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EEE 321 – 02

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EEE 321 Lab Work 1

The aim of this assignment is to investigate discrete cosine signals. Since digital signals are discrete and quantized, digital computers can only store and process digital signals.

1. $x_1[n] = 3\cos(0.13\pi n + 0.5)$

MATLAB code for generating and storing file for this discrete cosine signal for $n \in [0,127]$.as follows

```
% parameters
n = 0:127;
A = 3;
omega = 0.13*pi;
phi = 0.5;


% function
x1 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x1_signal.txt",'w');    % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x1);            % numbers in floating-point format
fclose(discreteCos);
```

In this code block, the parameters are defined as requested. A is amplitude, omega is frequency, phi is the phase shift. The parameters and the function represent the most general form of the discrete cosine signal which is

$$x[n] = A\cos(\omega n + \phi)$$

The last part of the code block creates the file in write mode and writes the data in .txt file. In this part, numbers are saved in floating-point format by using format specifier “%f”.

MATLAB represents floating-point numbers using the IEEE 754 standard, which provides 64-bit double-precision representation (1). This means that the amplitude values stored with a finite precision. These leads rounding errors if the numbers are not representable exactly in binary format.

Quantization error occur when mapping a continuous set of values to a discrete set. These errors generally small, however they can accumulate if the signal is processed further.

File storage precision can be increased by using different format specifier instead of “%f”. For example, “%e” and “%g” can be used to represent the numbers in scientific notation.

a) MATLAB code for this part as follows

```
% read the data
discreteCos = fopen("x1_signal.txt", "r");  % opens the file in 'read mode'
x1 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x1[%d]= %f\n', 3, x1(4));          % 1-based indexing
fprintf('x1[%d]= %f\n', 7, x1(8));
fprintf('x1[%d]= %f\n', 114, x1(115));
fprintf('x1[%d]= %f\n', 127, x1(128));
```

The first three line of this code block is to read data from an existing file and store these data in a variable. In this case, the data is stored in “x1”, which forms a vector.

By using “fprintf()” function, it is more functional to access an element and print the values at the required indices. Since MATLAB uses 1-based indexing and $n \in [0,127]$, x1(4) corresponds to x1[3], etc.

The output of the code block as follows

```
x1[3]= -0.461435
x1[7]= -2.929477
x1[114]= -2.993570
x1[127]= -1.520264
```

Which is correct respond, according to .txt file.

b) MATLAB code for this part as follows

```
% plot
figure;
stem(n, x1, MarkerFaceColor='r', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_1 [n]');
xlabel('n');
ylabel('x_1 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
```

```
ax.Box = 'off';


% omega value
fprintf("The value of the omega is %f radians.", omega);
```

The first code block of this code for plotting the stored data in vector x1. In this part, marker size and color adjusted for better visualization. The axis and graph are named properly.

At the second block, the location of the x and y axis set to origin and the box around the plot is removed. The graph of $x_1[n]$ is shown in figure 1.

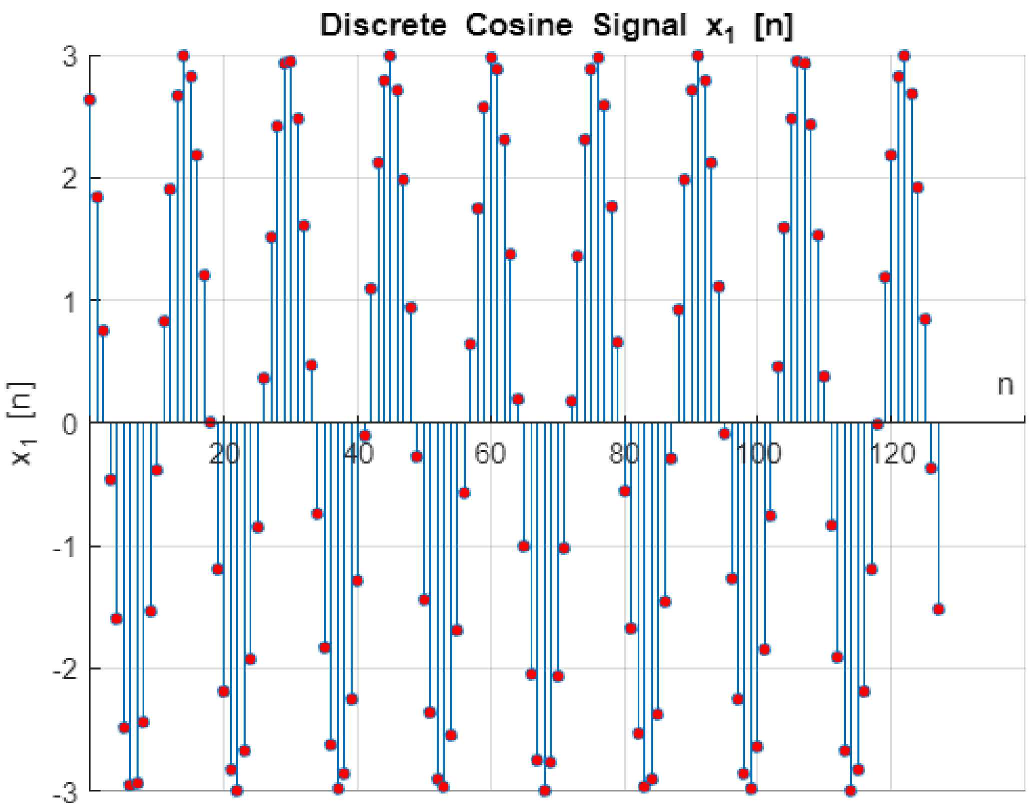

Figure 1: The Graph of Discrete Cosine Signal $x_1[n]$

Finally, value of ω is printed with "fprintf()" function. The output is

```
The value of the omega is 0.408407 radians.
```

Since the processes and logic is the same, the MATLAB code for other discrete cosine signals is listed in Appendix A.

2. MATLAB code for discrete cosine signal $x_2[n] = \cos(2.2\pi n)$ is given in Listing A.1.

a) MATLAB code for this part is given in Listing A.2.

The output of this part as follows

```
x2[3]= -0.309017
x2[7]= -0.309017
x2[114]= -0.809017
x2[127]= -0.309017
```

Which are coherent to the values in the created .txt file.

b) MATLAB code for this part is given in Listing A.3.

The graph of discrete cosine signal $x_2[n]$ is shown in figure 2.

