Experiment No: 04

Experiment Name: Identifying Signal Delay By Cross-correlation And Z transform

Theory: The cross-correlation theory of identifying signal delay is an important idea in signal processing and communication systems. Cross-correlation is a mathematical process that determines the similarity of two signals based on their relative delays. It is frequently used to calculate the time delay or synchronization of two signals. Consider two signals in the context of determining signal delay: the reference signal and the received signal. The known or desired signal is the reference signal, whereas the received signal is the signal being evaluated for delay.

By moving the received signal across the reference signal and computing the correlation coefficient at each place, the cross-correlation function is computed. The correlation coefficient calculates how similar the two signals are at a particular delay. The temporal delay between the reference signal and the received signal can be calculated by locating the delay at which the correlation coefficient is maximum.

Z Transform

The Z Transform is closely related to the DTFT and is extremely useful in transforming, analyzing, and manipulating discrete calculus equations. The Z transform is so named because the transformation variable is the letter 'z' (a lower-case Z).

So, the Z-transform of the discrete time signal x(n) in a power series can be written as −

$$X(z) = \sum_{n=-\infty}^{\infty} x\,(n) z^{-1}$$

The above equation represents a two-sided Z-transform equation.

Code:

1. **Identifying Signal Delay(continuous)**

```
clc;
clear all;

t=0:0.001:5;

x1= t>=0 & t<=1;
x2= t>=1.5 & t<=2.5;
x3= t>=3 & t<=4;
x=x1+2*x2+x3;

d1= t>=1 & t<=2;
d2= t>=2.5 & t<=3.5;
d3= t>=4 & t<=5;
d=d1+2*d2+d3;

N= -(length(t)-1):(length(t)-1);
c= xcorr(d,x);

subplot(3,1,1);
plot(x);
title('Input Signal');

subplot(3,1,2);
plot(d);
title('Delayed Signal');

subplot(3,1,3);
plot(N,c);
title('Correlated Signal');
```

Output:

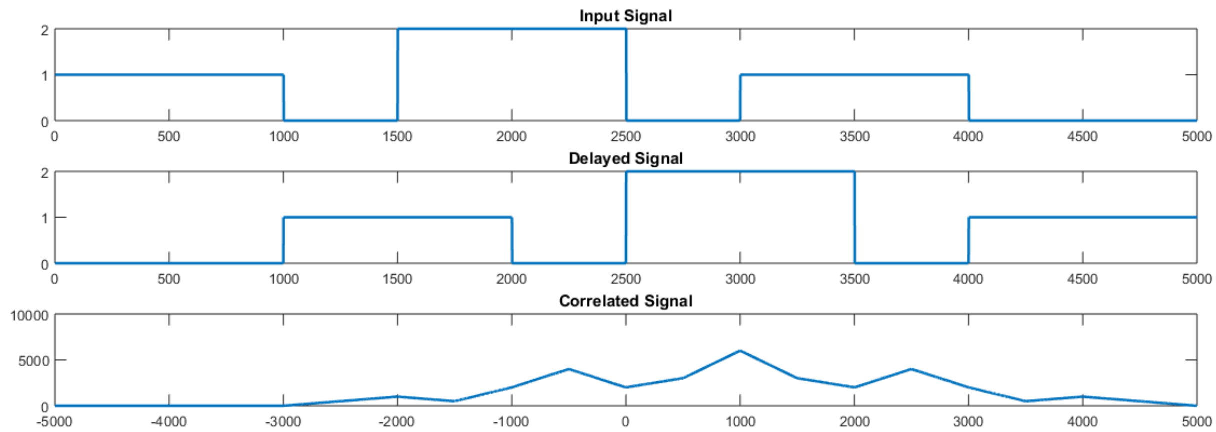

Figure 1: Identifying Signal Delay(continuous)

2. **Identifying Signal Delay(Discrete)**

Code:

```
clc;
clear all;

t=0:0.1:5;

x1= t>=0 & t<=1;
x2= t>=1.5 & t<=2.5;
x3= t>=3 & t<=4;
x=x1+2*x2+x3;

d1= t>=1 & t<=2;
d2= t>=2.5 & t<=3.5;
d3= t>=4 & t<=5;
d=d1+2*d2+d3;

N= -(length(t)-1):(length(t)-
1);
c= xcorr(x,d);

subplot(3,1,1);
stem(x);
title('Input Signal');

subplot(3,1,2);
stem(d);
title('Delayed Signal');

subplot(3,1,3);
stem(N,c);
title('Correlated Signal');
```

Output:

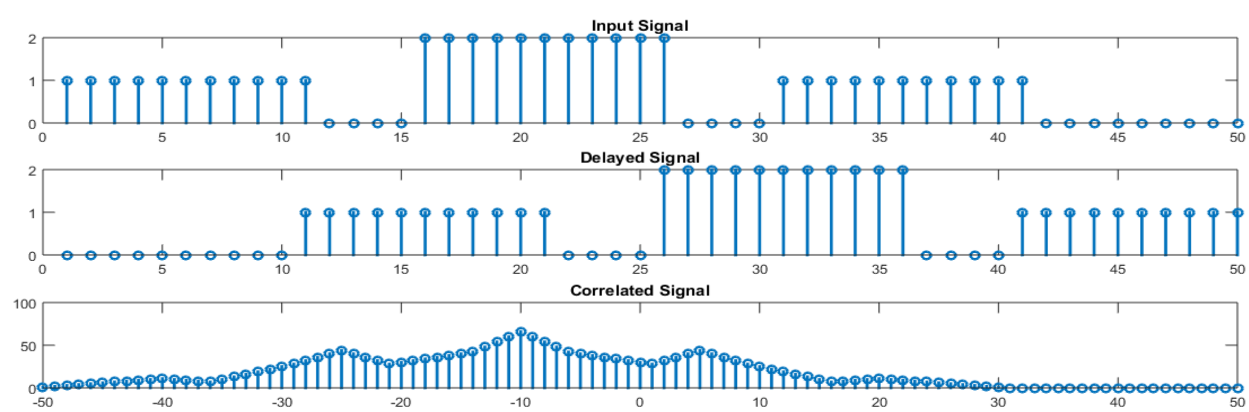

Figure 2: Identifying Signal Delay(Discrete)

3. Z transform:

Code:

```
clc;
clear all;

x = [1, 2, 3, 4, 5];
H=0;

N = length(x);
y= sym('Z');

for i=1:N
    H= H+x(i)*y^(1-i);
end

display(H);
```

Output:

```
H =

2/Z + 3/Z^2 + 4/Z^3 + 5/Z^4 + 1
```

Discussion: In this experiment we learned about identifying delay of a signal (continuous and discrete) and z transform. To identify signal delay we made cross-correlation between the input signal and delayed signal. The index of highest value of cross-correlation is the delay of signal. The input signal was square wave signal. The xcorr function was used to find the cross-correlation of this signal. Also done the z transformation using the z transform formula. For both case , got the expected result from the experiment.

Conclusion : This experiment was done successfully in the laboratory using MATLAB.