# EE141 Digital Signal Processing

# Lab 2: The Discrete Time Fourier Transform

# Lab Section: 022


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## Objective:

Verification of properties related to the D.T.F.T

## Results:

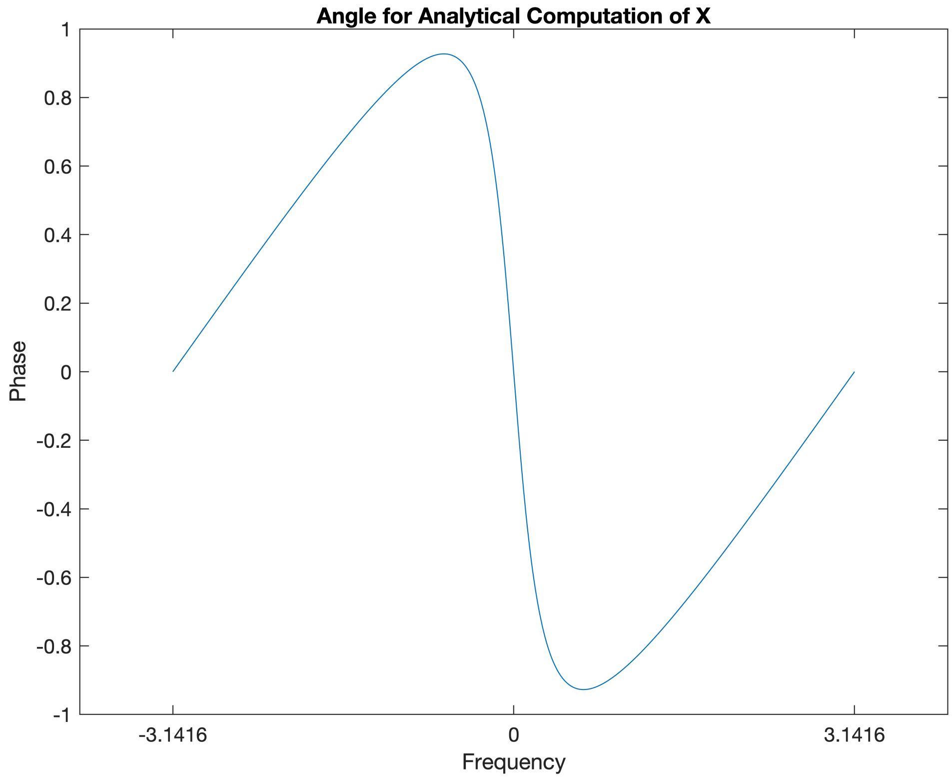
Successful analyitical and numerical computation of the DTFT for a right-sided signal . The same properties were then applied to a various linear transformations and the convolution of said signals  Additiaonlly, a deepended understanding of how to interpret the graph of D.T.F.T. Specifically, how the magnitude plots identify which frequencies would pass through and which ones would be attenuated if such a system was used as a filter. Moreover, the phase told me how all the frequencies align in time.