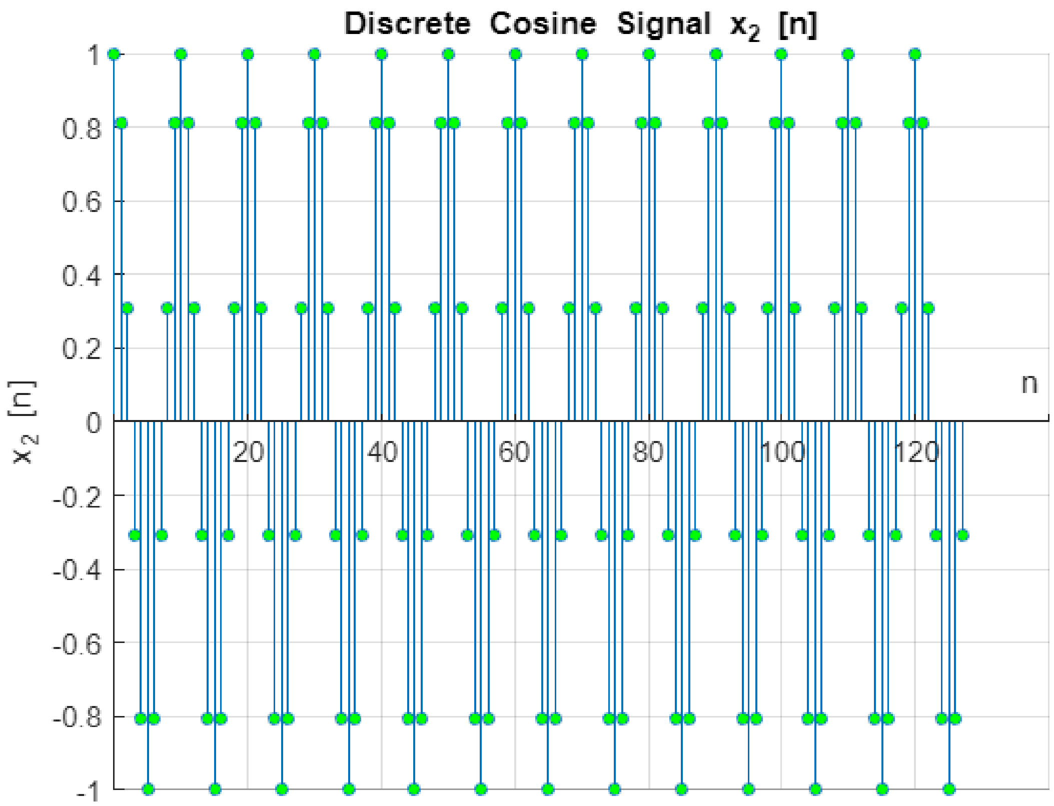

Figure 2: Graph of Discrete Cosine Signal $x_2[n]$

The value of ω is printed as

```
The value of the omega is 6.911504 radians.
```

3. MATLAB code for the discrete cosine signal $x_3[n] = \cos(-1.8\pi n)$ is given in Listing A.4.

a) The output of this part is

```
x3[3]= -0.309017
x3[7]= -0.309017
x3[114]= -0.809017
x3[127]= -0.309017
```

b) The graph of the discrete cosine signal $x_3[n]$ is given in figure 3.

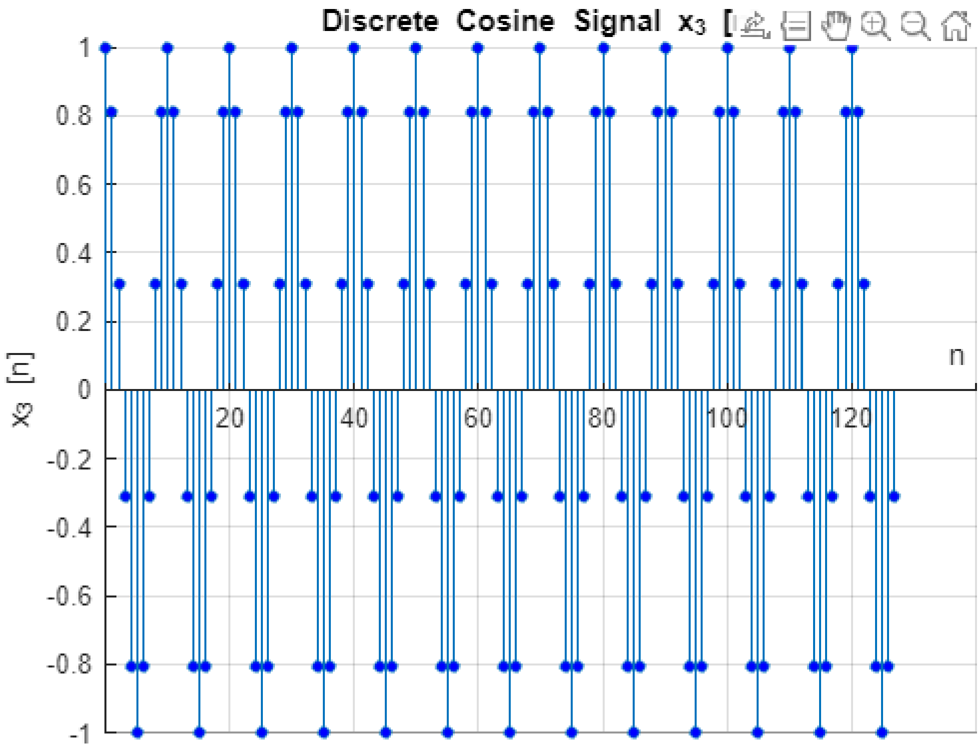

Figure 3: Graph of Discrete Cosine Signal $x_3[n]$

The value of ω is printed as

```
The value of the omega is -5.654867 radians.
```

Visual comparison of the graph of $x_2[n]$ and $x_3[n]$ shows that they are identical. Since cosine function has the property $\cos(x) = \cos(-x)$, $x_3[n] = \cos(-1.8\pi n) = \cos(1.8\pi n)$.

The fundamental period of $x_2[n]$ is

$$\frac{N_2}{k} = \frac{2\pi}{2.2\pi} = \frac{10}{11}$$

$$N_2 = \frac{10}{11}k$$

The fundamental period of $x_3[n]$ is

$$\frac{N_3}{k} = \frac{2\pi}{1.8\pi}$$

$$N_3 = \frac{10}{9}k$$

Since k and N are integer, k for $x_2[n]$ is 11 and k for $x_3[n]$ is 9. Hence the fundamental periods of these discrete cosine signals are same.

The amplitude of both signals is the same and 1 and their phase shifts also the same and 0. Also, the outputs from a) are the same for both signals.

More importantly, the maximum frequency of discrete cosine signal is πn, $|\pi n - \omega_2|$ and $|\pi n - \omega_3|$ are the same. Which means that $x_2[n]$ and $x_3[n]$ are the same functions.

4. MATLAB code for discrete cosine signal $x_4[n] = \cos(0.26\pi n)$ is given is Listing A.5.

a) The output for this part is

```
x4[3]= -0.770513
x4[7]= 0.844328
x4[114]= 0.425779
x4[127]= -0.998027
```

b) The graph of the discrete cosine signal $x_4[n]$ is shown in figure 4.

