.1266	0.185	0.2258	0.2647	0.2833	0.3099

BER_values4 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0.0186	0.0999	0.1918	0.2734	0.332	0.3794	0.4121	0.4355	

BER_values5 [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	0.001	0.0121	0.0383	0.0659	0.0979	0.1308	0.1574	

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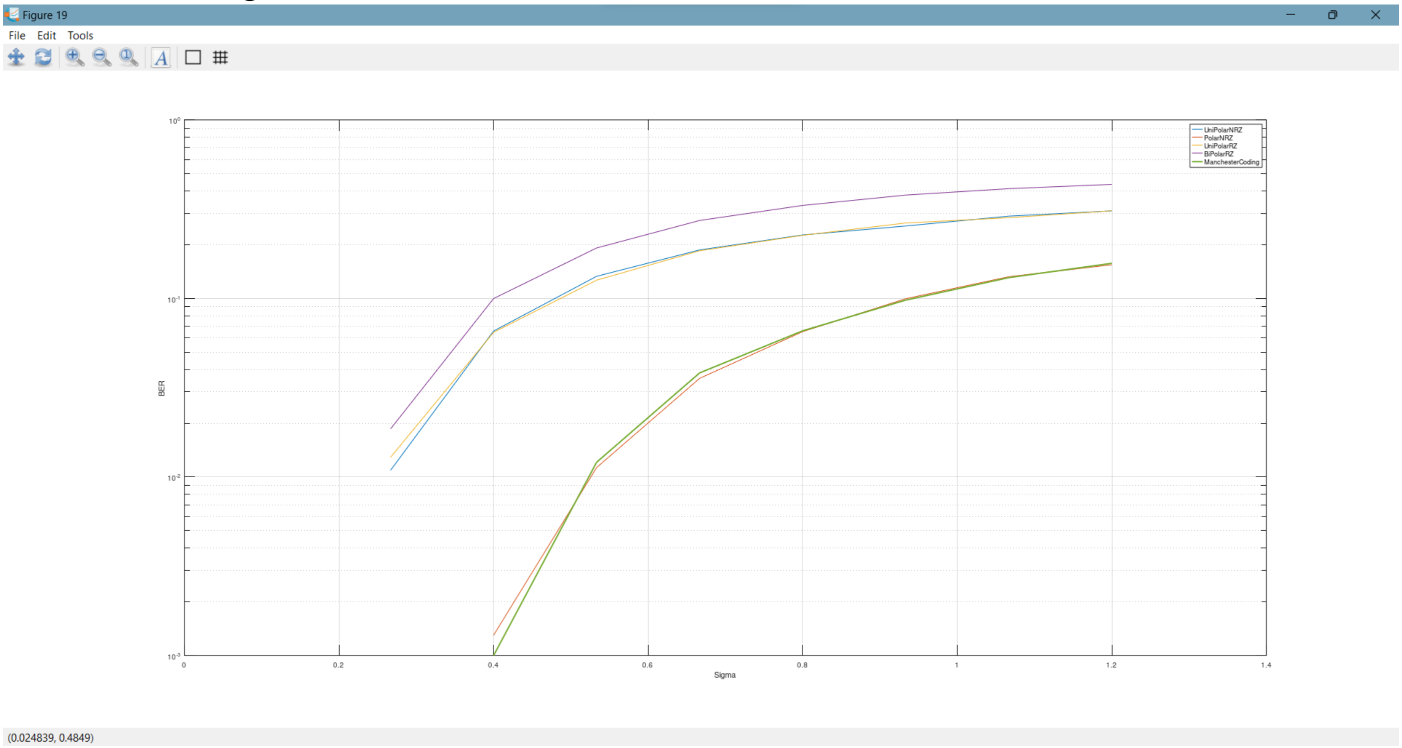
Plot BER vs sigma:



Step 11: **(Bonus)** For the case of Bipolar return to zero , design an error detection circuit:

Code:

Functions:

File: Bonus_Sweep_on_value_of_sigma.m

```
function [number_of_detected_errors] = Bonus_Sweep_on_value_of_sigma(lineCodeVec, voltage, timeVec, coding_scheme, noSamplesPerBit, noOfBits)
    % Generate 10 ranges for sigma that range from 0 to the maximum supply voltage
    sigma_ranges = linspace(0, voltage, 10);

    % Pre-allocate a vector to store the BER values & num_errors
    number_of_detected_errors = zeros(1, 10);

    % Loop chooses each value of sigma by index i
    for i = 1:10
        % Add noise to signal
        received_signal_with_noise = add_noise_to_linecoding(lineCodeVec, sigma_ranges(i), timeVec);

        % Path signal through Regenerative_Repeater
        [Repeater_output] = Regenerative_Repeater(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits);

        % Calculate number_of_detected_errors for this value of sigma
        number_of_detected_errors(i) = Error_Detection_Circuit(Repeater_output, voltage, noSamplesPerBit, noOfBits);
    end
end
```

File: Regenerative_Repeater.m

```
function [Repeater_output] = Regenerative_Repeater(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits)
    % This function represents the regenerative repeater block used in telephone lines.
    % When entering the receiver to select the type of line coding by coding scheme.
    switch (coding_scheme)
        case 'BiPolarRZ'
            Repeater_output = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
    end
end

function [Repeater_output] = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % Pre-allocate a vector to store the Receiver_output
    Repeater_output = zeros(1, length(timeVec));
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold_1 = voltage / 2;
    threshold_2 = (-1 * (voltage)) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit / 2;
    for i = 1:1:noOfBits
        if (received_signal_with_noise(L) < threshold_2)
            for k = M:1:P
                Repeater_output(k) = -1 * voltage;
            end
        elseif (received_signal_with_noise(L) > threshold_1)
            for k = M:1:P
                Repeater_output(k) = voltage;
            end
        elseif (received_signal_with_noise(L) < threshold_1)
            for k = M:1:P
                Repeater_output(k) = 0;
            end
        end
        M = M + noSamplesPerBit;
        P = P + noSamplesPerBit;
        L = L + noSamplesPerBit;
    end
end
```

File: Error_Detection_Circuit.m

```
function [number_of_detected_errors] = Error_Detection_Circuit(Repeater_output, voltage, noSamplesPerBit, noOfBits)
    % Error detection circuit for Bipolar return to zero
    number_of_detected_errors = 0;
    L = noSamplesPerBit / 4;

    for i = 1:1:noOfBits
        if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
            break;
        end

        % 1000000000...01
        if (Repeater_output(L) == voltage && Repeater_output(L + noSamplesPerBit) == 0)
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end

            while (Repeater_output(L) == 0)
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end
        end

        if (Repeater_output(L) == voltage)
            number_of_detected_errors = number_of_detected_errors + 1;
        end
        % -100000000...0-1
        elseif (Repeater_output(L) == -1 * voltage && Repeater_output(L + noSamplesPerBit) == 0)
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end

            while (Repeater_output(L) == 0)
                if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                    break;
                else
                    L = L + noSamplesPerBit;
```

```
                end
            end

            if (Repeater_output(L) == -1 * voltage)
                number_of_detected_errors = number_of_detected_errors + 1;
            end

        % -1-1
        elseif (Repeater_output(L) == -1 * voltage && Repeater_output(L + noSamplesPerBit) == -1 * voltage)
            number_of_detected_errors = number_of_detected_errors + 1;
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end

        % 11
        elseif (Repeater_output(L) == voltage && Repeater_output(L + noSamplesPerBit) == voltage)
            number_of_detected_errors = number_of_detected_errors + 1;
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end
        end

        if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
            break;
        else
            L = L + noSamplesPerBit;
        end
    end
end
```

Snapshots:

Workspace:

Workspace

Filter

Name	Class	Dimension	Value	Attribute
bitPeriod	double	1x1	1	
noBitsPerSegments	double	1x1	3	
noOfBits	double	1x1	10000	
noSamplesPerBit	double	1x1	200	
voltage	double	1x1	1.2000	
BER_values1	double	1x10	[0, 0, 0.010900, ...	
BER_values2	double	1x10	[0, 0, 0, 1.3000e-...	
BER_values3	double	1x10	[0, 0, 0.012900, ...	
BER_values4	double	1x10	[0, 0, 0.018600, ...	
BER_values5	double	1x10	[0, 0, 0, 1.0000e-...	
coding_scheme3	char	1x10	UniPolarRZ	
num_errors1	double	1x10	[0, 0, 109, 657, 1...	
num_errors2	double	1x10	[0, 0, 0, 13, 113, ...	
num_errors3	double	1x10	[0, 0, 129, 646, 1...	
num_errors4	double	1x10	[0, 0, 186, 999, 1...	
num_errors5	double	1x10	[0, 0, 0, 10, 121, ...	
number_of_detected_errors	double	1x10	[0, 0, 123, 551, 9...	
sigma_ranges	double	1x10	[0, 0.1333, 0.266...	
bit_stream	double	1x10000	[1, 0, 1, 0, 0, 0, 1,...	
coding_scheme1	char	1x11	UniPolarNRZ	
coding_scheme5	char	1x16	ManchesterCodi...	
f1	double	1x2000000	-100:0.0001:99.9...	
f2	double	1x2000000	-100:0.0001:99.9...	
f3	double	1x2000000	-100:0.0001:99.9...	
f4	double	1x2000000	-100:0.0001:99.9...	
f5	double	1x2000000	-100:0.0001:99.9...	
lineCodeVec1	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec2	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec3	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec4	double	1x2000000	[1.2000, 1.2000, ...	
lineCodeVec5	double	1x2000000	[1.2000, 1.2000, ...	
spectral_of_lineCodeVec1	double	1x2000000	[0, 4.6797e-17, ...	
spectral_of_lineCodeVec2	double	1x2000000	[0, 1.8719e-16, ...	
spectral_of_lineCodeVec3	double	1x2000000	[0, 1.1699e-17, ...	
spectral_of_lineCodeVec4	double	1x2000000	[0, 9.3060e-21, ...	
spectral_of_lineCodeVec5	double	1x2000000	[0, 4.6187e-24, ...	
timeVec1	double	1x2000000	0:0.005:10000	
timeVec2	double	1x2000000	0:0.005:10000	
timeVec3	double	1x2000000	0:0.005:10000	
timeVec4	double	1x2000000	0:0.005:10000	
timeVec5	double	1x2000000	0:0.005:10000	
coding_scheme2	char	1x8	PolarNRZ	
coding_scheme4	char	1x9	BiPolarRZ	

Number_of_detected_errors Vector:

number_of_detected_errors [1x10 double]

	1	2	3	4	5	6	7	8	9	10	11
1	0	0	123	551	948	1187	1465	1562	1716	1853	
2											
3											
4											

Part2: binary phase shift-keying:

Transmitter:

Step 1 : Generate stream of random bits:

Code:

<u>Used functions:</u>

File: generate_random_bits.m

```
function bit_stream = generate_random_bits(noOfBits)
    % Generate random sequence of binary data zeros and ones

    bit_stream = randi([0, 1], 1, noOfBits);
end
```

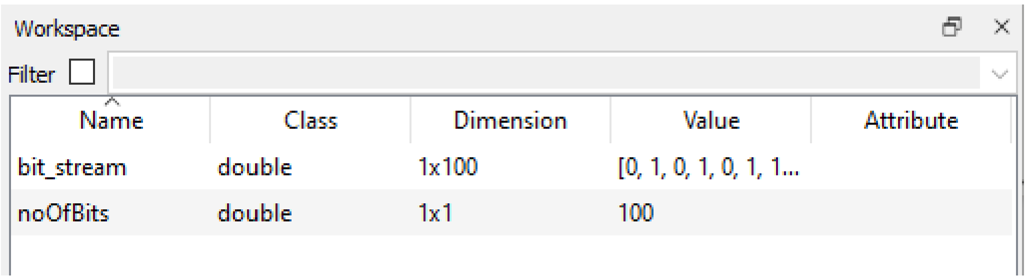
<u>Script:</u>

File: part2.m

```
% MATLAB Script for a Binary PSK (passband communication)

% Clear all variables and close all figures
clear all;
close all;

noOfBits = 100; % Number of time samples

% Generate bit stream
bit_stream = generate_random_bits(noOfBits);
```