## Procedure:

### a) Analytically compute $X(e^{j\omega})$ using:

$$X(e^{j\omega})\sum_{n=-\infty}^{\infty} x[n]e^{j\omega n}$$

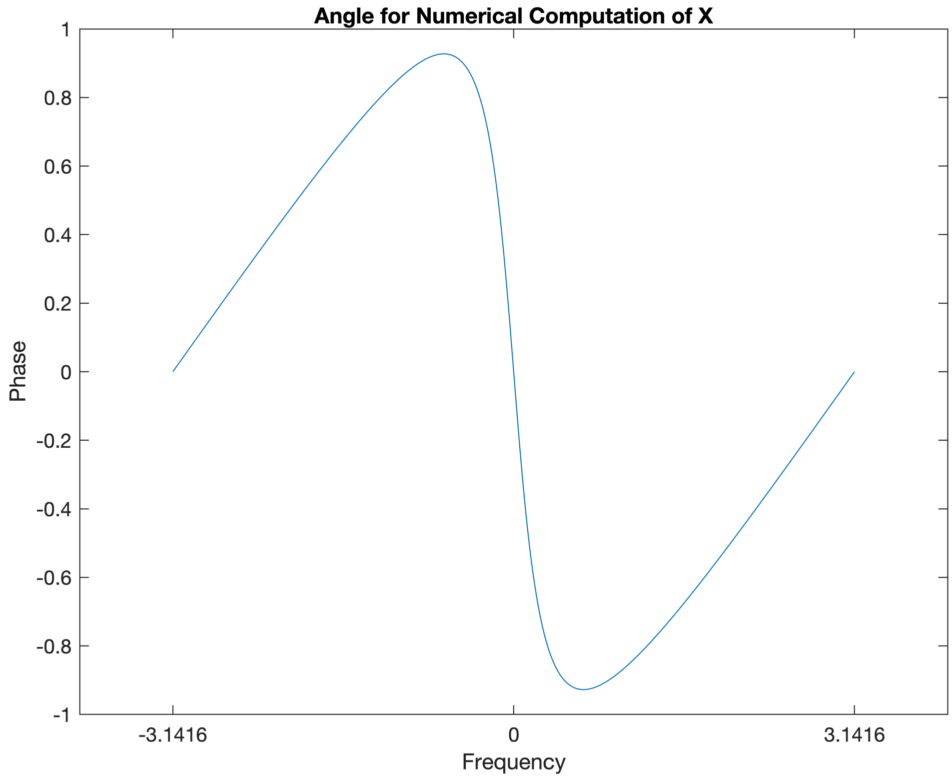
```
% Create a vector in MATLAB by sampling the omega interval from [-pi,pi]
% Using K uniform points for some large K
% and Evaluate for each sample point
K = 500;
w_k = -pi:(2*pi/K):pi;
% Recall that x[n] = 0.8^n*u[n].
% This is a geometric series. Recall that the D.T.F.T. for a geometric
% series whos alpha is less than one is always 1/1-ratio*exp(jwn))
X = 1./(1-0.8.*exp(-1i*w_k));
%plot
plot(w_k,angle(X))
set(gca,'XTick',-2*pi:pi:2*pi)
title('Angle for Analytical Computation of X')
xlabel('Frequency');
ylabel('Phase');
```




