Cairo University
Faculty of Engineering

Department of Computer
Engineering

ELC 325B – Spring 2023

Digital Communications

Assignment #3

Submitted to

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Submitted by

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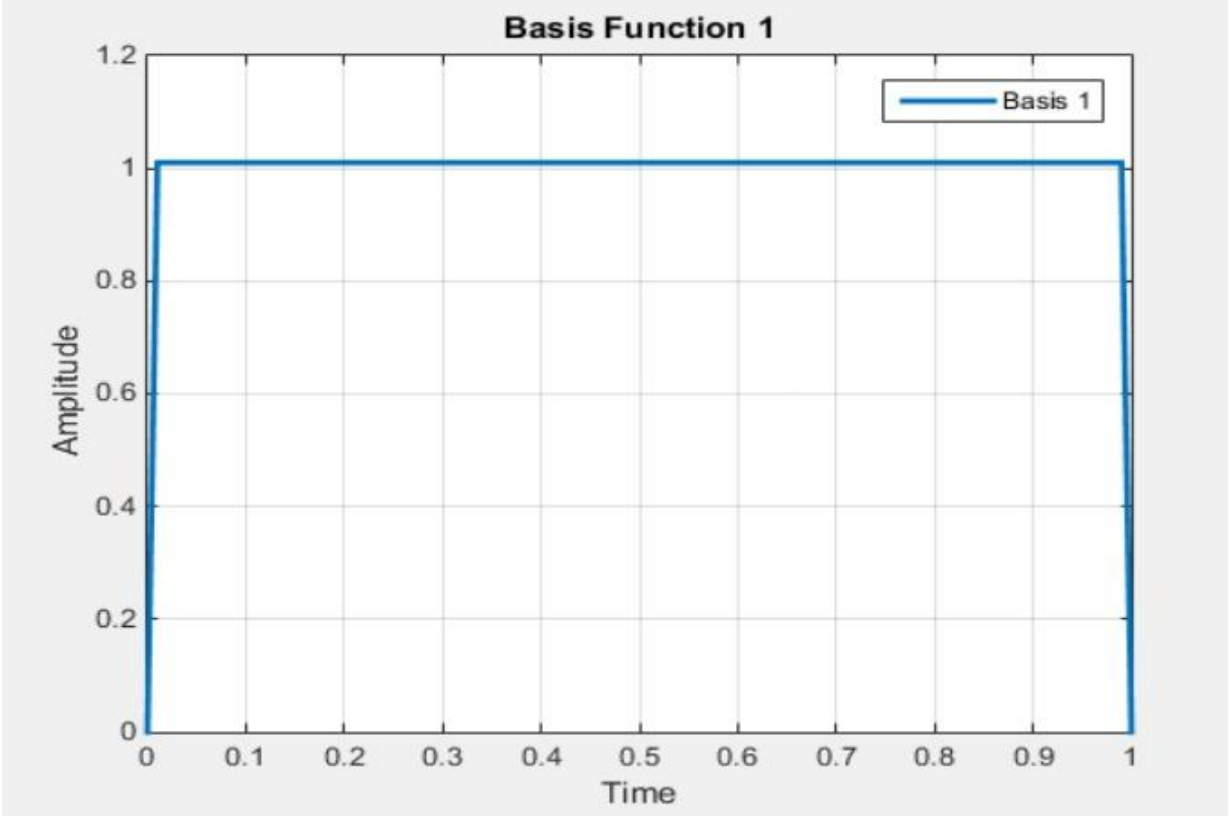
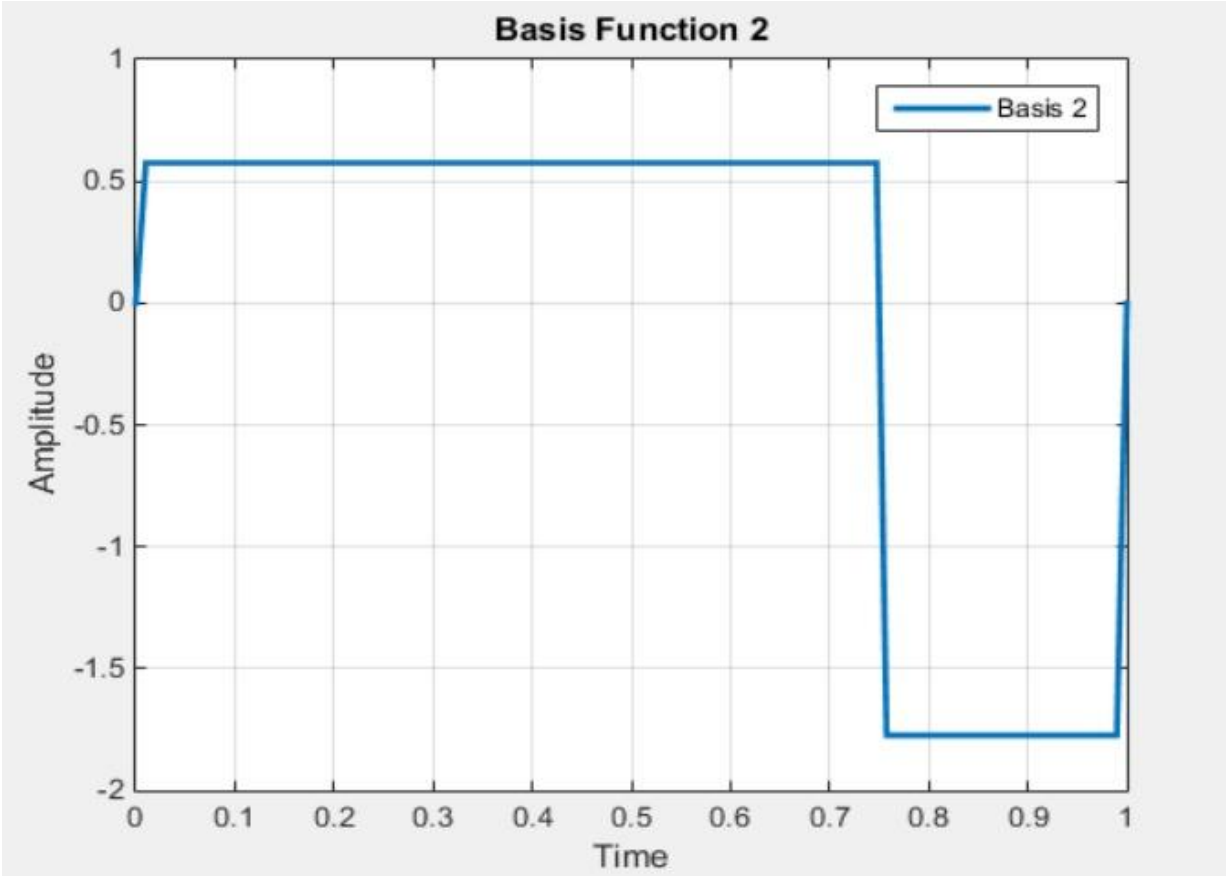
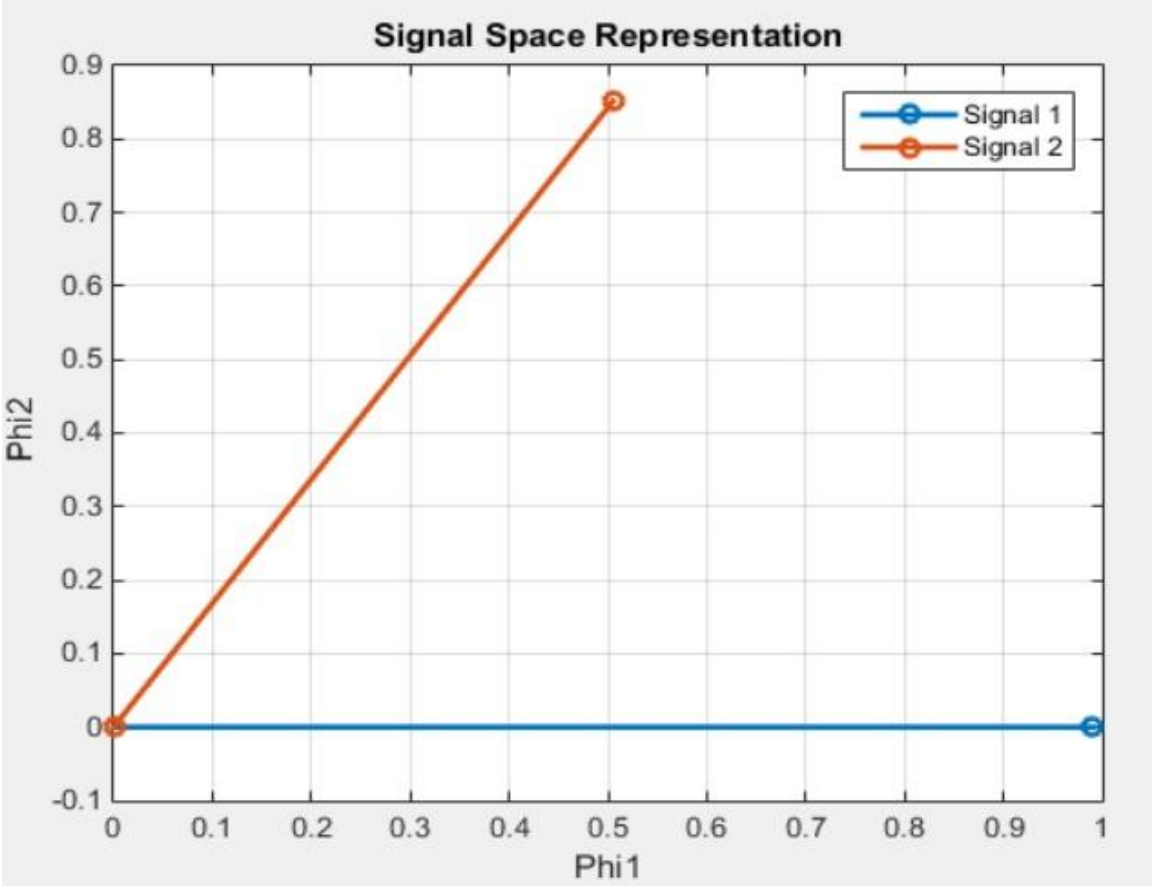
1)