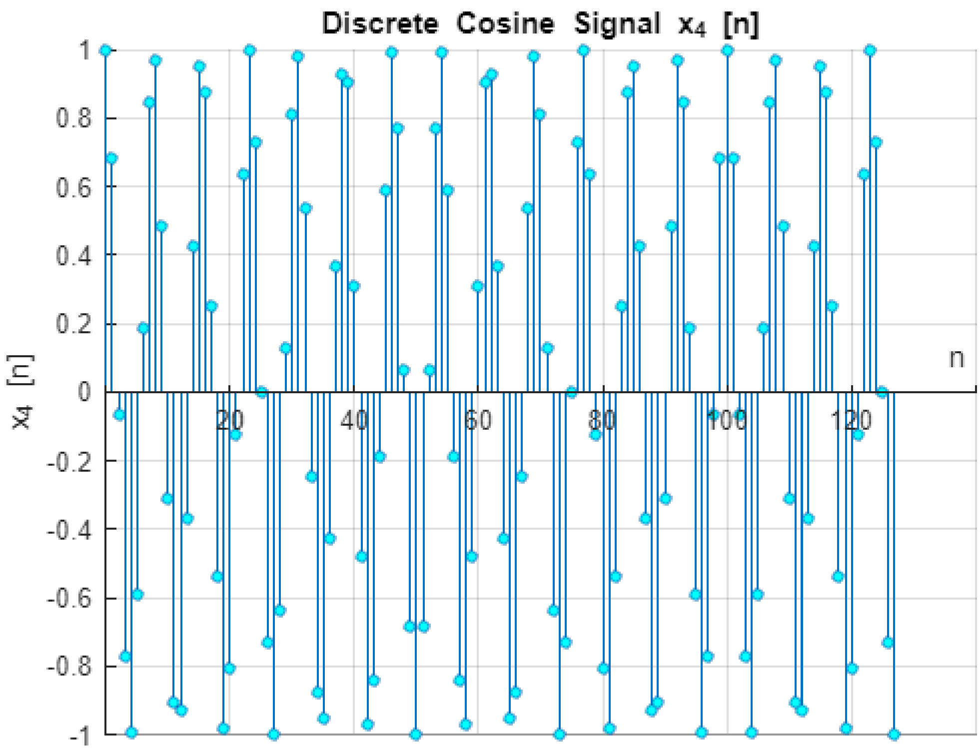

Figure 4: Graph of Discrete Cosine Signal $x_4[n]$

The value of ω is printed as

```
The value of the omega is 0.816814 radians.
```

5. MATLAB code for discrete cosine signal $x_5[n] = \cos(0.26\pi n + 0.7)$ is given in Listing A.6.

a) The output for this part is

```
x5[3]= -0.999961
x5[7]= 0.990967
x5[114]= 0.908560
x5[127]= -0.722882
```

b) The graph of the discrete cosine signal $x_5[n]$ is shown in figure 5

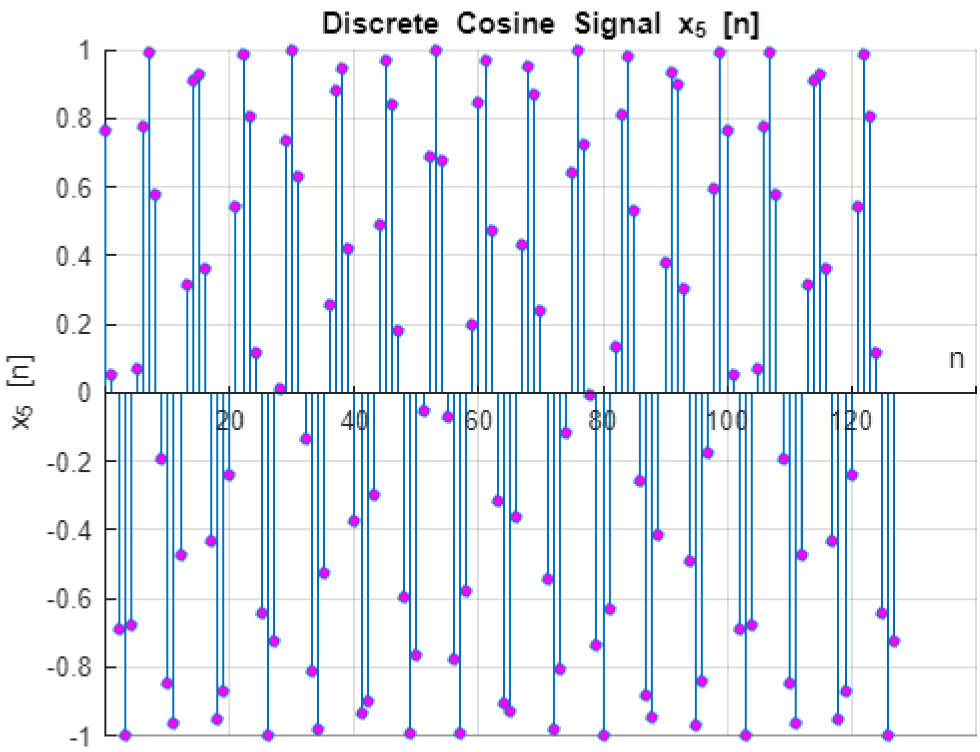

Figure 5: Graph of Discrete Cosine Signal $x_5[n]$

The value of ω is printed as

```
The value of the omega is 0.816814 radians.
```

Visual comparison of the graph of $x_4[n]$ and $x_5[n]$ shows that they have different pattern. Hence the values at the same indices are different which can be observed from the result of a).

Even though the amplitudes of the signals are the same, $x_4[n]$ has no phase shift while $x_5[n]$ has the phase shift of 0.7. Since the phase shift is not rational multiply of π and there is no integer which can give rational value for its division from π, Consequently, these signals are not the same and cannot be said that one of them is phase shifted of one another.

6. MATLAB code of discrete cosine signal $x_6[n] = \cos(0.01\pi n)$. is given in Listing A.7.

a) The output for this part is

```
x6[3]= 0.995562
x6[7]= 0.975917
x6[114]= -0.904827
x6[127]= -0.661312
```

b) The graph of the discrete cosine signal $x_6[n]$ is shown in figure 6.