**b) For each $w_k$, numerically compute $\widetilde{X}\left(e^{-j\omega_k}\right)$ using:**

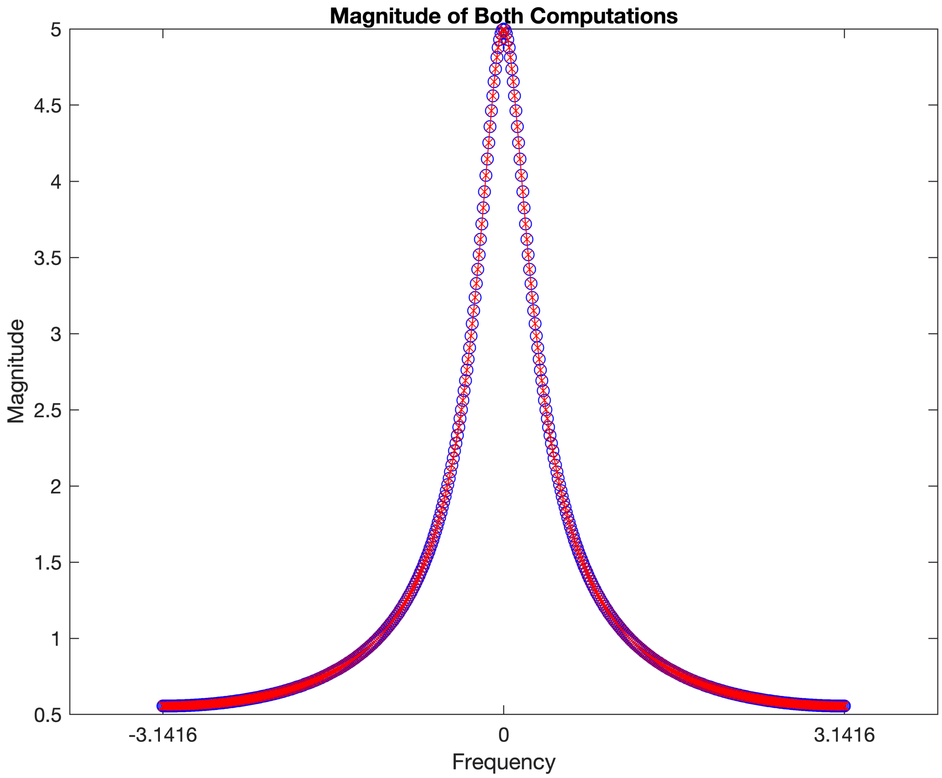
$$X(e^{j\omega})\sum_{n=0}^{\infty} x[n]e^{j\omega n}$$

```
%Pick a large enough N to satisify 0.9^N ~ 0.
N = 100;
n = 0:N;
for k = 1:K+1
    x(k) = sum((0.8.^(n)).*exp(-1i*w_k(k).*n));
end
plot(w_k, angle(x))
set(gca, 'XTick', -2*pi:pi:2*pi);
title('Angle for Numerical Computation of X')
xlabel('Frequency')
ylabel('Phase')
```