Snapshots:

workspace:



Step 2 : Line coding:

Code:

Used functions:

File: line_coding.m

```
function [lineCodeVec, timeVec] = line_coding(bit_stream, coding_scheme, voltage, bitPeriod, noSamplesPerBit, fc)
    switch nargin
        % Choose according to number of input arguments
        case 5
            [lineCodeVec, timeVec] = Baseband_communication(bit_stream, coding_scheme, voltage, bitPeriod, noSamplesPerBit);
        case 6
            % Belongs to Part 2
            [lineCodeVec, timeVec] = Passband_communication(bit_stream, coding_scheme, voltage, bitPeriod, noSamplesPerBit, fc);
    end
end

function [lineCodeVec, timeVec] = Passband_communication(bit_stream, coding_scheme, voltage, bitPeriod, noSamplesPerBit, fc)
    % This function implements the function of polarNRZ block in transmitter

    % Calculations
    noOfBits = length(bit_stream);
    fs = 10 * fc;  % Sampling frequency - Sampling rate - This will define the resolution
    ts = 1 / fs;   % Time step
    t = 0:ts:(noOfBits - 1) * ts;
% Generate time domain
timeVec = [];
for ii = 1:1:length(bit_stream)
timeVec = [timeVec t];
t = t + (noOfBits - 1) * ts;
end

noSamplesPerBit = length(t);

% Generate polarNRZ line coding
switch (coding_scheme)
case 'PolarNRZ'
lineCodeVec = polarNRZ(bit_stream, voltage, timeVec, noSamplesPerBit);
end
end
```

<u>Script:</u>

File: part2.m

```
%% Calculations
fc = 10^9;   % Frequency of Modulating Signal
fs = 10 * fc;  % Sampling frequency - Sampling rate - This will define the resolution
ts = 1 / fs;   % Time step
t = 0:ts:(noOfBits - 1) * ts;   % Time for one bit - Time of one bit = 1 second per one bit
T = (noOfBits) * (noOfBits * ts);   % Simulation time
Rb = noOfBits / T;   % Bit rate = N / simulation time

voltage = 1;
bitPeriod = t(end);
noSamplesPerBit = length(t);
coding_scheme = 'PolarNRZ';

%% The PolarNRZ Signal
[PolarNRZ, timeVec] = line_coding(bit_stream, coding_scheme, voltage, bitPeriod, noSamplesPerBit, fc);

% Plot the PolarNRZ Signal with time
figure;
plot(timeVec, PolarNRZ, 'r', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Amplitude (V)');
title('PolarNRZ Signal');
axis([0 timeVec(end) -1.5 1.5]);
grid on;
```

Snapshots:

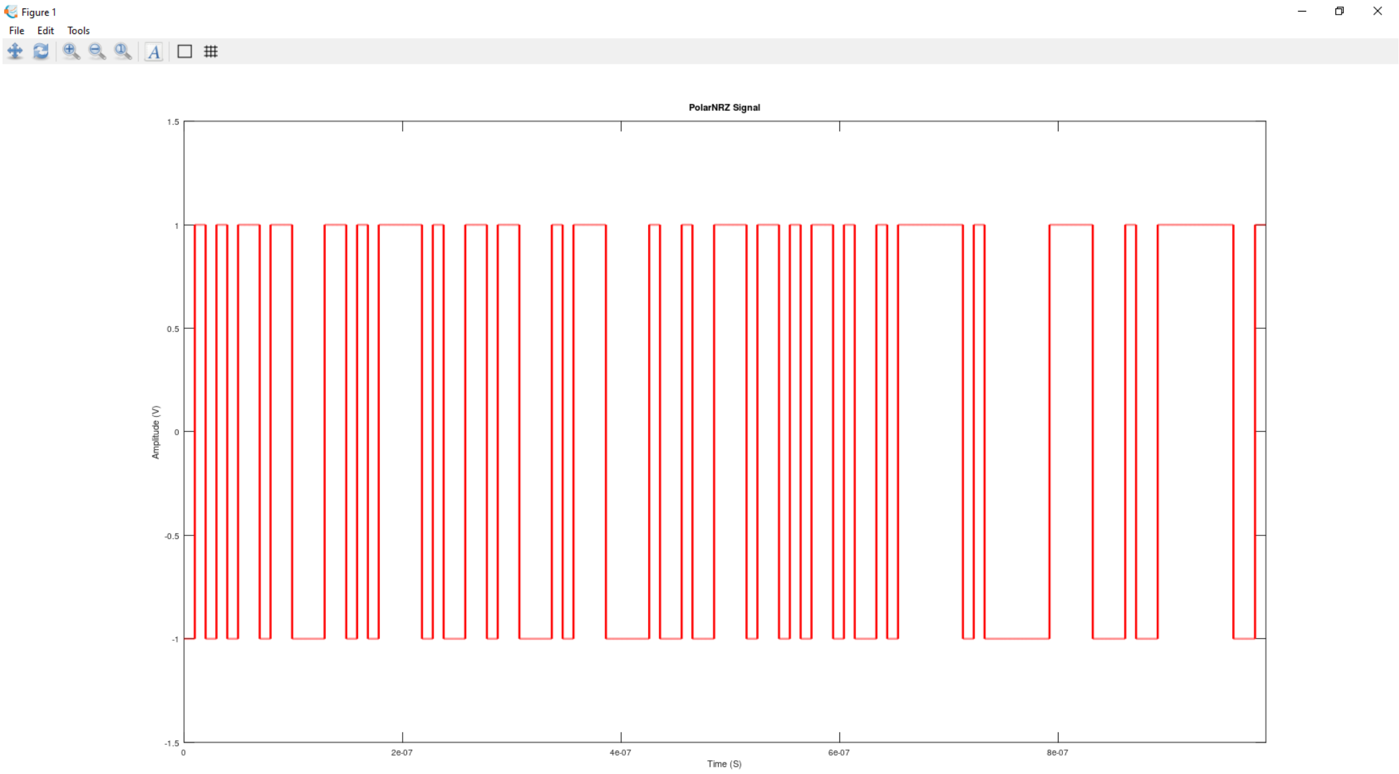
workspace:

Workspace

Filter

Name	Class	Dimension	Value	Attribute
PolarNRZ	double	1x10000	[-1, -1, -1, -1, -1...	
Rb	double	1x1	1.0000e+08	
T	double	1x1	1.0000e-06	
bitPeriod	double	1x1	9.9000e-09	
bit_stream	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
coding_scheme	char	1x8	PolarNRZ	
fc	double	1x1	1.0000e+09	
fs	double	1x1	1.0000e+10	
noOfBits	double	1x1	100	
noSamplesPerBit	double	1x1	100	
t	double	1x100	0:1e-10:9.9e-09	
timeVec	double	1x10000	[0, 1.0000e-10, 2...	
ts	double	1x1	1.0000e-10	
voltage	double	1x1	1	

plot of time domain with PolarNRZ signal:



Step 3 : spectral domain before Modulation:

Code:

Used functions:

File: spectral_domain.m

```
function [spectral, f, BW, Spec_Original_line_coding] = spectral_domain(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc)
    switch nargin
        % Choose according to number of input arguments
        case 4
            % Belongs to Part 1
            [spectral, f] = Baseband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod);
        case 5
            % Belongs to Part 2
            [spectral, f, BW, Spec_Original_line_coding] = Passband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc);
    end
end

function [spectral, f, BW, Spec_Original_line_coding] = Passband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc)
    % Calculation to generate frequency domain
    noOfBits = length(bit_stream);
    fs = 10 * fc;  % Sampling frequency - Sampling rate - This will define the resolution
    ts = 1 / fs;   % Time step
    T = (noOfBits) * (I apologize for the incomplete response in my previous message. Here's the remainder of the reformatted code starting from line 18 with line numbers:noOfBits * ts); % Simulation time
    Rb = noOfBits / T; % Bit rate = N / simulation time
    BW = Rb; % Polar & NRZ
    df = 1 / T; % Frequency step

% Spectrum of Original Digital Signal
Spec_Original_line_coding = (fftshift(fft(lineCodeVec))) / noOfBits; % We put message in frequency domain because it only shifts function in FFT

% Frequency domain
if (rem(noOfBits,2) == 0) % Even
f = ((-(0.5 * fs)):df:((0.5 * fs) - df)); % Frequency vector if x/f even
else % Odd
f = (-(0.5 * fs - 0.5 * df)) : df :(((0.5 * fs) + 1) - 0.5 * df); % Frequency vector if X/f is odd
end

% Power spectral of Original Digital Signal
spectral = abs(Spec_Original_line_codingand).^2;
end
```

Script:

File: part2.m

```
% Spectrum & Spectral of PolarNRZ Signal

[spectral_PolarNRZ_Signal, f, BW, Spec_PolarNRZ_Signal] = spectral_domain(PolarNRZ, bit_stream, noSamplesPerBit, bitPeriod, fc);

figure;
grid on;

plot(f, abs(Spec_PolarNRZ_Signal));
title('Spectrum of Original PolarNRZ Signal');
xlabel("Frequency (Hz)");
ylabel('Amplitude (V)');

figure;
plot(f, spectral_PolarNRZ_Signal);
title('Power Spectral Density of PolarNRZ Signal');
xlabel("Frequency (Hz)");
ylabel('Power Spectral Density');
```

Snapshots:

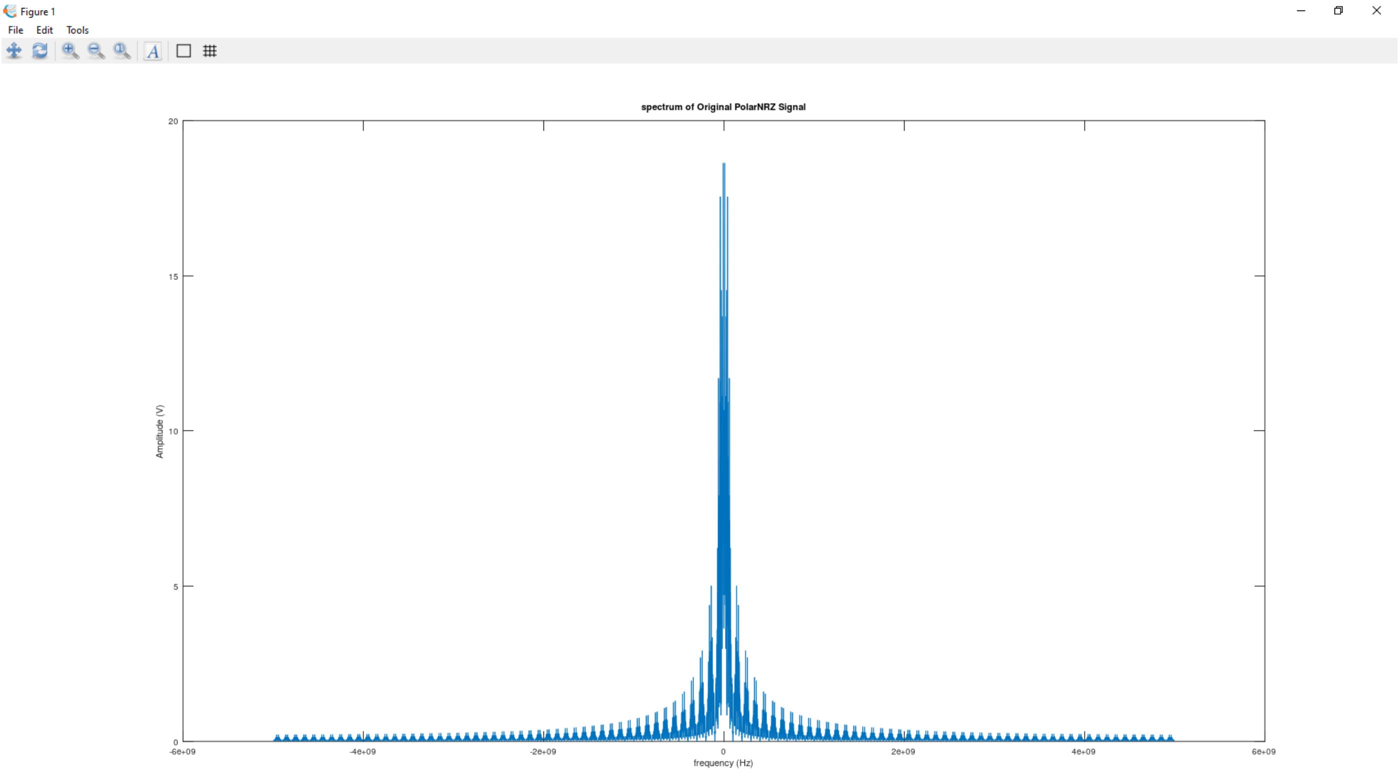
workspace:

Workspace

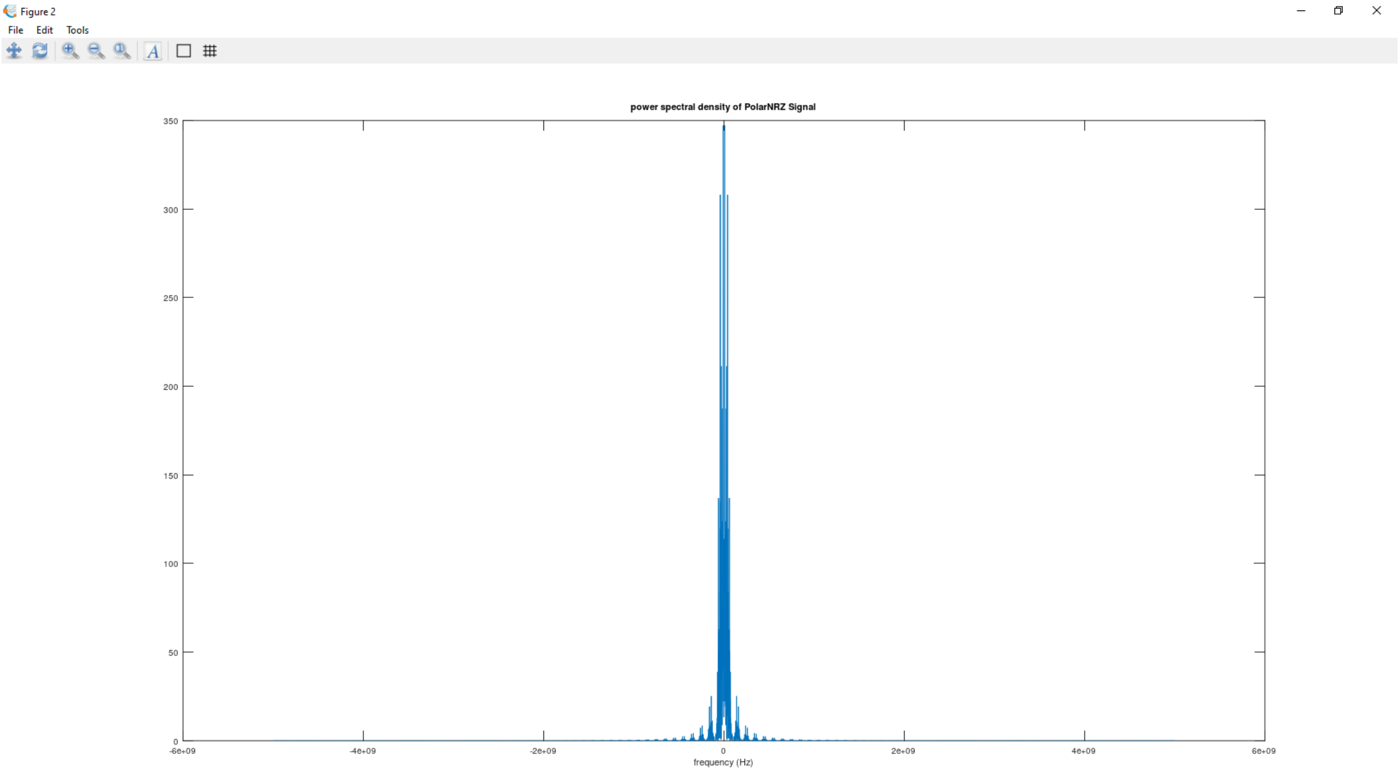
Filter

Name	Class	Dimension	Value	Attribute
BW	double	1x1	1.0000e+08	
PolarNRZ	double	1x10000	[-1, -1, -1, -1, -1...	
Rb	double	1x1	1.0000e+08	
Spec_PolarNRZ...	double	1x10000	[0 + 0i, -2.5426e...	complex
T	double	1x1	1.0000e-06	
bitPeriod	double	1x1	9.9000e-09	
bit_stream	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
coding_scheme	char	1x8	PolarNRZ	
f	double	1x10000	-5e+09:1e+06:4....	
fc	double	1x1	1.0000e+09	
fs	double	1x1	1.0000e+10	
noOfBits	double	1x1	100	
noSamplesPerBit	double	1x1	100	
spectral_PolarN...	double	1x10000	[0, 1.3085e-06, 1...	
t	double	1x100	0:1e-10:9.9e-09	
timeVec	double	1x10000	[0, 1.0000e-10, 2...	
ts	double	1x1	1.0000e-10	
voltage	double	1x1	1	

plot of PolarNRZ signal's spectrum:



plot of Power spectral of PolarNRZ signal:



Step 4 : time domain after Modulation:

Code:

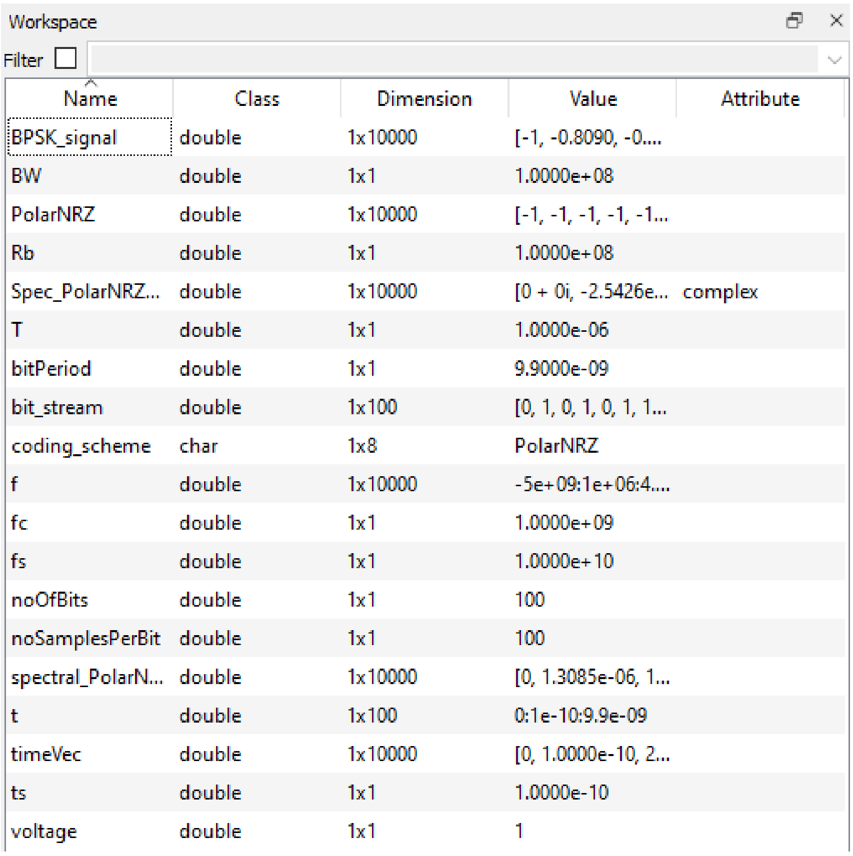
Script:

File: part2.m

```
% The BPSK Signal (modulated signal of PolarNRZ Signal after product modulator in transmitter circuit)
BPSK_signal = PolarNRZ .* cos(2 * pi * fc * timeVec);

% Plot the BPSK Signal (line coding) with time
figure;
plot(timeVec, BPSK_signal, 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Amplitude (V)');
title('BPSK Signal with Two Phase Shifts');
axis([0 timeVec(end) -1.5 1.5]);
grid on;
```

Snapshots:

workspace:

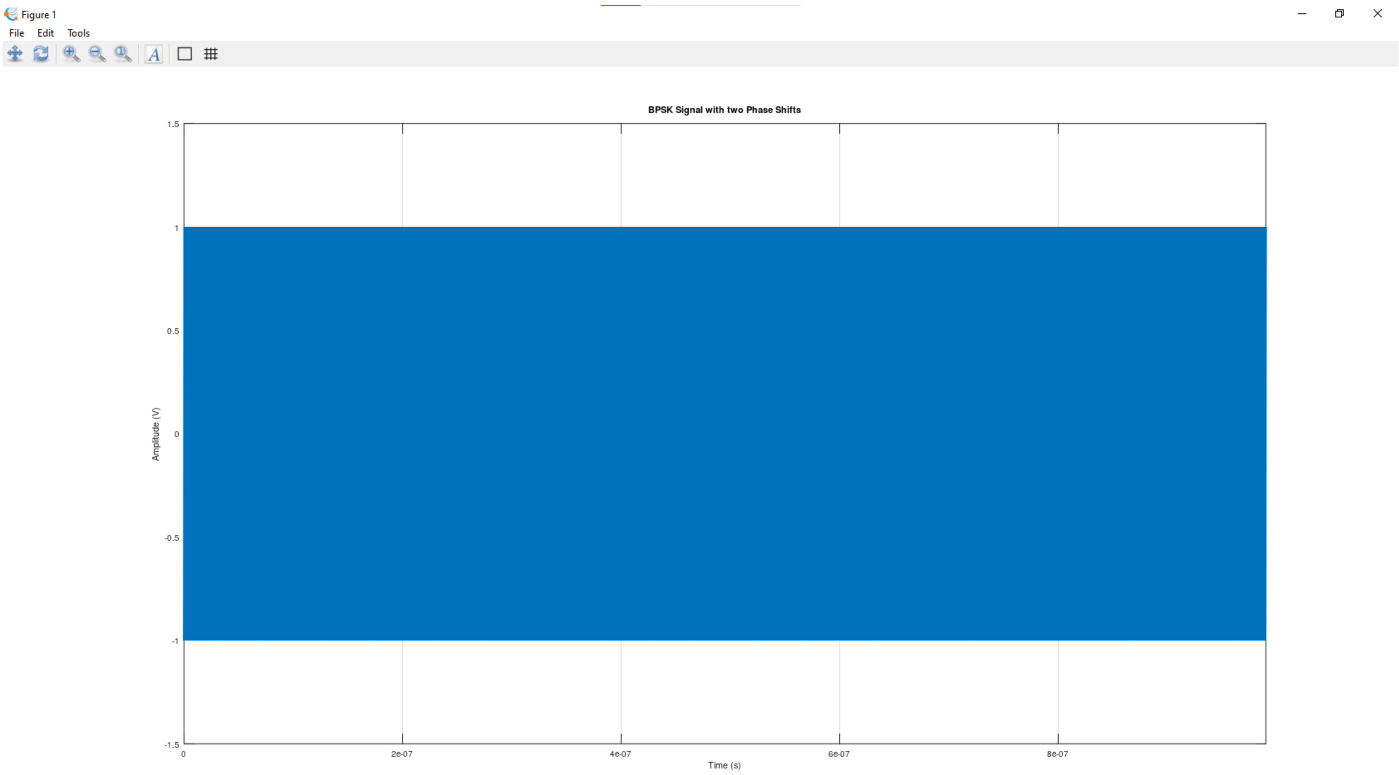


Workspace

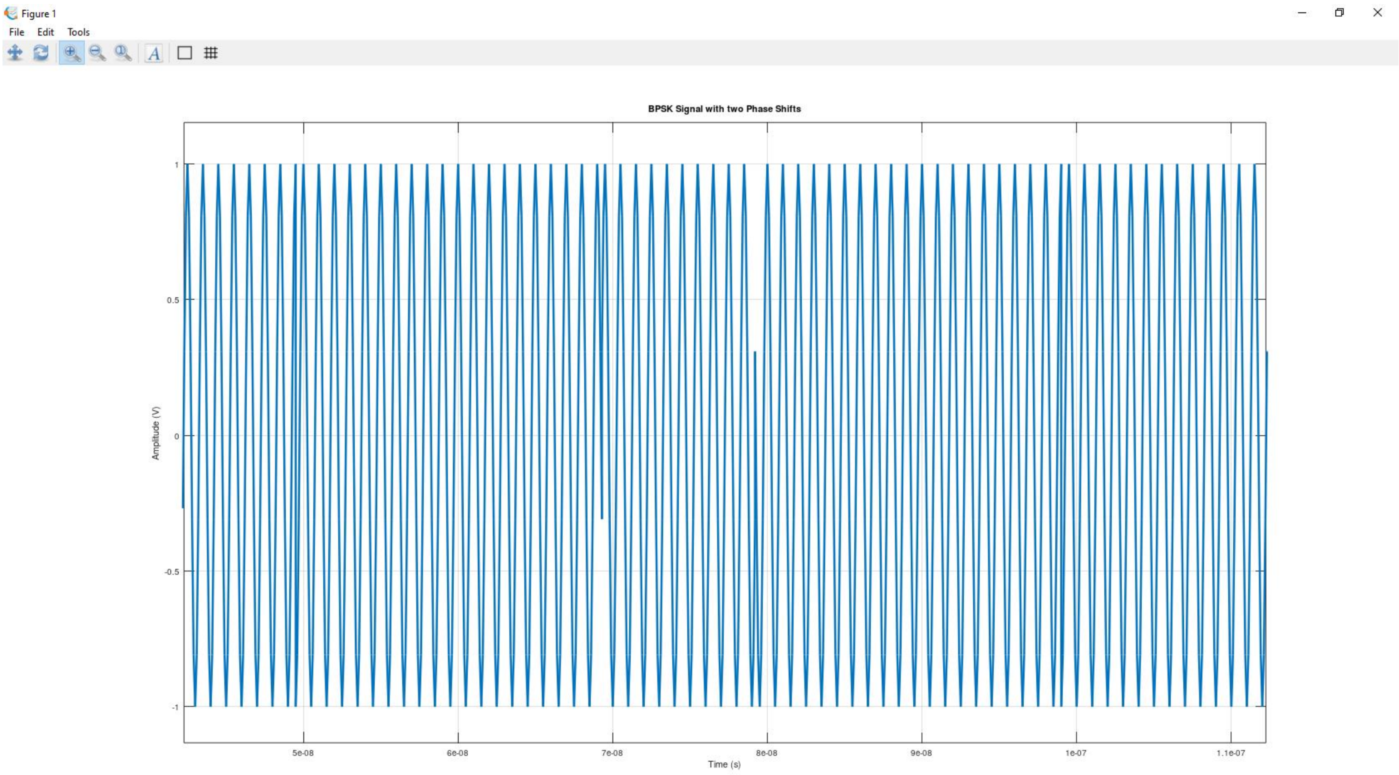
Filter

Name	Class	Dimension	Value	Attribute
BPSK_signal	double	1x10000	[-1, -0.8090, -0....	
BW	double	1x1	1.0000e+08	
PolarNRZ	double	1x10000	[-1, -1, -1, -1, -1...	
Rb	double	1x1	1.0000e+08	
Spec_PolarNRZ...	double	1x10000	[0 + 0i, -2.5426e...	complex
T	double	1x1	1.0000e-06	
bitPeriod	double	1x1	9.9000e-09	
bit_stream	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
coding_scheme	char	1x8	PolarNRZ	
f	double	1x10000	-5e+09:1e+06:4....	
fc	double	1x1	1.0000e+09	
fs	double	1x1	1.0000e+10	
noOfBits	double	1x1	100	
noSamplesPerBit	double	1x1	100	
spectral_PolarN...	double	1x10000	[0, 1.3085e-06, 1...	
t	double	1x100	0:1e-10:9.9e-09	
timeVec	double	1x10000	[0, 1.0000e-10, 2...	
ts	double	1x1	1.0000e-10	
voltage	double	1x1	1	

Plot of BPSK signal with two phase shifts:
Before zoom:



After zoom:



Step 5 : spectrum of the modulated BPSK signal:

Code:

Used functions:

File: spectral_domain.m

```
function [spectral, f, BW, Spec_Original_line_coding] = spectral_domain(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc)
    switch nargin
        % Choose according to number of input arguments
        case 4
            % Belongs to Part 1
            [spectral, f] = Baseband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod);
        case 5
            % Belongs to Part 2
            [spectral, f, BW, Spec_Original_line_coding] = Passband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc);
    end
end

function [spectral, f, BW, Spec_Original_line_coding] = Passband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc)
    % Calculation to generate frequency domain
    noOfBits = length(bit_stream);
    fs = 10 * fc;  % Sampling frequency - Sampling rate - This will define the resolution
    ts = 1 / fs;   % Time step
    T = (noOfBits) * (I apologize for the incomplete response in my previous message. Here's the remainder of the reformatted code starting from line 18 with line numbers:noOfBits * ts); % Simulation time
    Rb = noOfBits / T; % Bit rate = N / simulation time
    BW = Rb; % Polar & NRZ
    df = 1 / T; % Frequency step

% Spectrum of Original Digital Signal
Spec_Original_line_coding = (fftshift(fft(lineCodeVec))) / noOfBits; % We put message in frequency domain because it only shifts function in FFT

% Frequency domain
if (rem(noOfBits,2) == 0) % Even
f = ((-(0.5 * fs)):df:((0.5 * fs) - df)); % Frequency vector if x/f even
else % Odd
f = (-(0.5 * fs - 0.5 * df)) : df :(((0.5 * fs) + 1) - 0.5 * df); % Frequency vector if X/f is odd
end

% Power spectral of Original Digital Signal
spectral = abs(Spec_Original_line_codingand).^2;
end
```

Script:
File: part2.m

```
% Spectrum & Spectral of BPSK signal

[spectral_BPSK_signal, f, BW, spec_BPSK_signal] = spectral_domain(BPSK_signal,
bit_stream, noSamplesPerBit, bitPeriod, fc);

figure(3);
grid on;

subplot(1, 2, 1);
plot(f, abs(spec_BPSK_signal));
title("Spectrum of Modulated BPSK Signal");
xlabel("Frequency (Hz)");
ylabel('Amplitude (V)');

subplot(1, 2, 2);
plot(f, spectral_BPSK_signal);
title("Power Spectral Density of Modulated BPSK Signal");
xlabel("Frequency (Hz)");
ylabel('Power Spectral Density');
```

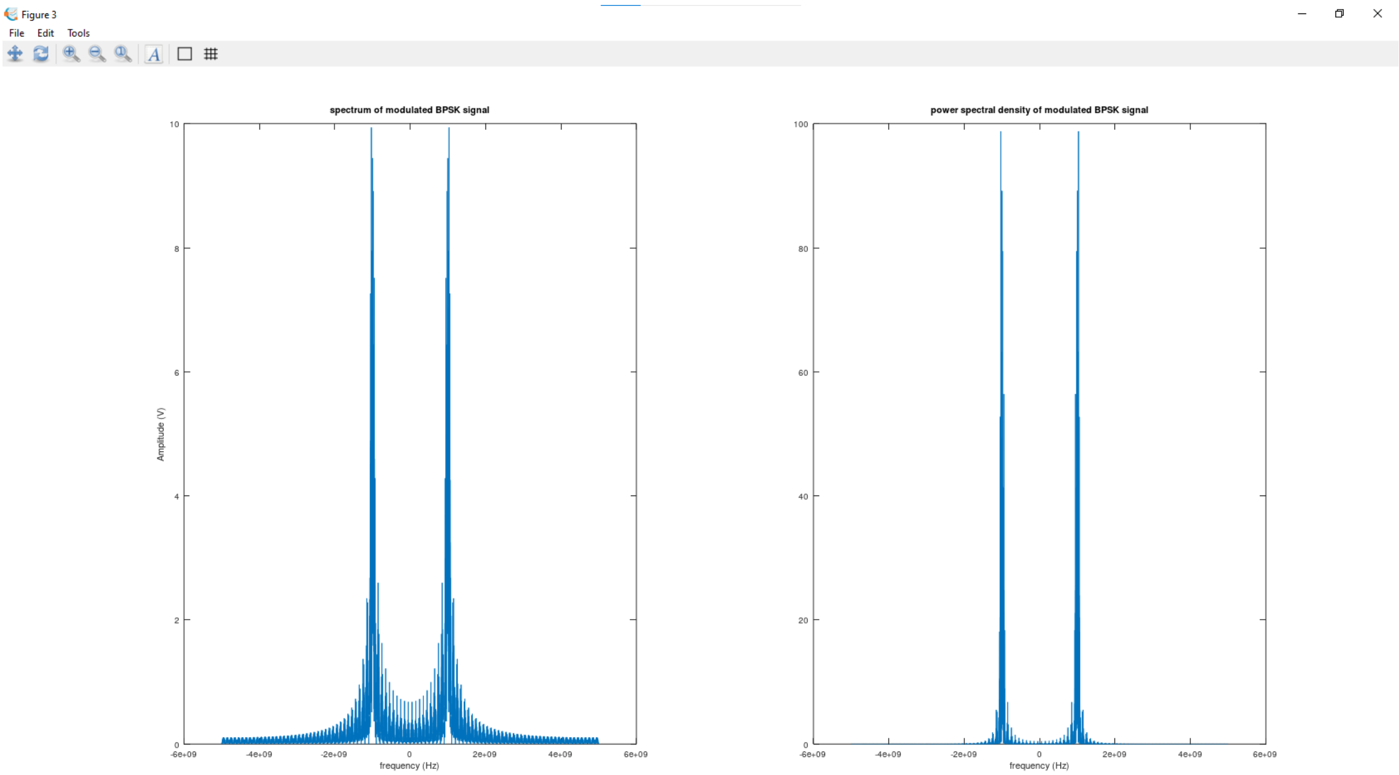
Snapshots:
workspace:

Workspace

Filter

Name	Class	Dimension	Value	Attribute
BPSK_signal	double	1x10000	[-1, -0.8090, -0....	
BW	double	1x1	1.0000e+08	
PolarNRZ	double	1x10000	[-1, -1, -1, -1, -1...	
Rb	double	1x1	1.0000e+08	
Spec_PolarNRZ...	double	1x10000	[0 + 0i, -2.5426e...	complex
T	double	1x1	1.0000e-06	
bitPeriod	double	1x1	9.9000e-09	
bit_stream	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
coding_scheme	char	1x8	PolarNRZ	
f	double	1x10000	-5e+09:1e+06:4....	
fc	double	1x1	1.0000e+09	
fs	double	1x1	1.0000e+10	
noOfBits	double	1x1	100	
noSamplesPerBit	double	1x1	100	
spec_BPSK_signal	double	1x10000	[-1.0083e-13 + ...	complex
spectral_BPSK_s...	double	1x10000	[1.0166e-26, 3.1...	
spectral_PolarN...	double	1x10000	[0, 1.3085e-06, 1...	
t	double	1x100	0:1e-10:9.9e-09	
timeVec	double	1x10000	[0, 1.0000e-10, 2...	
ts	double	1x1	1.0000e-10	
voltage	double	1x1	1	

Plot of spectrum of moduled BPSK signal & Power of spectral moduled BPSK signal:



Receiver:

Step 6 : Design a receiver:

Code:

<u>Used functions:</u>

File: decision_device.m

```
function [Reciever_output] = decision_device(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits)
    % to select the type of line coding by coding scheme
    switch (coding_scheme)
        case 'UniPolarNRZ'
            Reciever_output = r_unipolarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'PolarNRZ'
            Reciever_output = r_polarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'UniPolarRZ'
            Reciever_output = r_unipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'BiPolarRZ'
            Reciever_output = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'ManchesterCoding'
            Reciever_output = r_manchesterCoding(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
    end
end

function [Reciever_output] = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold_1, threshold_2)
    % pre-allocate a vector to store the Reciever_output
    Reciever_output = zeros(1, length(timeVec));
    switch nargin
        case 8
            for i = 1:1:noOfBits
                if (received_signal_with_noise(L) < threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 0;
                    end
                elseif (received_signal_with_noise(L) > threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                end
                M = M + noSamplesPerBit;
                P = P + noSamplesPerBit;
                L = L + noSamplesPerBit;
            end
        case 9
```

```
            for i = 1:1:noOfBits
                if (received_signal_with_noise(L) < threshold_2)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                elseif (received_signal_with_noise(L) > threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                elseif (received_signal_with_noise(L) < threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 0;
                    end
                end
                M = M + noSamplesPerBit;
                P = P + noSamplesPerBit;
                L = L + noSamplesPerBit;
            end
    end
end

function [Reciever_output] = r_unipolarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = voltage / 2;
    L = noSamplesPerBit / 2;
    M = 1;
    P = noSamplesPerBit;
    [Reciever_output] = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end

function [Reciever_output] = r_polarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = (voltage + (-1 * (voltage))) / 2;
    L = noSamplesPerBit / 2;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end

function [Reciever_output] = r_unipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = voltage / 2;
    L = noSamplesPerBit / 4;
```

```
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise,
noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end

function [Reciever_output] = r_bipolarRZ(received_signal_with_noise, voltage, timeVec,
noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold_1 = voltage / 2;
    threshold_2 = (-1 * (voltage)) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise,
noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold_1, threshold_2);
end

function [Reciever_output] = r_manchesterCoding(received_signal_with_noise, voltage,
timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = (voltage + (-1 * (voltage))) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise,
noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end
```

File: convert_into_Binary_data.m

```
function
[binary_data]=convert_into_Binary_data(Reciever_output,bit_stream,noSamplesPerBit)
    % pre-allocate an vector to store the binary_data
    binary_data = zeros(1, length(bit_stream));
    L = noSamplesPerBit / 2;
    for P = 1:1:length(bit_stream)
        if (Reciever_output(L) == 0)
            binary_data(P) = 0;
        elseif (Reciever_output(L) == 1)
            binary_data(P) = 1;
         end
         L = L + noSamplesPerBit;
     end
end
```

Script:

File: part2.m

```
% demodulated signal (demodulation for BPSK signal after product modulator in recivied circuit)
demodulated_BPSK_signal = BPSK_signal .* cos(2 * pi * fc * timeVec);

% specterum & spectral of recieved signal (demodulated BPSK signal) after product modulator in reciver circuit
[spectral_demodulated_BPSK_signal,f,BW,spec_demodulated_BPSK_signal] = spectral_domain(demodulated_BPSK_signal, bit_stream, noSamplesPerBit, bitPeriod, fc);
figure(4);
grid on;
subplot(1,2,1);
plot(f, abs(spec_demodulated_BPSK_signal));
title("specterum of recieved signal after product modulator in reciver circuit ");
xlabel("frequency (Hz)");
ylabel("Amplitude (V)");
subplot(1,2,2);
plot(f, spectral_demodulated_BPSK_signal);
title("power spectral density of demodulated BPSK signal");
xlabel("frequency (Hz)");
ylabel("power spectral density ");

% LPF (Ideal)
H = abs(f) < (BW);

% specterum &spectral of demodulated BPSK signal After LPF
demodulated_BPSK_signal_After_Lpf = abs(real(H .* spec_demodulated_BPSK_signal));
figure(5);
grid on;
subplot(1,2,1);
plot(f, demodulated_BPSK_signal_After_Lpf);
title("spectrum of demodulated BPSK signal After Lpf");
xlabel("frequency (Hz)");
ylabel("Amplitude (V)");
subplot(1,2,2);
plot(f, (demodulated_BPSK_signal_After_Lpf .^ 2));
title("power spectral density of demodulated BPSK signal After Lpf");
xlabel("frequency (Hz)");
ylabel("power spectral density");

% demodulated BPSK signal AFTER LPF in time domain
demodulated_BPSK_signal_After_Lpf_t = real(ifft(fftshift(H .* spec_demodulated_BPSK_signal) * noOfBits)); %1/N

figure(6);
grid on;
subplot(2,1,1);
plot(timeVec, demodulated_BPSK_signal_After_Lpf_t, 'LineWidth', 2);
axis([0 timeVec(end) -1*voltage voltage]);
title("demodulated BPSK signal After LPF in time domain");
```

```
xlabel("time(s)");
ylabel("Amplitude (V)");

% decision device circuit give wave form in ones and zeros and remove effect of LPF
[Reciever_output] = decision_device(demodulated_BPSK_signal_After_Lpf_t,
coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits);

subplot(2,1,2);
plot(timeVec, Reciever_output, 'color', [0.6350 0.0780 0.1840], 'LineWidth', 2);
axis([0 timeVec(end) 0 voltage]);
title("Reciever output");
xlabel("time(s)");
ylabel("Amplitude (V)");

% return reciever output in form of binary data
binary_data = convert_into_Binary_data(Reciever_output, bit_stream, noSamplesPerBit);
```

Snapshots:

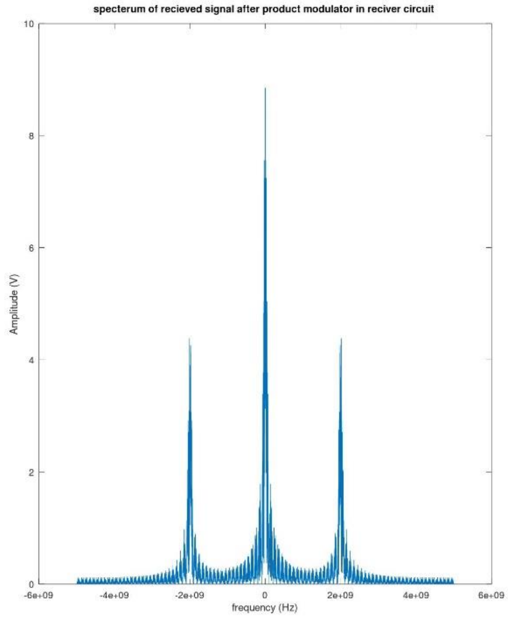
workspace:

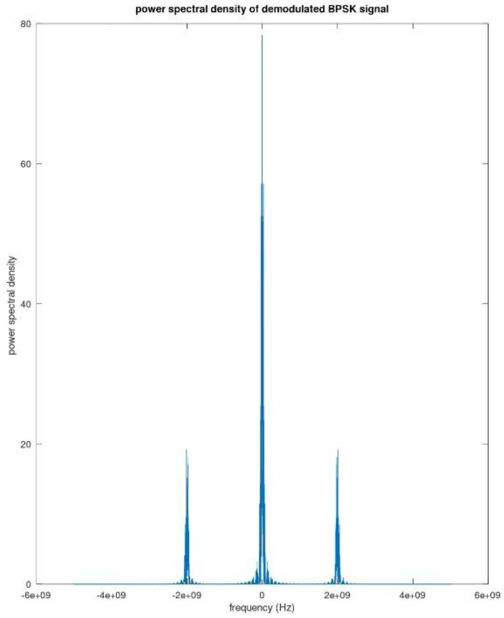
Workspace

Filter

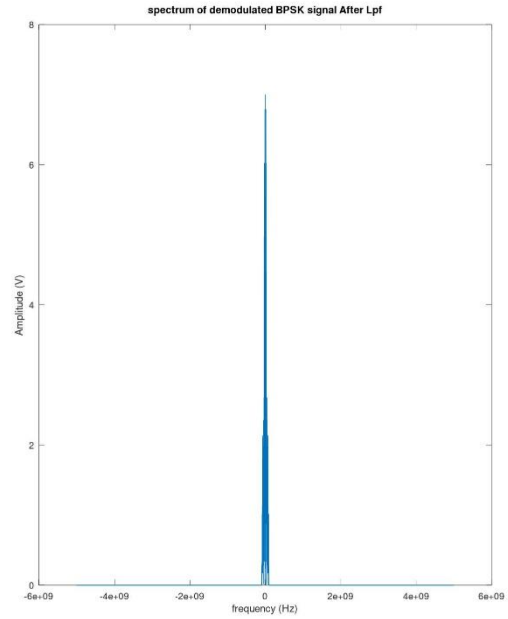
Name	Class	Dimension	Value	Attribute
BPSK_signal	double	1x10000	[-1, -0.8090, -0....	
BW	double	1x1	1.0000e+08	
H	logical	1x10000	[0, 0, 0, 0, 0, 0, 0...	
PolarNRZ	double	1x10000	[-1, -1, -1, -1, -1...	
Rb	double	1x1	1.0000e+08	
Reciever_output	double	1x10000	[0, 0, 0, 0, 0, 0, 0...	
Spec_PolarNRZ...	double	1x10000	[0 + 0i, -2.5426e...	complex
T	double	1x1	1.0000e-06	
binary_data	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
bitPeriod	double	1x1	9.9000e-09	
bit_stream	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
coding_scheme	char	1x8	PolarNRZ	
demodulated_B...	double	1x10000	[-1, -0.6545, -0....	
demodulated_B...	double	1x10000	[0, 0, 0, 0, 0, 0, 0...	
demodulated_B...	double	1x10000	[-0.010618, -0.0...	
f	double	1x10000	-5e+09:1e+06:4....	
fc	double	1x1	1.0000e+09	
fs	double	1x1	1.0000e+10	
noOfBits	double	1x1	100	
noSamplesPerBit	double	1x1	100	
spec_BPSK_signal	double	1x10000	[-1.0083e-13 + ...	complex
spec_demodula...	double	1x10000	[-7.3612e-14 + ...	complex
spectral_BPSK_s...	double	1x10000	[1.0166e-26, 3.1...	
spectral_PolarN...	double	1x10000	[0, 1.3085e-06, 1...	
t	double	1x100	0:1e-10:9.9e-09	
timeVec	double	1x10000	[0, 1.0000e-10, 2...	
ts	double	1x1	1.0000e-10	
voltage	double	1x1	1	

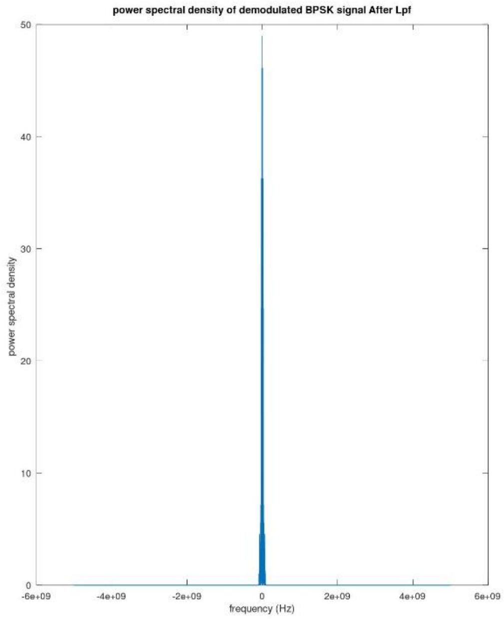
plot of spectrum of moduled signal & Power spectral demoduled BPSK signal:



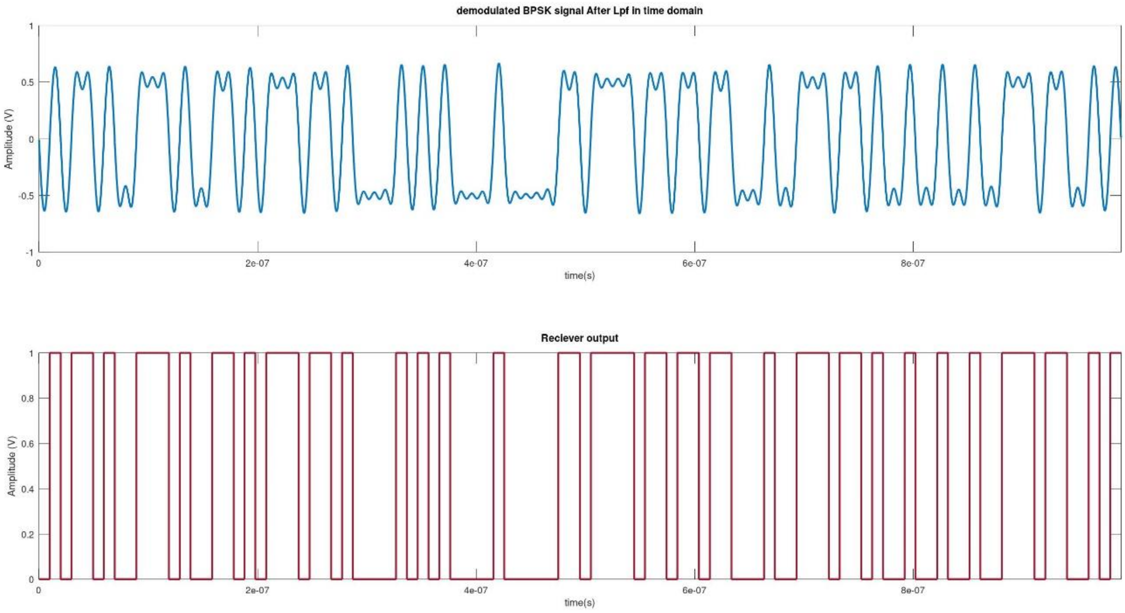


plot of spectrum of BPSK signal after LPF& Power spectral BPSK signal after LPF:





plot of demodulated BPSK signal after LPF in time domain& Output BPSK signal:



Step 7: calculate bit error rate (BER):

Code:

Used functions:

File: BER_device.m

```
function [BER, num_errors] = BER_device(Reciever_output, bit_stream)
    % count the number of errors & calculate BER
    num_errors = sum(Reciever_output ~= bit_stream);
    BER = num_errors / length(bit_stream);
end
```

Script:

File: part2.m

```
% calculate BER & num_errors
[BER, num_errors] = BER_device(binary_data, bit_stream);
```

Snapshots:

workspace:

Workspace

Filter

Name	Class	Dimension	Value	Attribute
BER	double	1x1	0	
BPSK_signal	double	1x10000	[-1, -0.8090, -0....	
BW	double	1x1	1.0000e+08	
H	logical	1x10000	[0, 0, 0, 0, 0, 0, 0...	
PolarNRZ	double	1x10000	[-1, -1, -1, -1, -1...	
Rb	double	1x1	1.0000e+08	
Reciever_output	double	1x10000	[0, 0, 0, 0, 0, 0, 0...	
Spec_PolarNRZ...	double	1x10000	[0 + 0i, -2.5426e...	complex
T	double	1x1	1.0000e-06	
binary_data	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
bitPeriod	double	1x1	9.9000e-09	
bit_stream	double	1x100	[0, 1, 0, 1, 0, 1, 1...	
coding_scheme	char	1x8	PolarNRZ	
demodulated_B...	double	1x10000	[-1, -0.6545, -0....	
demodulated_B...	double	1x10000	[0, 0, 0, 0, 0, 0, 0...	
demodulated_B...	double	1x10000	[-0.010618, -0.0...	
f	double	1x10000	-5e+09:1e+06:4....	
fc	double	1x1	1.0000e+09	
fs	double	1x1	1.0000e+10	
noOfBits	double	1x1	100	
noSamplesPerBit	double	1x1	100	
num_errors	double	1x1	0	
spec_BPSK_signal	double	1x10000	[-1.0083e-13 + ...	complex
spec_demodula...	double	1x10000	[-7.3612e-14 + ...	complex
spectral_BPSK_s...	double	1x10000	[1.0166e-26, 3.1...	
spectral_PolarN...	double	1x10000	[0, 1.3085e-06, 1...	
t	double	1x100	0:1e-10:9.9e-09	
timeVec	double	1x10000	[0, 1.0000e-10, 2...	
ts	double	1x1	1.0000e-10	
voltage	double	1x1	1	

Code as text:

Script Part 1:

part1.m

```
% Clear all variables and close all figures
clear all;
close all;

%set values
voltage=1.2;

noOfBits=10000;
bitPeriod=1;
noSamplesPerBit=200;
noBitsPerSegments=3;

coding_scheme1='UniPolarNRZ';
coding_scheme2='PolarNRZ';
coding_scheme3='UniPolarRZ';
coding_scheme4='BiPolarRZ';
coding_scheme5='ManchesterCoding';


% generate bit_stream
bit_stream = generate_random_bits( noOfBits );

[lineCodeVec1, timeVec1] = line_coding(bit_stream, coding_scheme1, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec2, timeVec2] = line_coding(bit_stream, coding_scheme2, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec3, timeVec3] = line_coding(bit_stream, coding_scheme3, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec4, timeVec4] = line_coding(bit_stream, coding_scheme4, voltage, bitPeriod, noSamplesPerBit);
[lineCodeVec5, timeVec5] = line_coding(bit_stream, coding_scheme5, voltage, bitPeriod, noSamplesPerBit);


%% plot 5 line coding in time domain
% UniPolarNRZ line coding
figure(1);
plot(timeVec1, lineCodeVec1, 'color', [0.4940 0.1840 0.5560], 'LineWidth', 2);
axis([0 timeVec1(end) 0 - voltage/2 voltage*3/2]);
title("UniPolarNRZ line coding");
legend('UniPolarNRZ');

% Zoomed
figure(2);
```

```
plot(timeVec1, lineCodeVec1, 'color', [0.4940 0.1840 0.5560], 'LineWidth', 2);
axis([0 100*bitPeriod 0 - voltage/2 voltage*3/2]);
title("UniPolarNRZ line coding (zoomed to first 100 bits)");
legend('UniPolarNRZ');
grid on;


% PolarNRZ line coding
figure(3);
plot(timeVec2, lineCodeVec2, 'color', [1 0 0], 'LineWidth', 2);
axis([0 timeVec2(end) -3*voltage/2 3*voltage/2]);
title("PolarNRZ line coding");
legend('PolarNRZ');

% Zoomed
figure(4);
plot(timeVec2, lineCodeVec2, 'color', [1 0 0], 'LineWidth', 2);
axis([0 100*bitPeriod -3*voltage/2 3*voltage/2]);
title("PolarNRZ line coding (zoomed to first 100 bits)");
legend('PolarNRZ');
grid on;


% UniPolarRZ line coding
figure(5);
plot(timeVec3, lineCodeVec3, 'color', [0.8500 0.3250 0.0980], 'LineWidth', 2);
axis([0 timeVec3(end) 0 - voltage/2 voltage*3/2]);
title("UniPolarRZ line coding");
legend('UniPolarRZ');

% Zoomed
figure(6);
plot(timeVec3, lineCodeVec3, 'color', [0.8500 0.3250 0.0980], 'LineWidth', 2);
axis([0 100*bitPeriod 0 - voltage/2 voltage*3/2]);
title("UniPolarRZ line coding (zoomed to first 100 bits)");
legend('UniPolarRZ');

% BiPolarRZ line coding
figure(7);
plot(timeVec4, lineCodeVec4, 'color', [0 0.4470 0.7410], 'LineWidth', 2);
axis([0 timeVec4(end) -3*voltage/2 3*voltage/2]);
title("BiPolarRZ line coding");
legend('BiPolarRZ');

% Zoomed
figure(8);
plot(timeVec4, lineCodeVec4, 'color', [0 0.4470 0.7410], 'LineWidth', 2);
axis([0 100*bitPeriod -3*voltage/2 3*voltage/2]);
title("BiPolarRZ line coding (zoomed to first 100 bits)");
legend('BiPolarRZ');
grid on;
```

```


% ManchesterCoding line coding
figure(9);
plot(timeVec5, lineCodeVec5, 'color', [0.6350 0.0780 0.1840], 'LineWidth', 2);
axis([0 timeVec5(end) -3*voltage/2 3*voltage/2]);
title("ManchesterCoding line coding");
legend('ManchesterCoding');

% Zoomed
figure(10);
plot(timeVec5, lineCodeVec5, 'color', [0.6350 0.0780 0.1840], 'LineWidth', 2);
axis([0 100*bitPeriod -3*voltage/2 3*voltage/2]);
title("ManchesterCoding line coding (zoomed to first 100 bits)");
legend('ManchesterCoding');
grid on;
figure(11);
subplot(1,5,1);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec1 , bitPeriod);
title("eye diagram of UniPolarNRZ");
legend('UniPolarNRZ');
ylim([0-voltage/4 3*voltage/2]);
grid on;
% PolarNRZ
subplot(1,5,2);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec2 , bitPeriod);
title("eye diagram of PolarNRZ");
legend('PolarNRZ');
ylim([-3*voltage/2 3*voltage/2]);
grid on;
% UniPolarRZ
subplot(1,5,3);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec3 , bitPeriod);
title("eye diagram of UniPolarRZ");
legend('UniPolarRZ');
ylim([0-voltage/4 3*voltage/2]);
grid on;
% BiPolarRZ
subplot(1,5,4);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec4 , bitPeriod);
title("eye diagram of BiPolarRZ");
legend('BiPolarRZ');
ylim([-3*voltage/2 3*voltage/2]);
grid on;
% ManchesterCoding
subplot(1,5,5);
plot_eye_diagram(noBitsPerSegments , noSamplesPerBit , lineCodeVec5 , bitPeriod);
title("eye diagram of ManchesterCoding");
legend('ManchesterCoding');
ylim([-3*voltage/2 3*voltage/2]);
grid on;
```

```
%% get power spectrum of line coding (transmitted signal)
[spectral_of_lineCodeVec1,f1] = spectral_domain(lineCodeVec1,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec2,f2] = spectral_domain(lineCodeVec2,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec3,f3] = spectral_domain(lineCodeVec3,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec4,f4] = spectral_domain(lineCodeVec4,noSamplesPerBit,bitPeriod,bit_stream);
[spectral_of_lineCodeVec5,f5] = spectral_domain(lineCodeVec5,noSamplesPerBit,bitPeriod,bit_stream);
%% plot power spectrum of any type of line coding
% UniPolarNRZ
figure(12);
plot(f1,spectral_of_lineCodeVec1,'color',[0.4940 0.1840 0.5560],'LineWidth',2);
title("power spectral of UniPolarNRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarNRZ');
grid on;
% Zoomed UniPolarNRZ
figure(13);
plot(f1,spectral_of_lineCodeVec1,'color',[0.4940 0.1840 0.5560],'LineWidth',2);
title("power spectral of UniPolarNRZ (zoomed)");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarNRZ');
axis([-3 3 0 0.0003]);
grid on;
% PolarNRZ
figure(14);
plot(f2,spectral_of_lineCodeVec2,'color',[1 0 0],'LineWidth',2);
title("power spectral of PolarNRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('PolarNRZ');
grid on;
axis([-5 5 0 0.0012]);
% UniPolarRZ
figure(15);
plot(f3,spectral_of_lineCodeVec3,'color',[0.8500 0.3250 0.0980],'LineWidth',2);
title("power spectral of UniPolarRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarRZ');
grid on;
```

```

% Zoomed UniPolarRZ
figure(16);
plot(f3,spectral_of_lineCodeVec3,'color',[0.8500 0.3250 0.0980],'LineWidth',2);
title("power spectral of UniPolarRZ (zoomed)");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('UniPolarRZ');
grid on;
axis([-6 6 0 0.0001]);

% BiPolarRZ
figure(17);
plot(f4,spectral_of_lineCodeVec4,'color',[0 0.4470 0.7410],'LineWidth',2);
title("power spectral of BiPolarRZ");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('BiPolarRZ');
axis([-15 15 0 0.00025]);
grid on;

% ManchesterCoding
figure(18);
plot(f5,spectral_of_lineCodeVec5,'color',[0.6350 0.0780 0.1840],'LineWidth',2);
title("power spectral of ManchesterCoding");
xlabel("frequency (Hz)");
ylabel('power spectral density');
legend('ManchesterCoding');
axis([-10 10 0 0.0008]);

figure(19);
sigma_ranges = linspace(0, voltage, 10);
[BER_values1, num_errors1] = Sweep_on_value_of_sigma(lineCodeVec1, voltage, timeVec1, coding_scheme1, noSamplesPerBit, noOfBits, bit_stream);
[BER_values2, num_errors2] = Sweep_on_value_of_sigma(lineCodeVec2, voltage, timeVec2, coding_scheme2, noSamplesPerBit, noOfBits, bit_stream);
[BER_values3, num_errors3] = Sweep_on_value_of_sigma(lineCodeVec3, voltage, timeVec3, coding_scheme3, noSamplesPerBit, noOfBits, bit_stream);
[BER_values4, num_errors4] = Sweep_on_value_of_sigma(lineCodeVec4, voltage, timeVec4, coding_scheme4, noSamplesPerBit, noOfBits, bit_stream);
[BER_values5, num_errors5] = Sweep_on_value_of_sigma(lineCodeVec5, voltage, timeVec5, coding_scheme5, noSamplesPerBit, noOfBits, bit_stream);

semilogy(sigma_ranges, BER_values1, sigma_ranges, BER_values2, sigma_ranges, BER_values3, sigma_ranges, BER_values4, sigma_ranges, BER_values5, 'LineWidth', 2);

grid on;
xlabel('Sigma');
ylabel('BER');
legend({'UniPolarNRZ', 'PolarNRZ', 'UniPolarRZ', 'BiPolarRZ', 'ManchesterCoding'});
%% BONUS
```

```
[number_of_detected_errors]=Bonus_Sweep_on_value_of_sigma(lineCodeVec4,voltage,timeVec4,coding_scheme4,noSamplesPerBit,noOfBits);
```