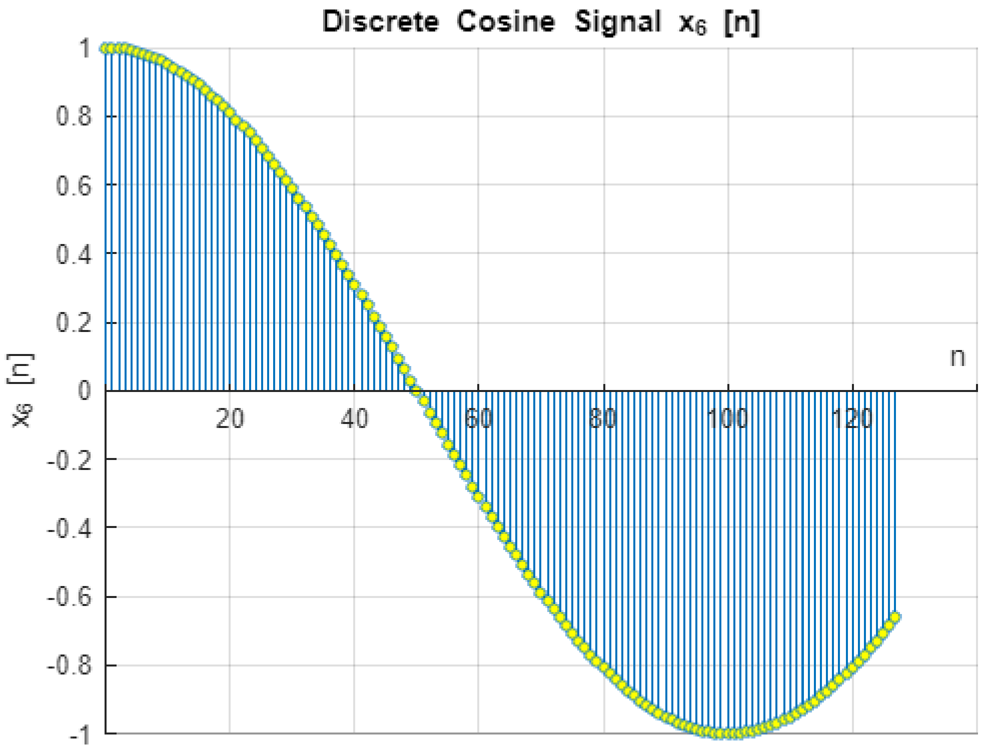

Figure 6: Graph of Discrete Cosine Signal $x_6[n]$

The value of ω is printed as

```
The value of the omega is 0.031416 radians.
```

7. MATLAB code of discrete cosine signal $x_7[n] = \cos(0.39\pi n)$ is given in Listing A.8.

a) The output for this part is

```
x7[3]= -0.860742
x7[7]= -0.661312
x7[114]= 0.125333
x7[127]= 0.094108
```

b) The graph of the discrete cosine signal $x_7[n]$ is given in the figure 7.

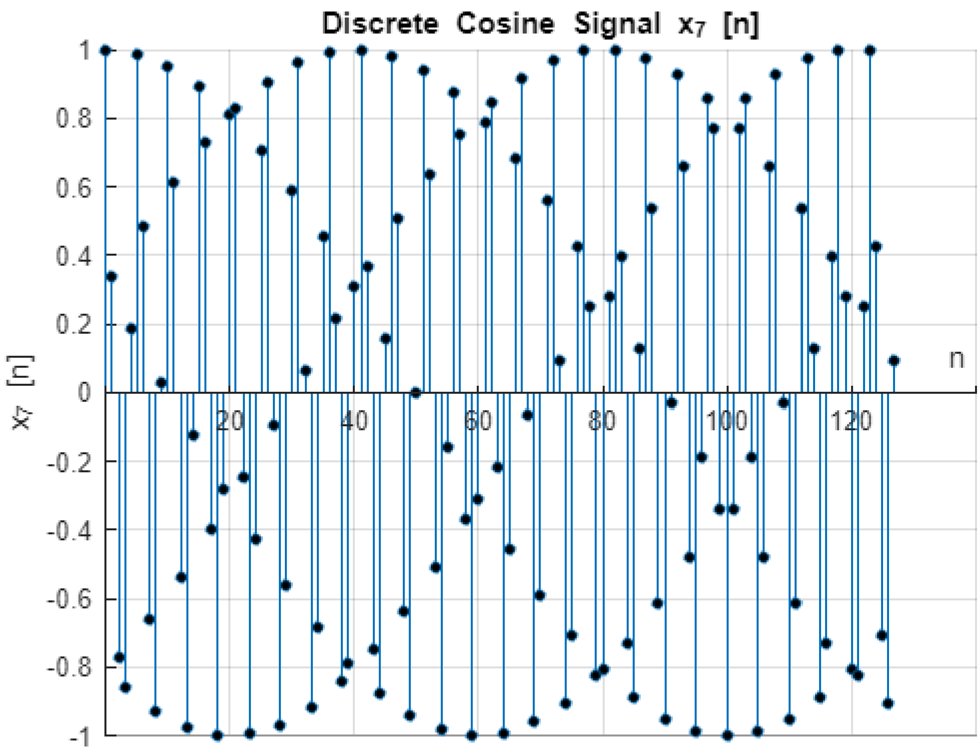

Figure 7: Graph of Discrete Cosine Signal $x_7[n]$

The value of ω is printed as

```
The value of the omega is 1.225221 radians.
```

8. MATLAB code for discrete cosine signal $x_8[n] = \cos(\pi n)$ is listed in Listing A.9. The signals is equal to $(-1)^n$ and it has the maximum frequency of a discrete cosine signal can have.

a) The output of this part as follows

```
x8[3]= -1.000000
x8[7]= -1.000000
x8[114]= 1.000000
x8[127]= -1.000000
```

b) The graph of the discrete cosine signal $x_8[n]$ is shown in figure 8.

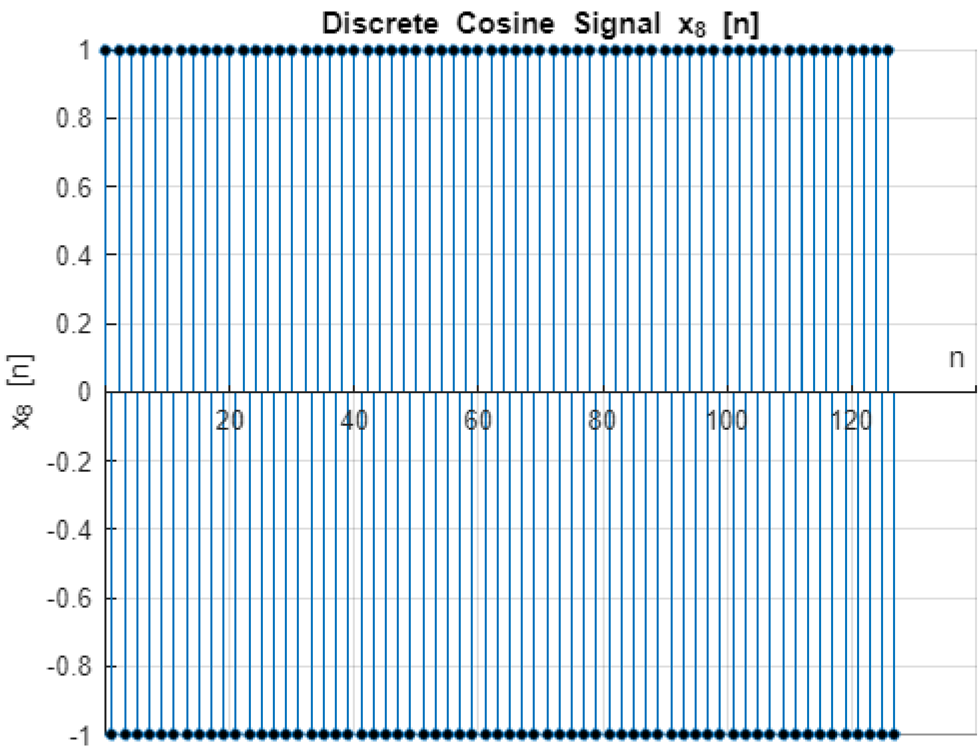

Figure 8: Graph of Discrete Cosine Signal $x_8[n]$

The value of ω is printed as

```
The value of the omega is 3.141593 radians.
```

9. MATLAB code for discrete cosine signal $x_9[n] = \cos(1.08\pi n)$ is listed in Listing A.10.

a) The output of this part is

```
x9[3]= -0.728969
x9[7]= 0.187381
x9[114]= -0.929776
x9[127]= -0.876307
```

b) The graph of the discrete cosine signal $x_9[n]$ is shown in figure 9.