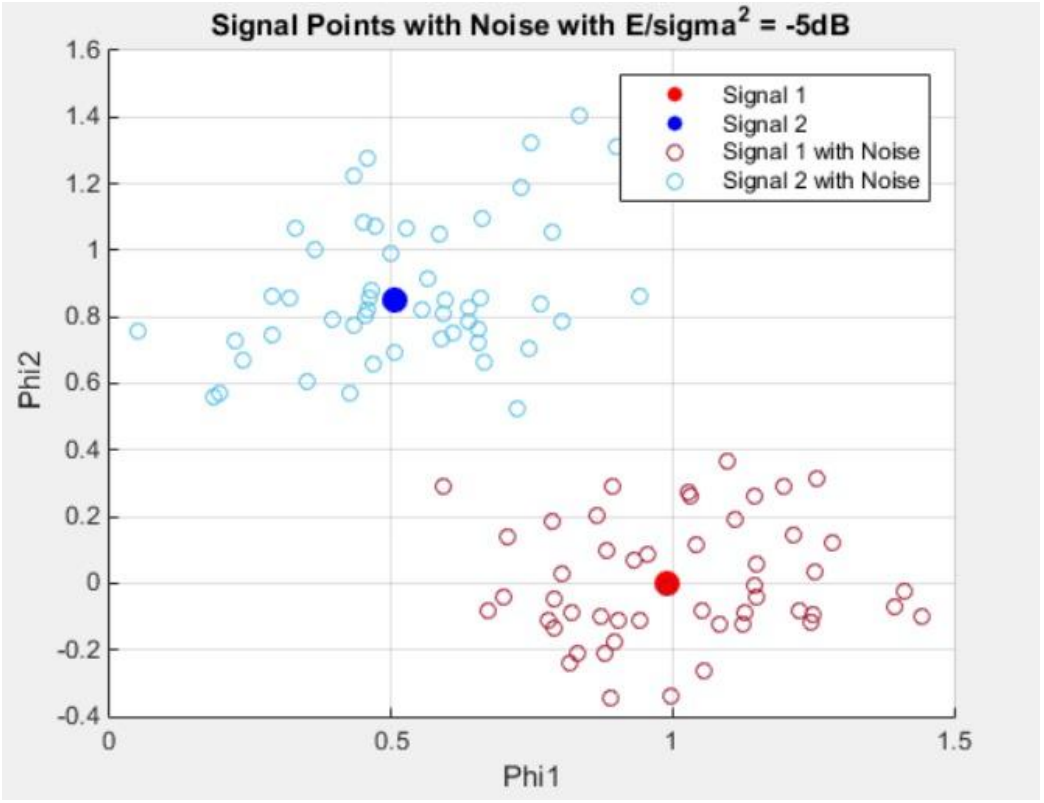

Basis Function 1
Basis 1
Amplitude
Time
1.2
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

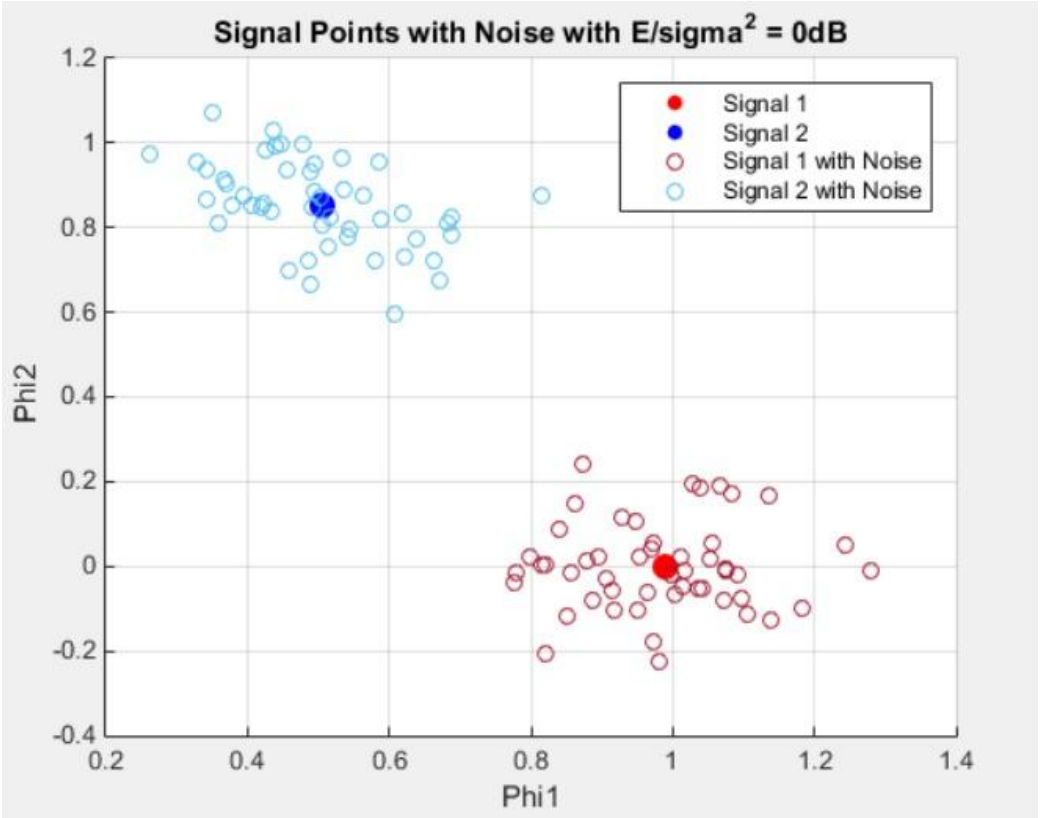

Basis Function 2
Basis 2
Amplitude
Time
1
0.5
0
-0.5
-1
-1.5
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