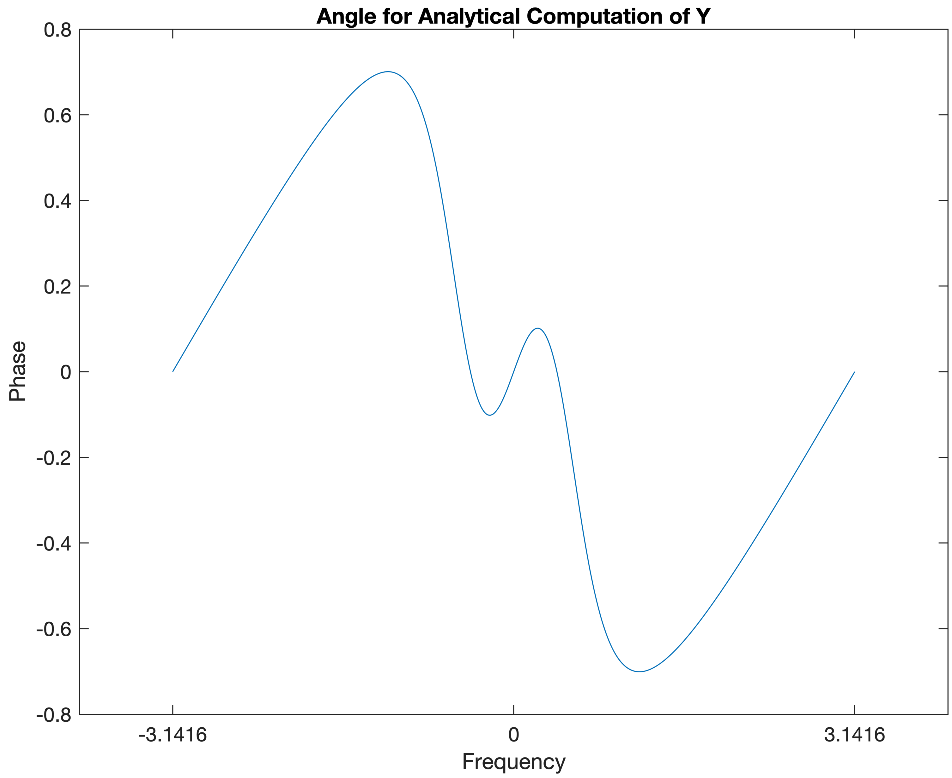

### c) Plot $\left|X\left(e^{j\omega_k}\right)\right|$ and $\left|\tilde{X}\left(e^{j\omega_k}\right)\right|$ on the same graph using different colors

```
plot(w_k,abs(X), 'b-o')
hold on
plot(w_k,abs(x), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Magnitude of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```

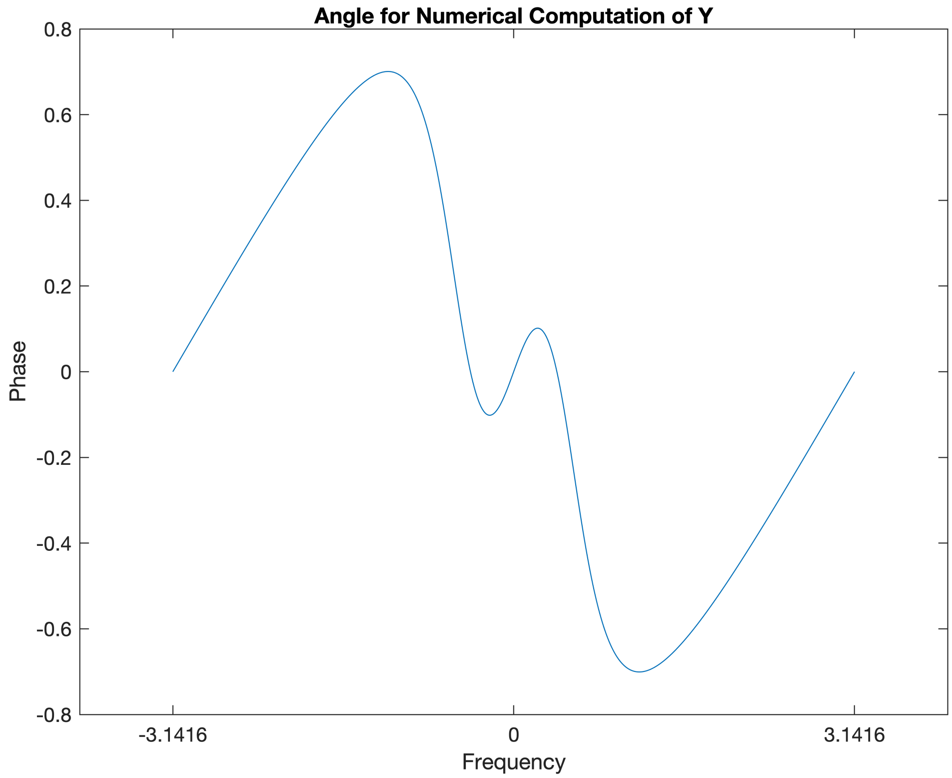



**d) Using the same $N$ and $K$, repeat a through c for $Y(e^{j\omega})$ and its approximation $\tilde{Y}(e^{j\omega})$**

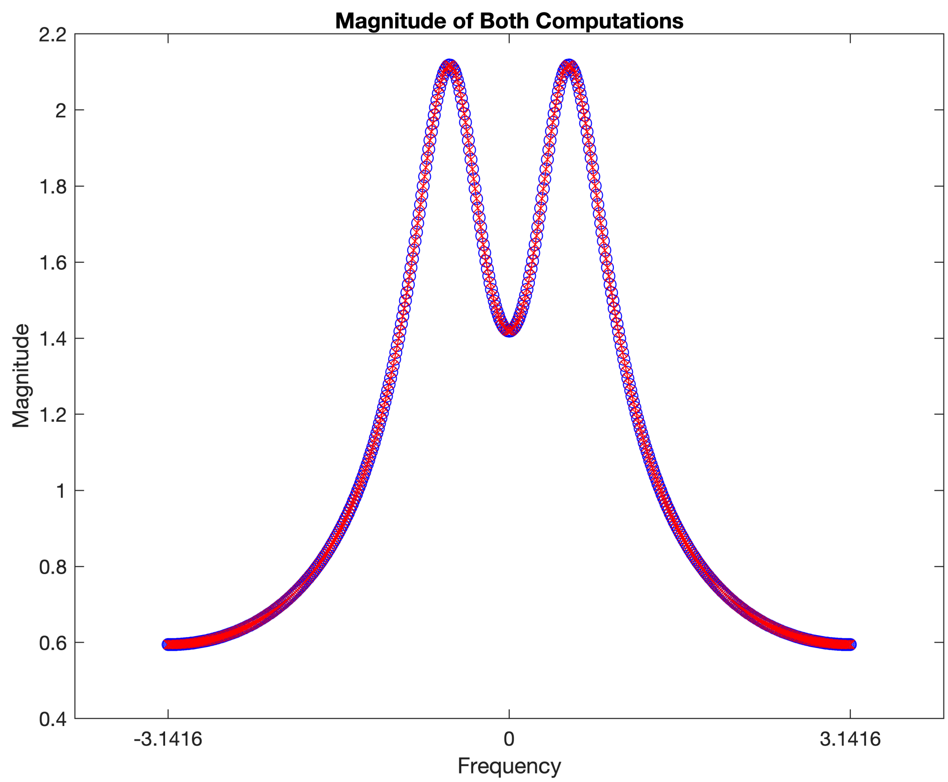
```
K = 500;
w_k = -pi:(2*pi/K):pi;
Y = 0.5.*((1./(1-0.7.*exp(1i*((pi/6)-w_k)))) + (1./(1-0.7.*exp(-1i*((pi/6)+w_k)))));
plot(w_k,angle(Y))
set(gca,'XTick',-2*pi:pi:2*pi)
title('Angle for Analytical Computation of Y')
xlabel('Frequency');
ylabel('Phase');
```