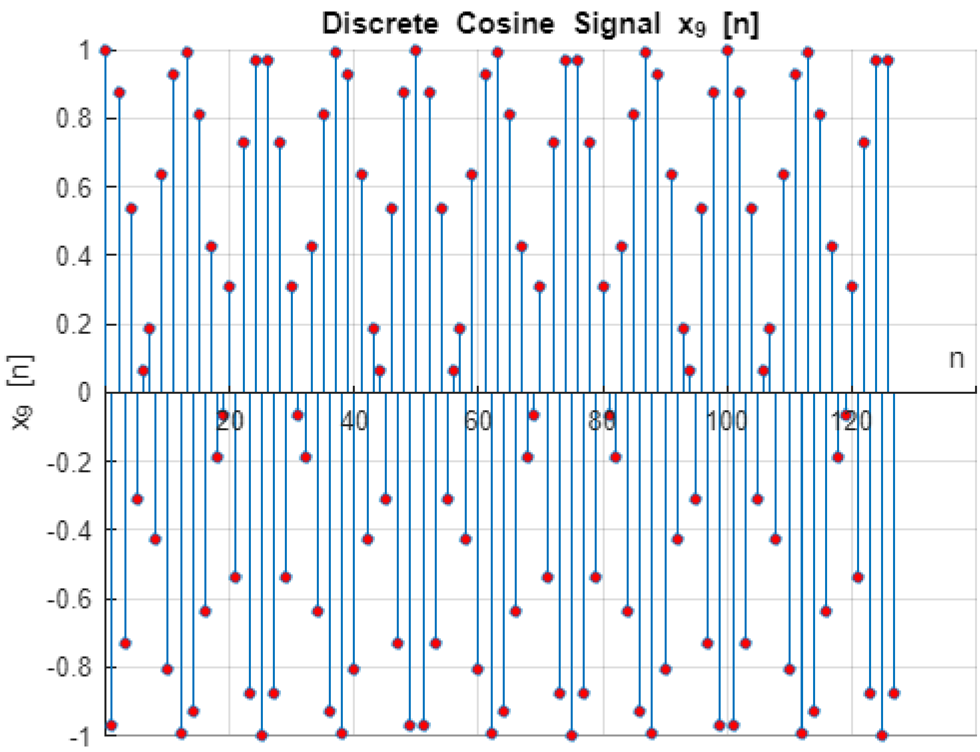

Figure 9: Graph of Discrete Cosine Signal $x_9[n]$

The value of ω is printed as

```
The value of the omega is 3.392920 radians.
```

10. MATLAB code for discrete cosine signal $x_{10}[n] = \cos(0.92\pi n)$ is given in Listing A.11.

a) The output for this part is

```
x10[3]= -0.728969
x10[7]= 0.187381
x10[114]= -0.929776
x10[127]= -0.876307
```

b) The graph of discrete cosine signal $x_{10}[n]$ is shown in figure 10.

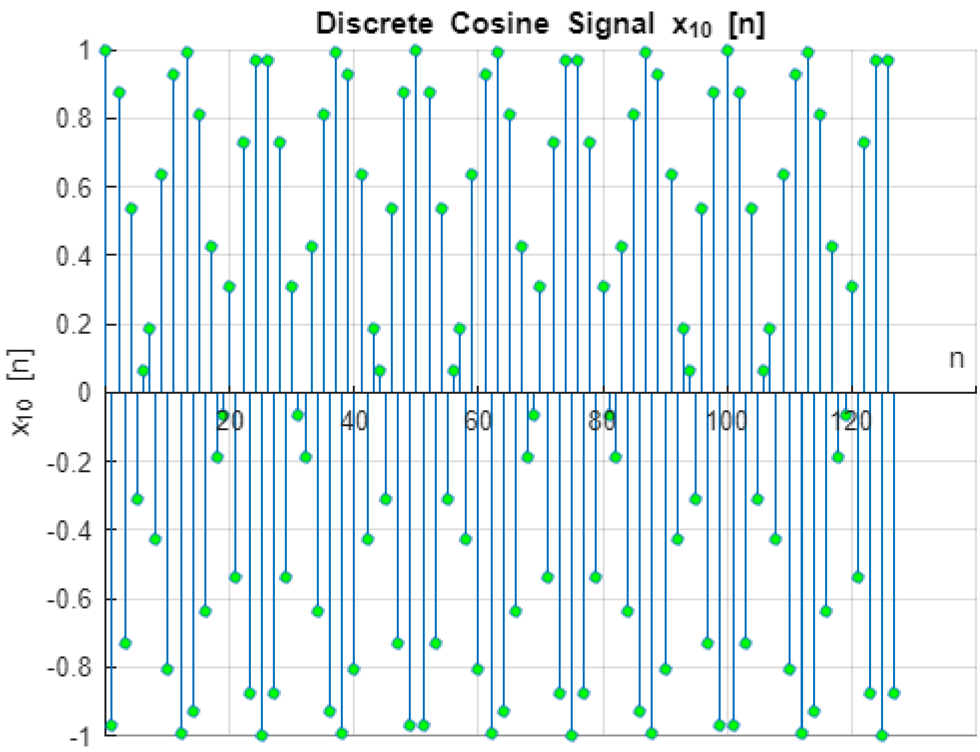

Figure 10: Graph of Discrete Cosine Signal $x_{10}[n]$

The value of ω is printed as

```
The value of the omega is 2.890265 radians.
```

Visual comparison of the graph of $x_9[n]$ and $x_{10}[n]$ shows that they are identical.

The fundamental period of $x_9[n]$ is

$$\frac{N_9}{k} = \frac{2\pi}{1.08\pi} = \frac{50}{27}$$

$$N_9 = \frac{50}{27}k$$

The fundamental period of $x_{10}[n]$ is

$$\frac{N_{10}}{k} = \frac{2\pi}{0.92\pi}$$

$$N_{10} = \frac{50}{23}k$$

Since k and N are integer, k for $x_9[n]$ is 27 and k for $x_{10}[n]$ is 23. Hence the fundamental periods of these discrete cosine signals are same. Also, the outputs from a) are the same for both signals.