Script Part 2 :

part2.m:

```
% octave Script for a Binary PSK (passband communication)
% Clear all variables and close all figures
clear all;
close all;
noOfBits = 100; % Number of time samples
% Generate bit stream
bit_stream = generate_random_bits(noOfBits);
%% Calculations
fc = 10^9;   % Frequency of Modulating Signal
fs = 10 * fc;  % Sampling frequency - Sampling rate - This will define the resolution
ts = 1 / fs;   % Time step
t = 0:ts:(noOfBits - 1) * ts;   % Time for one bit - Time of one bit = 1 second per one bit
T = (noOfBits) * (noOfBits * ts);   % Simulation time
Rb = noOfBits / T;   % Bit rate = N / simulation time
voltage = 1;
bitPeriod = t(end);
noSamplesPerBit = length(t);
coding_scheme = 'PolarNRZ';
%% The PolarNRZ Signal
[PolarNRZ, timeVec] = line_coding(bit_stream, coding_scheme, voltage, bitPeriod, noSamplesPerBit, fc);
% Plot the PolarNRZ Signal with time
figure;
plot(timeVec, PolarNRZ, 'r', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Amplitude (V)');
title('PolarNRZ Signal');
axis([0 timeVec(end) -1.5 1.5]);
grid on;
% Spectrum & Spectral of PolarNRZ Signal
[spectral_PolarNRZ_Signal, f, BW, Spec_PolarNRZ_Signal] = spectral_domain(PolarNRZ, bit_stream, noSamplesPerBit, bitPeriod, fc);
figure;
grid on;
plot(f, abs(Spec_PolarNRZ_Signal));
title('Spectrum of Original PolarNRZ Signal');
xlabel("Frequency (Hz)");
```

```
ylabel('Amplitude (V)');

figure;
plot(f, spectral_PolarNRZ_Signal);
title('Power Spectral Density of PolarNRZ Signal');
xlabel("Frequency (Hz)");
ylabel('Power Spectral Density');

% The BPSK Signal (modulated signal of PolarNRZ Signal after product modulator in transmitter circuit)
BPSK_signal = PolarNRZ .* cos(2 * pi * fc * timeVec);

% Plot the BPSK Signal (line coding) with time
figure;
plot(timeVec, BPSK_signal, 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Amplitude (V)');
title('BPSK Signal with Two Phase Shifts');
axis([0 timeVec(end) -1.5 1.5]);
grid on;

% Spectrum & Spectral of BPSK signal

[spectral_BPSK_signal, f, BW, spec_BPSK_signal] = spectral_domain(BPSK_signal, bit_stream, noSamplesPerBit, bitPeriod, fc);

figure(3);
grid on;

subplot(1, 2, 1);
plot(f, abs(spec_BPSK_signal));
title("Spectrum of Modulated BPSK Signal");
xlabel("Frequency (Hz)");
ylabel('Amplitude (V)');

subplot(1, 2, 2);
plot(f, spectral_BPSK_signal);
title("Power Spectral Density of Modulated BPSK Signal");
xlabel("Frequency (Hz)");
ylabel('Power Spectral Density');

% demodulated signal (demodulation for BPSK signal after product modulator in recivied circuit)
demodulated_BPSK_signal = BPSK_signal .* cos(2 * pi * fc * timeVec);

% specterum & spectral of recieved signal (demodulated BPSK signal) after product modulator in reciver circuit
[spectral_demodulated_BPSK_signal,f,BW,spec_demodulated_BPSK_signal] = spectral_domain(demodulated_BPSK_signal, bit_stream, noSamplesPerBit, bitPeriod, fc);
figure(4);
grid on;
```

```
subplot(1,2,1);
plot(f, abs(spec_demodulated_BPSK_signal));
title("specterum of recieved signal after product modulator in reciver circuit ");
xlabel("frequency (Hz)");
ylabel("Amplitude (V)");
subplot(1,2,2);
plot(f, spectral_demodulated_BPSK_signal);
title("power spectral density of demodulated BPSK signal");
xlabel("frequency (Hz)");
ylabel("power spectral density ");

% LPF (Ideal)
H = abs(f) < (BW);

% specterum &spectral of demodulated BPSK signal After LPF
demodulated_BPSK_signal_After_Lpf = abs(real(H .* spec_demodulated_BPSK_signal));
figure(5);
grid on;
subplot(1,2,1);
plot(f, demodulated_BPSK_signal_After_Lpf);
title("spectrum of demodulated BPSK signal After Lpf");
xlabel("frequency (Hz)");
ylabel("Amplitude (V)");
subplot(1,2,2);
plot(f, (demodulated_BPSK_signal_After_Lpf .^ 2));
title("power spectral density of demodulated BPSK signal After Lpf");
xlabel("frequency (Hz)");
ylabel("power spectral density ");

% demodulated BPSK signal AFTER LPF in time domain
demodulated_BPSK_signal_After_Lpf_t = real(ifft(fftshift(H .* spec_demodulated_BPSK_signal) * noOfBits)); %1/N

figure(6);
grid on;
subplot(2,1,1);
plot(timeVec, demodulated_BPSK_signal_After_Lpf_t, 'LineWidth', 2);
axis([0 timeVec(end) -1*voltage voltage]);
title("demodulated BPSK signal After LPF in time domain");
xlabel("time(s)");
ylabel("Amplitude (V)");

% decision device circuit give wave form in ones and zeros and remove effect of LPF
[Reciever_output] = decision_device(demodulated_BPSK_signal_After_Lpf_t, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits);

subplot(2,1,2);
plot(timeVec, Reciever_output, 'color', [0.6350 0.0780 0.1840], 'LineWidth', 2);
axis([0 timeVec(end) 0 voltage]);
title("output demodulated BPSK signal from recieved circuit");
xlabel("time(s)");
```

```
ylabel("Amplitude (V)");

% return reciever output in form of binary data
binary_data = convert_into_Binary_data(Reciever_output, bit_stream, noSamplesPerBit);

% calculate BER & num_errors
[BER, num_errors] = BER_device(binary_data, bit_stream);
```

Functions codes:

File: generate_random_bits.m

```
function bit_stream = generate_random_bits( noOfBits )
   % generate random sequence of binary data zeros and ones
   bit_stream = randi( [ 0 , 1 ] , 1 , noOfBits );
end
```

File: line_coding.m

```
function [lineCodeVec,timeVec]=line_coding(bit_stream,coding_scheme,voltage,bitPeriod,noSamplesPerBit,fc )
   switch nargin
       %choose according to number of input arguments
       case 5
           %belong to part 1
           [lineCodeVec,timeVec]=Baseband_communication(bit_stream,coding_scheme,voltage,bitPeriod,noSamplesPerBit);
       case 6
           %belong to part 2
           [lineCodeVec,timeVec]=Passband_communication(bit_stream,coding_scheme,voltage,bitPeriod,noSamplesPerBit,fc);
   end
end
function [lineCodeVec, timeVec] = Passband_communication(bit_stream, coding_scheme, voltage, bitPeriod, noSamplesPerBit, fc)
    % This function implements the function of polarNRZ block in transmitter

    % Calculations
    noOfBits = length(bit_stream);
    fs = 10 * fc;  % Sampling frequency - Sampling rate - This will define the resolution
    ts = 1 / fs;   % Time step
    t = 0:ts:(noOfBits - 1) * ts;
% Generate time domain
timeVec = [];
for ii = 1:1:length(bit_stream)
timeVec = [timeVec t];
t = t + (noOfBits - 1) * ts;
end

noSamplesPerBit = length(t);
```

```
% Generate polarNRZ line coding
switch (coding_scheme)
case 'PolarNRZ'
lineCodeVec = polarNRZ(bit_stream, voltage, timeVec, noSamplesPerBit);
end
end
function lineCodeVec = polarNRZ(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = unipolarNRZ(bit_stream , voltage , timeVec , noSamplesPerBit);
    %same as unipolarNRZ but change all the zeros into -ve voltage
    lineCodeVec(lineCodeVec == 0) = -1 * voltage;
end
function lineCodeVec = unipolarRZ(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = zeros(1 , length(timeVec));
    for i = 1 : length(bit_stream)
        if bit_stream(i) == 1
            %+ve voltage for the first half cycle of the bits
            lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = voltage;
            % 0 voltage for the other half cycle of the bit
            lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = 0;
        end
    end
end
function lineCodeVec = bipolarRZ(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = zeros(1 , length(timeVec));
    flag = 0; % to indicate whether the voltage to be +ve or -ve
    for i = 1 : length(bit_stream)
        if bit_stream(i) == 1
            if (flag == 0)
                %+ve voltage for the first half cycle of the bits
                lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = voltage;
                % 0 voltage for the other half cycle of the bit
                lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = 0;
                flag = 1; %update the flag
            elseif(flag == 1)
                %-ve voltage for the first half cycle of the bits
                lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = -voltage;
                % 0 voltage for the other half cycle of the bit
                lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = 0;
                flag = 0; %update the flag
            end
        end
    end
end
```

```
function lineCodeVec = manchesterCoding(bit_stream , voltage , timeVec , noSamplesPerBit)
    lineCodeVec = zeros(1 , length(timeVec));
    for i = 1 : length(bit_stream)
        if bit_stream(i) == 1
            %+ve voltage for the first half cycle of the bits
            lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = voltage;
            %-ve voltage for the other half cycle of the bit
            lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = -1* voltage;
        else
            %-ve voltage for the first half cycle of the bits
            lineCodeVec( ((i - 1) * noSamplesPerBit) + 1 : (i * noSamplesPerBit) - (noSamplesPerBit / 2)) = -1 * voltage;
            %+ve voltage for the other half cycle of the bit
            lineCodeVec( (i * noSamplesPerBit) - (noSamplesPerBit / 2) + 1 : i * noSamplesPerBit) = voltage;
        end
    end
end
```

File: plot_eye_diagram.m

```
function plot_eye_diagram(noBitsPerSegments , noSamplePerBit , lineCodeVec , bitPeriod)
    % segment is a collection of bits we need to shift them to create the eye diagram
    % segmentLength: total samples in a segment
    segmentLength = noSamplePerBit * noBitsPerSegments;
    % periodic time of the samples
    samplePeriod = bitPeriod / noSamplePerBit;
    % time vector is created with a step of samplePeriod, and the end is the total time a segment
    % could be calculated using noBitsPerSegments and bitPeriod, with a step = samplePeriod
    timeVec = (0 : segmentLength - 1) * samplePeriod;
    % to center the zero in the mid
    timeVec = timeVec - (noBitsPerSegments * bitPeriod / 2);
    % total number of segment layers to place on top of each other
    % segmentLayers = total number of samples in line code / total number of samples in the segment
    % it's rounded down to the nearest integer, as we need to keep the size of the segment
    % equal to the size of the time vector in terms of the samples
    segmentLayers = floor(length(lineCodeVec) / segmentLength);
    for i = 1 : segmentLayers
        % find the start and end points of the segment in the line code
        % it's multiplied by the number of bits per segment
        segmentStart = (i - 1) * segmentLength + 1;
```

```
        segmentEnd = i * segmentLength;
        % x-axis is the time vector, and the y-axis is the amplitude of each bit
        plot(timeVec , lineCodeVec(segmentStart : segmentEnd),'LineWidth',2);
        % hold to plot all the segments on top of each other
        hold on;
    end
    axis([-1.5 1.5 -bitPeriod bitPeriod]);
end
```