```
%Pick a large enough N to satisify 0.9^N ~ 0.
N = 100;
n = 0:N;
for k = 1:K+1
    y(k) = sum((0.7.^(n).*cos((pi.*n)/6)).*exp(-1i*w_k(k).*n));
end
plot(w_k, angle(y))
set(gca, 'XTick', -2*pi:pi:2*pi);
title('Angle for Numerical Computation of Y')
xlabel('Frequency')
ylabel('Phase')
```



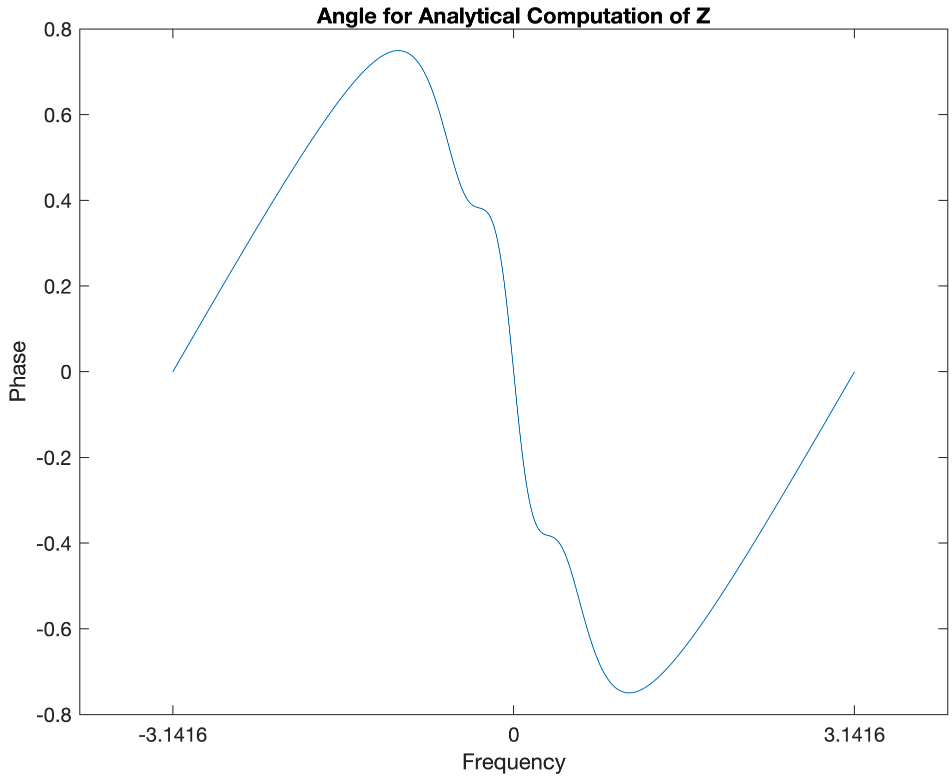