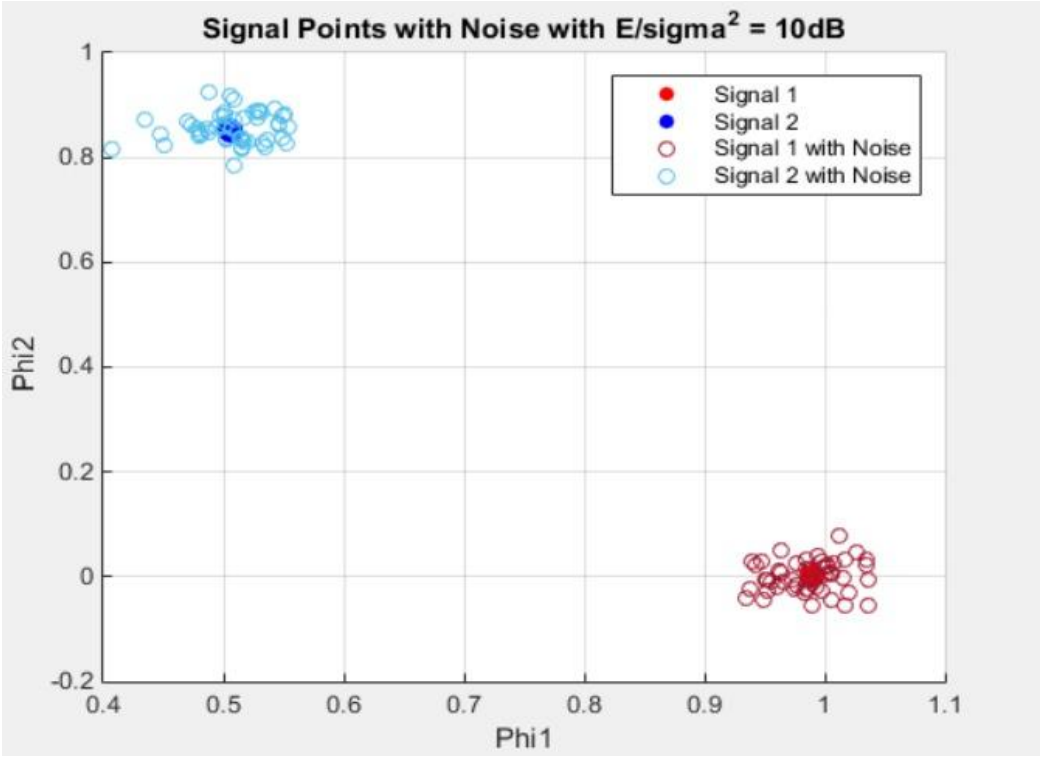
2)


Signal Space Representation
Signal 1
Signal 2
Phi2
Phi1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

3)


Signal Points with Noise with E/sigma^2 = -5dB
Signal 1
Signal 2
Signal 1 with Noise
Signal 2 with Noise
Phi2
Phi1
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
0.5
1
1.5


Signal Points with Noise with E/sigma^2 = 0dB
Signal 1
Signal 2
Signal 1 with Noise
Signal 2 with Noise
Phi2
Phi1
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0.2
0.4
0.6
0.8
1
1.2
1.4



4) How does the noise affect the signal space? Does the noise effect increase or decrease with increasing σ2?

Ans.

As the variance of the noise (σ^2) increases, the effect of noise on the signal space representation also increases. This results in a greater scattering of signal points and a decreased ability to distinguish or separate the signals accurately in the presence of high noise levels.