Again, the maximum frequency of discrete cosine signal is πn, $|\pi n - \omega_9|$ and $|\pi n - \omega_{10}|$ are the same. Which means that $x_9[n]$ and $x_{10}[n]$ are the same functions.

11. MATLAB code of discrete cosine signal $x_{11}[n] = \cos(n)$ is listed in Listing A.12.

a) The output of this part is

```
x11[3]= -0.989992
x11[7]= 0.753902
x11[114]= 0.619521
x11[127]= 0.232359
```

b) The graph of discrete cosine signal $x_{11}[n]$ is shown in figure 11.

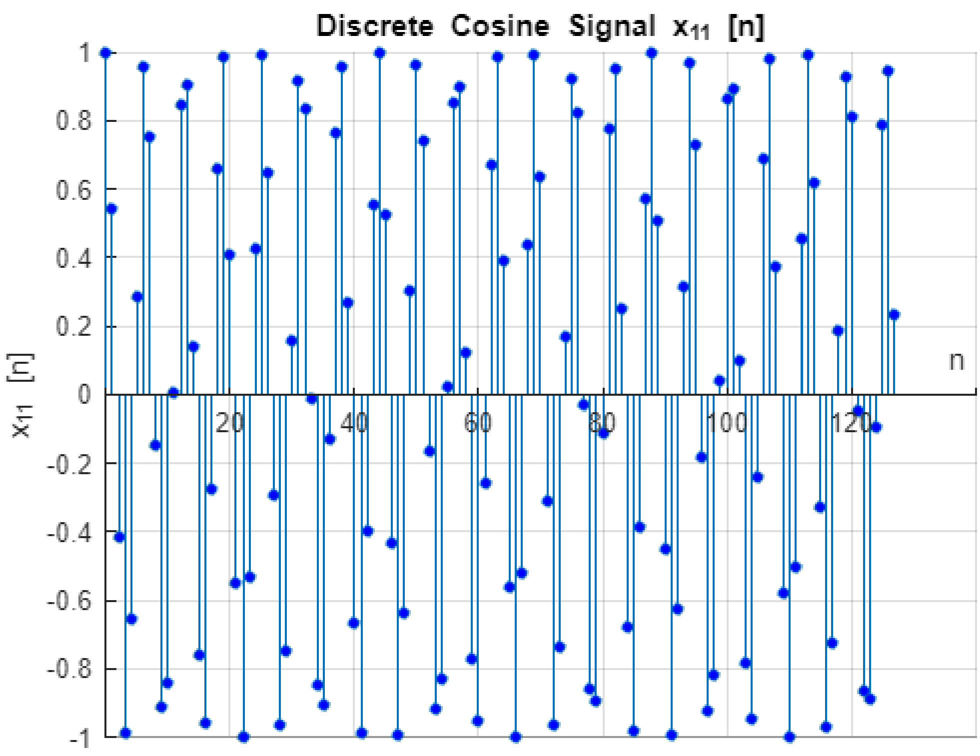

Figure 11: Graph of Discrete Cosine Signal $x_{11}[n]$

The value of ω is printed as

```
The value of the omega is 1.000000 radians.
```

12. MATLAB code for discrete cosine signal $x_{12}[n] = \cos(0.9n + 0.3)$ is listed in Listing A.13.

a) The output for this part is

```
x12[3]= -0.989992
x12[7]= 0.950233
x12[114]= -0.716128
x12[127]= 0.068079
```

b) The graph of discrete cosine signal $x_{12}[n]$ is shown in figure 12.

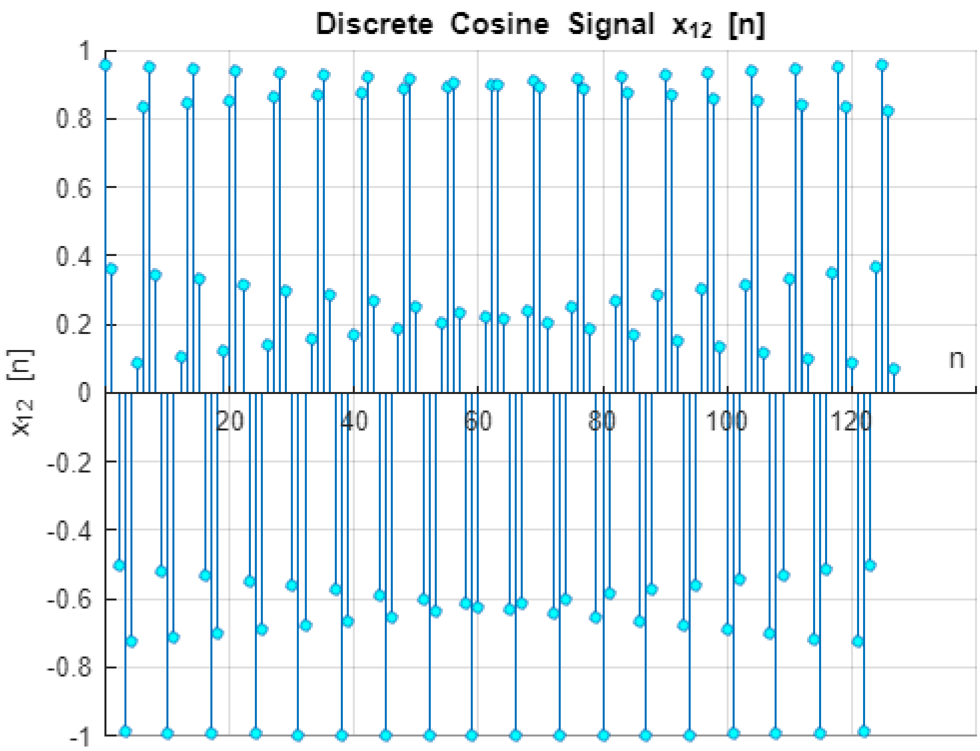

Figure 12: Graph of Discrete Cosine Signal $x_{12}[n]$

The value of ω is printed as

```
The value of the omega is 0.900000 radians.
```

13.