File: spectral_domain.m

```
function [spectral, f, BW, Spec_Original_line_coding] = spectral_domain(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc)
    switch nargin
        % choose according to number of input arguments
        case 4
            [spectral, f] = Baseband_communication(lineCodeVec, noSamplesPerBit, bitPeriod, bit_stream);
        case 5
            [spectral, f, BW, Spec_Original_line_coding] = Passband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc);
    end
end

function [spectral, f, BW, Spec_Original_line_coding] = Passband_communication(lineCodeVec, bit_stream, noSamplesPerBit, bitPeriod, fc)
    % Calculation to generate frequency domain
    noOfBits = length(bit_stream);
    fs = 10 * fc;  % Sampling frequency - Sampling rate - This will define the resolution
    ts = 1 / fs;   % Time step
    T = noOfBits * ts; % Simulation time
    Rb = noOfBits / T; % Bit rate = N / simulationtime
    BW = Rb; % Polar & NRZ
    df = 1 / T; % Frequency step

    % Spectrum of Original Digital Signal
    Spec_Original_line_coding = (fftshift(fft(lineCodeVec))) / noOfBits; % We put message in frequency domain because it only shifts function in FFT

    % Frequency domain
    if (rem(noOfBits,2) == 0) % Even
        f = ((-(0.5 * fs)):df:((0.5 * fs) - df)); % Frequency vector if x/f even
    else % Odd
        f = (-(0.5 * fs - 0.5 * df)) : df :(((0.5 * fs) + 1) - 0.5 * df); % Frequency vector if X/f is odd
    end

    % Power spectral of Original Digital Signal
    spectral = abs(Spec_Original_line_codingand).^2;
```

```
end

function [spectral, f] = Baseband_communication(lineCodeVec, noSamplesPerBit, bitPeriod, bit_stream)
    % Calculation to generate frequency domain
    T = length(bit_stream) * bitPeriod; % Simulation time
    df =It  %frequency  step
   fs=noSamplesPerBit/bitPeriod; % sampling frequency
  N=noSamplesPerBit*length(bit_stream);
  %spectrum of Original Digital Signal
 Spec_Original_line_coding = (fftshift(fft(lineCodeVec)))/N;
  % frequency doomain
 if(rem(N,2)==0) %% even
 f = ((-(0.5*fs)): df : ((0.5*fs)-df));%% frequency vector if x/f even
 else %% odd
 f = (-(0.5*fs-0.5*df)) : df :(((0.5*fs)+1)-0.5*df); %% frequecy vector if X/f is odd
 end
  %power spectral of Original Digital Signal
 spectral =abs(Spec_Original_line_coding).^2;
  end
```

File: Sweep_on_value_of_sigma.m

```
function [BER_values, num_errors] = Sweep_on_value_of_sigma(lineCodeVec, voltage, timeVec, coding_scheme, noSamplesPerBit, noOfBits, bit_stream)
    % generate 10 ranges for sigma that range from 0 to the maximum supply voltage
    sigma_ranges = linspace(0, voltage, 10);

    % pre-allocate a vector to store the BER values & num_errors
    BER_values = zeros(1, 10);
    num_errors = zeros(1, 10);

    % loop choose each value of sigma by index i
     for i = 1:10
         % add noise to signal
         received_signal_with_noise = add_noise_to_linecoding(lineCodeVec, sigma_ranges(i), timeVec);

         % path signal through the decision device
         Reciever_output = decision_device(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits);

         % this loop is used to convert Reciever output into binary data
         binary_data = convert_into_Binary_data(Reciever_output, bit_stream, noSamplesPerBit);

         % calculate the BER & num_errors for this value of sigma
         [BER_values(i), num_errors(i)] = BER_device(binary_data, bit_stream); % insert your code for calculating BER & num_errors here
```

```
    end
end
```

File: add_noise_to_linecoding.m

```
function received_signal_with_noise = add_noise_to_linecoding(lineCode, sigma, Vectime)
    % this function simulates external noise from the communication channel (telephone line) or noise from the receiver added to the transmitted line coding

    % define your time vector
    t = Vectime;

    % noise
    n = sigma * randn(1, length(t));

    % add the noise to your received signal
    received_signal_with_noise = lineCode + n;
end
```

File: decision_device.m

```
function [Reciever_output] = decision_device(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits)
    % to select the type of line coding by coding scheme
    switch (coding_scheme)
        case 'UniPolarNRZ'
            Reciever_output = r_unipolarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'PolarNRZ'
            Reciever_output = r_polarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'UniPolarRZ'
            Reciever_output = r_unipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'BiPolarRZ'
            Reciever_output = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
        case 'ManchesterCoding'
            Reciever_output = r_manchesterCoding(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
    end
end

function [Reciever_output] = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold_1, threshold_2)
    % pre-allocate a vector to store the Reciever_output
    Reciever_output = zeros(1, length(timeVec));
```

```
    switch nargin
        case 8
            for i = 1:1:noOfBits
                if (received_signal_with_noise(L) < threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 0;
                    end
                elseif (received_signal_with_noise(L) > threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                end
                M = M + noSamplesPerBit;
                P = P + noSamplesPerBit;
                L = L + noSamplesPerBit;
            end
        case 9
            for i = 1:1:noOfBits
                if (received_signal_with_noise(L) < threshold_2)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                elseif (received_signal_with_noise(L) > threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 1;
                    end
                elseif (received_signal_with_noise(L) < threshold_1)
                    for k = M:1:P
                        Reciever_output(k) = 0;
                    end
                end
                M = M + noSamplesPerBit;
                P = P + noSamplesPerBit;
                L = L + noSamplesPerBit;
            end
    end
end

function [Reciever_output] = r_unipolarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = voltage / 2;
    L = noSamplesPerBit / 2;
    M = 1;
    P = noSamplesPerBit;
    [Reciever_output] = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end
```

```
function [Reciever_output] = r_polarNRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = (voltage + (-1 * (voltage))) / 2;
    L = noSamplesPerBit / 2;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end

function [Reciever_output] = r_unipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = voltage / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end

function [Reciever_output] = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold_1 = voltage / 2;
    threshold_2 = (-1 * (voltage)) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold_1, threshold_2);
end

function [Reciever_output] = r_manchesterCoding(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold = (voltage + (-1 * (voltage))) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit;
    Reciever_output = Master_source_and_comparator(received_signal_with_noise, noOfBits, noSamplesPerBit, timeVec, L, M, P, threshold);
end
```

File: convert_into_Binary_data.m

```
function [binary_data] = convert_into_Binary_data(Reciever_output, bit_stream, noSamplesPerBit)
    % pre-allocate a vector to store the binary_data
    binary_data = zeros(1, length(bit_stream));

    L = noSamplesPerBit / 2;

    for P = 1:1:length(bit_stream)
        if (Reciever_output(L) == 0)
            binary_data(P) = 0;
        elseif (Reciever_output(L) == 1)
             binary_data(P) = 1;
        end

         L = L + noSamplesPerBit;
     end
end
```

File: BER_device.m

```
function [BER, num_errors] = BER_device(Reciever_output, bit_stream)
    % count the number of errors & calculate BER
    num_errors = sum(Reciever_output ~= bit_stream);
    BER = num_errors / length(bit_stream);
end
```

File: Regenerative_Repeater.m

```
function [Repeater_output] = Regenerative_Repeater(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits)
    % This function represents the regenerative repeater block used in telephone lines.
    % When entering the receiver to select the type of line coding by coding scheme.
    switch (coding_scheme)
        case 'BiPolarRZ'
            Repeater_output = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits);
    end
end

function [Repeater_output] = r_bipolarRZ(received_signal_with_noise, voltage, timeVec, noSamplesPerBit, noOfBits)
    % Pre-allocate a vector to store the Receiver_output
    Repeater_output = zeros(1, length(timeVec));
    % L decision level of timing circuit
    % M, P time of bit in our time vector
    threshold_1 = voltage / 2;
    threshold_2 = (-1 * (voltage)) / 2;
    L = noSamplesPerBit / 4;
    M = 1;
    P = noSamplesPerBit / 2;
```

```
    for i = 1:1:noOfBits
        if (received_signal_with_noise(L) < threshold_2)
            for k = M:1:P
                Repeater_output(k) = -1 * voltage;
            end
        elseif (received_signal_with_noise(L) > threshold_1)
            for k = M:1:P
                Repeater_output(k) = voltage;
            end
        elseif (received_signal_with_noise(L) < threshold_1)
            for k = M:1:P
                Repeater_output(k) = 0;
            end
        end
        M = M + noSamplesPerBit;
        P = P + noSamplesPerBit;
        L = L + noSamplesPerBit;
    end
end
```

File: Error_Detection_Circuit.m

```
function [number_of_detected_errors] = Error_Detection_Circuit(Repeater_output, voltage, noSamplesPerBit, noOfBits)
    % Error detection circuit for Bipolar return to zero
    number_of_detected_errors = 0;
    L = noSamplesPerBit / 4;

    for i = 1:1:noOfBits
        if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
            break;
        end

        % 1000000000...01
        if (Repeater_output(L) == voltage && Repeater_output(L + noSamplesPerBit) == 0)
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end

            while (Repeater_output(L) == 0)
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end
        end
```

```

        if (Repeater_output(L) == voltage)
            number_of_detected_errors = number_of_detected_errors + 1;
        end
        % -100000000...0-1
        elseif (Repeater_output(L) == -1 * voltage && Repeater_output(L + noSamplesPerBit) == 0)
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end

            while (Repeater_output(L) == 0)
                if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                    break;
                else
                    L = L + noSamplesPerBit;
                end
            end

            if (Repeater_output(L) == -1 * voltage)
                number_of_detected_errors = number_of_detected_errors + 1;
            end

        % -1-1
        elseif (Repeater_output(L) == -1 * voltage && Repeater_output(L + noSamplesPerBit) == -1 * voltage)
            number_of_detected_errors = number_of_detected_errors + 1;
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end

        % 11
        elseif (Repeater_output(L) == voltage && Repeater_output(L + noSamplesPerBit) == voltage)
            number_of_detected_errors = number_of_detected_errors + 1;
            if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
                break;
            else
                L = L + noSamplesPerBit;
            end
        end

```

```
        if (L >= noOfBits * noSamplesPerBit || (L + noSamplesPerBit) >= noOfBits * noSamplesPerBit)
            break;
        else
            L = L + noSamplesPerBit;
        end
    end
end
```

File: Bonus_Sweep_on_value_of_sigma.m

```
function [number_of_detected_errors] = Bonus_Sweep_on_value_of_sigma(lineCodeVec, voltage, timeVec, coding_scheme, noSamplesPerBit, noOfBits)
    % Generate 10 ranges for sigma that range from 0 to the maximum supply voltage
    sigma_ranges = linspace(0, voltage, 10);

    % Pre-allocate a vector to store the BER values & num_errors
    number_of_detected_errors = zeros(1, 10);

    % Loop chooses each value of sigma by index i
    for i = 1:10
        % Add noise to signal
        received_signal_with_noise = add_noise_to_linecoding(lineCodeVec, sigma_ranges(i), timeVec);

        % Path signal through Regenerative_Repeater
        [Repeater_output] = Regenerative_Repeater(received_signal_with_noise, coding_scheme, voltage, timeVec, noSamplesPerBit, noOfBits);

        % Calculate number_of_detected_errors for this value of sigma
        number_of_detected_errors(i) = Error_Detection_Circuit(Repeater_output, voltage, noSamplesPerBit, noOfBits);
    end
end
```