Matlab Code:

```
function [v1, v2] = signalSpace(s, phi1, phi2)
    v1 = dot(s, phi1) / length(s);
    v2 = dot(s, phi2) / length(s);
end

function r = signalSpaceWithNoise(s, sigma)
```

```
    % Generate additive white Gaussian noise (AWGN)
    noise = sigma * randn(size(s));

    % Add noise to the signal
    r = s + noise;
end

function [phi1, phi2] = calculateGM_Bases(s1, s2)
    phi1 = s1 / norm(s1);

    v2 = s2 - dot(s2, phi1) * phi1;
    phi2 = v2 / norm(v2);

    phi1 = phi1 * sqrt(numel(s1));
    phi2 = phi2 * sqrt(numel(s2));
end

function plotSignalWithNoise(testCase, s1_v1, s1_v2, s2_v1, s2_v2, s1, s2,
phi1, phi2)
    % Draw the signal space representation of the signals before adding
noise
    figure('Name', 'Signal Points with Noise', 'NumberTitle', 'off');
    scatter(s1_v1, s1_v2, 100, 'r', 'filled');
    hold on;
    scatter(s2_v1, s2_v2, 100, 'b', 'filled');

    % E / sigma^2 list in dB
    EoSigma = [-5, 0, 10];
```

```
  Es1 = norm(s1) / sqrt(numel(s1));
  Es2 = norm(s2) / sqrt(numel(s2));

  sigma1 = Es1 ./ db2mag(EoSigma);
  sigma2 = Es2 ./ db2mag(EoSigma);

  for i = 1:50
    r1 = signalSpaceWithNoise(s1, sigma1(testCase));
    r2 = signalSpaceWithNoise(s2, sigma2(testCase));

    % Calculate signal space representation of the generated samples
    [r1_v1, r1_v2] = signalSpace(r1, phi1, phi2);
    [r2_v1, r2_v2] = signalSpace(r2, phi1, phi2);

    % Draw the signal space representation of the signals after adding
noise
    scatter(r1_v1, r1_v2, [], [0.6350 0.0780 0.1840]);
    scatter(r2_v1, r2_v2, [], [0.3010 0.7450 0.9330]);
  end

  legend('Signal 1', 'Signal 2', 'Signal 1 with Noise', 'Signal 2 with Noise');
  xlabel('Phi1');
  ylabel('Phi2');
  title(['Signal Points with Noise with E/sigma^2 = '
num2str(EoSigma(testCase)) 'dB']);
  grid on;
end
```

```
clear all;

% Construct the signals
t = linspace(0, 1, 100);
s1 = rectangularPulse(0, 1, t);
s1(1) = 0; s1(end) = 0;

s2 = rectangularPulse(0, 0.75, t) - 1 * rectangularPulse(0.75, 1, t);
s2(1) = 0; s2(end) = 0;

% Calculate GM bases
[phi1, phi2] = calculateGM_Bases(s1, s2);

% Plot basis functions
figure('Name', 'Basis Functions', 'NumberTitle', 'off');
plot(t, phi1, 'LineWidth', 2);
legend('Basis 1');
xlabel('Time');
ylabel('Amplitude');
title('Basis Function 1');
grid on;

figure('Name', 'Basis Functions', 'NumberTitle', 'off');
plot(t, phi2, 'LineWidth', 2);
legend('Basis 2');
xlabel('Time');
ylabel('Amplitude');
title('Basis Function 2');
```

```
grid on;

% Signal space representation
[s1_v1, s1_v2] = signalSpace(s1, phi1, phi2);
[s2_v1, s2_v2] = signalSpace(s2, phi1, phi2);

% Plot signal space representation
figure('Name', 'Signal Space Representation', 'NumberTitle', 'off');
plot([0 s1_v1], [0 s1_v2], '-o', 'LineWidth', 2);
hold on;
plot([0 s2_v1], [0 s2_v2], '-o', 'LineWidth', 2);
legend('Signal 1', 'Signal 2');
xlabel('Phi1');
ylabel('Phi2');
title('Signal Space Representation');
grid on;

% Plot signals with noise
plotSignalWithNoise(1, s1_v1, s1_v2, s2_v1, s2_v2, s1, s2, phi1, phi2);
plotSignalWithNoise(2, s1_v1, s1_v2, s2_v1, s2_v2, s1, s2, phi1, phi2);
plotSignalWithNoise(3, s1_v1, s1_v2, s2_v1, s2_v2, s1, s2, phi1, phi2);
```