-

$$x_1(n) = 3\cos(0.13\pi n + 0.5)$$

$$\frac{N_1}{k_1} = \frac{2\pi}{0.13\pi} = \frac{2 \cdot 100}{13} = \frac{200}{13} \text{ rational} \Rightarrow \text{periodic}$$

$$N_1 = \frac{200}{13} \cdot k_1$$

$$N_1 = 200$$

- $$x_2(n) = \cos(2.2\pi n)$$

$$\frac{N_2}{k_2} = \frac{2\pi}{2.2\pi} = \frac{10}{11} \text{ rational} \Rightarrow \text{periodic}$$

$$N_2 = \frac{10}{11} \cdot k_2$$

$$N_2 = 10$$

- $$x_3(n) = \cos(-1.8\pi n)$$

$$\frac{N_3}{k_3} = \frac{2\pi}{-1.8\pi} = \frac{10}{9} \text{ rational} \Rightarrow \text{periodic}$$

$$N_3 = \frac{10}{9} \cdot k_3$$

$$N_3 = 10$$

- $$x_4(n) = \cos(0.26\pi n)$$

$$\frac{N_4}{k_4} = \frac{2\pi}{0.26\pi} = \frac{100}{13} \text{ rational} \Rightarrow \text{periodic}$$

$$N_4 = \frac{100}{13} \cdot k_4$$

$$N_2 = 100$$

- $$x_5(n) = \cos(0.26\pi n + 0.7)$$

$$\frac{N_5}{k_5} = \frac{2\pi}{0.26\pi} = \frac{100}{13} \text{ rational} \Rightarrow \text{periodic}$$

$$N_5 = \frac{100}{13} \cdot k_5$$

$$N_5 = 100$$

- $$x_6(n) = \cos(0.01\pi n)$$

$$\frac{N_6}{k_6} = \frac{2\pi}{0.01\pi} = 200 \text{ rational} \Rightarrow \text{periodic}$$

$$N_6 = 200 \cdot k_2$$

$$N_6 = 200$$

- $$x_7(n) = \cos(0.39\pi n)$$

$$\frac{N_7}{k_7} = \frac{2\pi}{0.39\pi} = \frac{200}{39} \text{ rational} \Rightarrow \text{periodic}$$

$$N_7 = \frac{200}{39} \cdot k_7$$

$$N_7 = 200$$

- $$x_8(n) = \cos(\pi n)$$

$$\frac{N_8}{k_8} = \frac{2\pi}{\pi} = 2 \text{ rational} \Rightarrow \text{periodic}$$

$$N_8 = 2 \cdot k_8$$

$$N_8 = 2$$

- $$x_9(n) = \cos(1.08\pi n)$$

$$\frac{N_9}{k_9} = \frac{2\pi}{1.08\pi} = \frac{50}{27} \text{ rational} \Rightarrow \text{periodic}$$

$$N_9 = \frac{50}{27} \cdot k_9$$

$$N_9 = 50$$

- $$x_{10}(n) = \cos(0.92\pi n)$$

$$\frac{N_{10}}{k_{10}} = \frac{2\pi}{0.92\pi} = \frac{50}{23} \text{ rational} \Rightarrow \text{periodic}$$

$$N_{10} = \frac{50}{23} \cdot k_{10}$$

$$N_{10} = 50$$

- $$x_{11}(n) = \cos(n)$$
  $$\frac{N_{11}}{k_{11}} = \frac{2\pi}{1} \text{ irrational} \Rightarrow \text{not periodic}$$

- $$x_{12}(n) = \cos(0.9n\ +\ 0.3)$$
  $$\frac{N_{12}}{k_{12}} = \frac{2\pi}{0.9} \text{ irrational} \Rightarrow \text{not periodic}$$

14.

$\frac{2\pi}{\omega}$ must be rational for periodicity which is equal to $\frac{N}{k}$. N and k are integers. Since $\omega\ =\ \frac{2\pi k}{N}$, ω should be a rational multiple of 2π.

15.

Continuous cosine signals are always periodic, for every nonzero ω. Because any frequency will generate a repeating pattern over time.

Discrete cosine signal is periodic only when $\frac{2\pi}{\omega}$ is rational. If it is irrational, no finite N can satisfy the periodicity condition, and the signal is considered as aperiodic.

If a continuous signal is sampled at a rate, the resulting discrete signal will have a normalized frequency according to its sampling rate and frequency. This can lead to scenarios where the discrete signal appears to have a different period compared to the continuous signal, especially if the sampling rate is low. This causes aliasing.

Conclusion

This lab assignment explored the properties of discrete cosine signals and compared them with their continuous counterparts. A series of discrete cosine signals with varying frequencies and phase shifts were generated and analyzed to study their behavior in both time and frequency domains. The primary focus was to understand the periodicity conditions of discrete signals and the impact of quantization and sampling.

Continuous cosine signals are inherently periodic for any frequency, while discrete cosine signals require the normalized angular frequency to be a rational multiple of 2π for the signal to be periodic. This restriction arises due to the sampling process and the discrete nature of digital signals. If the frequency condition is not met, the discrete signal may appear non-periodic, or its period may be difficult to determine due to aliasing effects.

The lab exercise demonstrated how different frequencies influence the signal's behavior, highlighting the importance of frequency selection and its impact on periodicity in digital signal processing.

Appendix A

Listing 1: MATLAB Code for Generating and Storing $x_2[n]$ in a File

```
% parameters
n = 0:127;
A = 1;
omega = 2.2*pi;
phi = 0;


% function
x2 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x2_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x2);           % numbers in floating-point format
fclose(discreteCos);
```

Listing 2: Retrieving and Reading the File, Printing Requested Values

```
% read the data
discreteCos = fopen("x2_signal.txt", "r");  % opens the file in 'read mode'
x2 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x2[%d]= %f\n', 3, x2(4));          % 1-based indexing
fprintf('x2[%d]= %f\n', 7, x2(8));
fprintf('x2[%d]= %f\n', 114, x2(115));
fprintf('x2[%d]= %f\n', 127, x2(128));
```

Listing 3: Code to Plot Discrete Cosine Signal $x_2[n]$

```
% plot
figure;
stem(n, x2, MarkerFaceColor='g', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_2 [n]');
xlabel('n');
ylabel('x_2 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 4: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_3[n]$

```
% parameters
n = 0:127;
A = 1;
omega = -1.8*pi;
phi = 0;


% function
x3 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x3_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x3);           % numbers in floating-point format
fclose(discreteCos);


% read the data
discreteCos = fopen("x3_signal.txt", "r");  % opens the file in 'read mode'
x3 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x3[%d]= %f\n', 3, x3(4));          % 1-based indexing
fprintf('x3[%d]= %f\n', 7, x3(8));
fprintf('x3[%d]= %f\n', 114, x3(115));
fprintf('x3[%d]= %f\n', 127, x3(128));


% plot
figure;
stem(n, x3, MarkerFaceColor='b', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_3 [n]');
xlabel('n');
ylabel('x_3 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 5: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_4[n]$

```
% parameters
n = 0:127;
A = 1;
omega = 0.26*pi;
phi = 0;


% function
x4 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x4_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x4);           % numbers in floating-point format
fclose(discreteCos);


% read the data
discreteCos = fopen("x4_signal.txt", "r");  % opens the file in 'read mode'
x4 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x4[%d]= %f\n', 3, x4(4));          % 1-based indexing
fprintf('x4[%d]= %f\n', 7, x4(8));
fprintf('x4[%d]= %f\n', 114, x4(115));
fprintf('x4[%d]= %f\n', 127, x4(128));


% plot
figure;
stem(n, x4, MarkerFaceColor='c', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_4 [n]');
xlabel('n');
ylabel('x_4 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 6: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_5[n]$

```
% parameters
n = 0:127;
A = 1;
omega = 0.26*pi;
phi = 0.7;


% function
x5 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x5_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x5);           % numbers in floating-point format
fclose(discreteCos);


% read the data
discreteCos = fopen("x5_signal.txt", "r");  % opens the file in 'read mode'
x5 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x5[%d]= %f\n', 3, x5(4));          % 1-based indexing
fprintf('x5[%d]= %f\n', 7, x5(8));
fprintf('x5[%d]= %f\n', 114, x5(115));
fprintf('x5[%d]= %f\n', 127, x5(128));


% plot
figure;
stem(n, x5, MarkerFaceColor='m', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_5 [n]');
xlabel('n');
ylabel('x_5 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 7: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_6[n]$

```
% parameters
n = 0:127;
A = 1;
omega = 0.01*pi;
phi = 0;


% function
x6 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x6_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x6);           % numbers in floating-point format
fclose(discreteCos);


% read the data
discreteCos = fopen("x6_signal.txt", "r");  % opens the file in 'read mode'
x6 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x6[%d]= %f\n', 3, x6(4));          % 1-based indexing
fprintf('x6[%d]= %f\n', 7, x6(8));
fprintf('x6[%d]= %f\n', 114, x6(115));
fprintf('x6[%d]= %f\n', 127, x6(128));


% plot
figure;
stem(n, x6, MarkerFaceColor='y', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_6 [n]');
xlabel('n');
ylabel('x_6 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 8: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_7[n]$

```
% parameters
n = 0:127;
A = 1;
omega = 0.39*pi;
phi = 0;


% function
x7 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x7_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x7);           % numbers in floating-point format
fclose(discreteCos);


% read the data
discreteCos = fopen("x7_signal.txt", "r");  % opens the file in 'read mode'
x7 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x7[%d]= %f\n', 3, x7(4));          % 1-based indexing
fprintf('x7[%d]= %f\n', 7, x7(8));
fprintf('x7[%d]= %f\n', 114, x7(115));
fprintf('x7[%d]= %f\n', 127, x7(128));


% plot
figure;
stem(n, x7, MarkerFaceColor='k', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_7 [n]');
xlabel('n');
ylabel('x_7 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 9: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_8[n]$

```
% parameters
n = 0:127;
A = 1;
omega = pi;
phi = 0;


% function
x8 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x8_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x8);           % numbers in floating-point format
fclose(discreteCos);


% read the data
discreteCos = fopen("x8_signal.txt", "r");  % opens the file in 'read mode'
x8 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x8[%d]= %f\n', 3, x8(4));          % 1-based indexing
fprintf('x8[%d]= %f\n', 7, x8(8));
fprintf('x8[%d]= %f\n', 114, x8(115));
fprintf('x8[%d]= %f\n', 127, x8(128));


% plot
figure;
stem(n, x8, MarkerFaceColor='k', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_8 [n]');
xlabel('n');
ylabel('x_8 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 10: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_9[n]$

```
% parameters
n = 0:127;
A = 1;
omega = 1.08*pi;
phi = 0;


% function
x9 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x9_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x9);           % numbers in floating-point format
fclose(discreteCos);


% read the data
discreteCos = fopen("x9_signal.txt", "r");  % opens the file in 'read mode'
x9 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x9[%d]= %f\n', 3, x9(4));          % 1-based indexing
fprintf('x9[%d]= %f\n', 7, x9(8));
fprintf('x9[%d]= %f\n', 114, x9(115));
fprintf('x9[%d]= %f\n', 127, x9(128));


% plot
figure;
stem(n, x9, MarkerFaceColor='r', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_9 [n]');
xlabel('n');
ylabel('x_9 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 11: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal x_{10}[n]

```
% parameters
n = 0:127;
A = 1;
omega = 0.92*pi;
phi = 0;


% function
x10 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x10_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x10);           % numbers in floating-point
format
fclose(discreteCos);


% read the data
discreteCos = fopen("x10_signal.txt", "r");  % opens the file in 'read mode'
x10 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x10[%d]= %f\n', 3, x10(4));          % 1-based indexing
fprintf('x10[%d]= %f\n', 7, x10(8));
fprintf('x10[%d]= %f\n', 114, x10(115));
fprintf('x10[%d]= %f\n', 127, x10(128));


% plot
figure;
stem(n, x10, MarkerFaceColor='g', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_10 [n]');
xlabel('n');
ylabel('x_10 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';
```

```
% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 12: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_{11}[n]$

```
% parameters
n = 0:127;
A = 1;
omega = 1;
phi = 0;


% function
x11 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x11_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x11);           % numbers in floating-point
format
fclose(discreteCos);


% read the data
discreteCos = fopen("x11_signal.txt", "r");  % opens the file in 'read mode'
x11 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x11[%d]= %f\n', 3, x11(4));          % 1-based indexing
fprintf('x11[%d]= %f\n', 7, x11(8));
fprintf('x11[%d]= %f\n', 114, x11(115));
fprintf('x11[%d]= %f\n', 127, x11(128));


% plot
figure;
stem(n, x11, MarkerFaceColor='b', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_11 [n]');
xlabel('n');
ylabel('x_11 [n]');


% cleaner look
ax = gca;                                   % get current axis
ax.XAxisLocation = 'origin';
```

```
ax.YAxisLocation = 'origin';
ax.Box = 'off';


% omega value
fprintf("The value of the omega is %f radians.", omega);
```

Listing 13: Generating, Storing, Retrieving, Reading, Printing and Plotting Discrete Cosine Signal $x_{12}[n]$

```
% parameters
n = 0:127;
A = 1;
omega = 0.9;
phi = 0.3;


% function
x12 = A*cos(omega*n + phi);


% write the data
discreteCos = fopen("x12_signal.txt",'w');   % opens the file in 'write mode'
fprintf(discreteCos, '%f\n', x12);           % numbers in floating-point
format
fclose(discreteCos);


% read the data
discreteCos = fopen("x12_signal.txt", "r");  % opens the file in 'read mode'
x12 = fscanf(discreteCos,'%f');
fclose(discreteCos);


%values
fprintf('x12[%d]= %f\n', 3, x12(4));          % 1-based indexing
fprintf('x12[%d]= %f\n', 7, x12(8));
fprintf('x12[%d]= %f\n', 114, x12(115));
fprintf('x12[%d]= %f\n', 127, x12(128));


% plot
figure;
stem(n, x12, MarkerFaceColor='c', MarkerSize=4);
grid on;
title('Discrete Cosine Signal x_12 [n]');
xlabel('n');
ylabel('x_12 [n]');


% cleaner look
```

```
ax = gca;                                          % get current axis
ax.XAxisLocation = 'origin';
ax.YAxisLocation = 'origin';
ax.Box = 'off';


% omega value
fprintf("The value of the omega is %f radians.", omega);
```

REFERENCES

[1] MathWorks, “Floating-Point Numbers,” MATLAB & Simulink. [Online]. Available: https://www.mathworks.com/help/matlab/matlab_prog/floating-point-numbers.html. [Accessed: 29-Sep-2024].