```
plot(w_k,abs(Y), 'b-o')
hold on
plot(w_k,abs(y), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Magnitude of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```




## e) Let $x[n] = 2x[n] + 3y[n]$

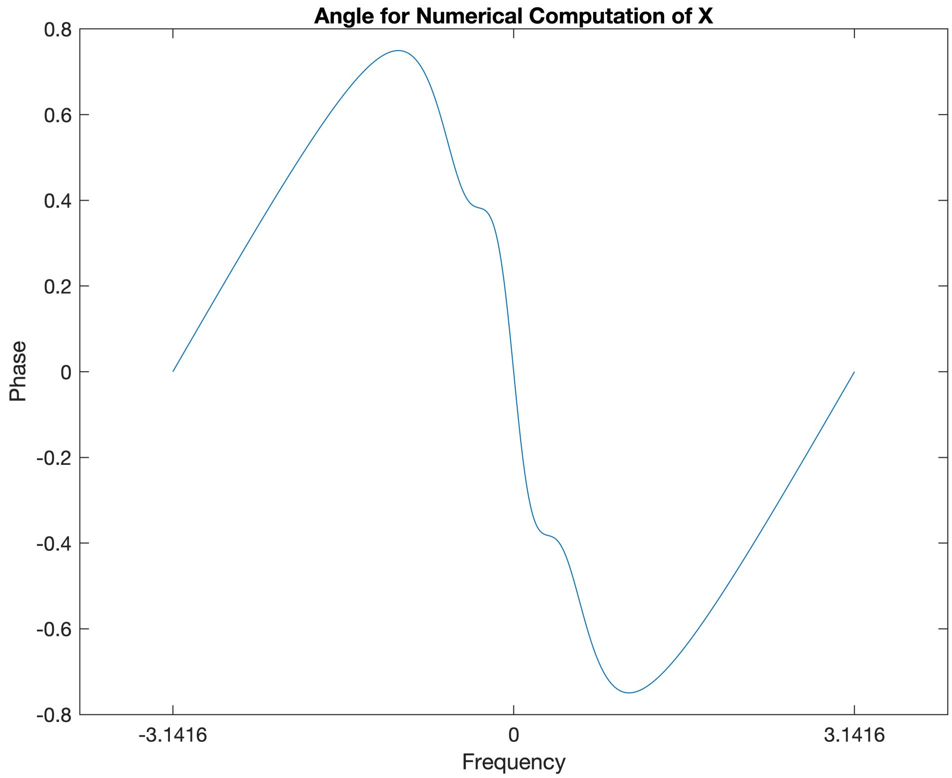
### 1) Analytically compute $Z(e^{j\omega})$ using $X(e^{j\omega}), Y(e^{j\omega})$, and the relevant property of DTFT.

```
Z = 2*X + 3*Y;
plot(w_k,angle(Z))
set(gca,'XTick',-2*pi:pi:2*pi)
title('Angle for Analytical Computation of Z')
xlabel('Frequency');
ylabel('Phase');
```



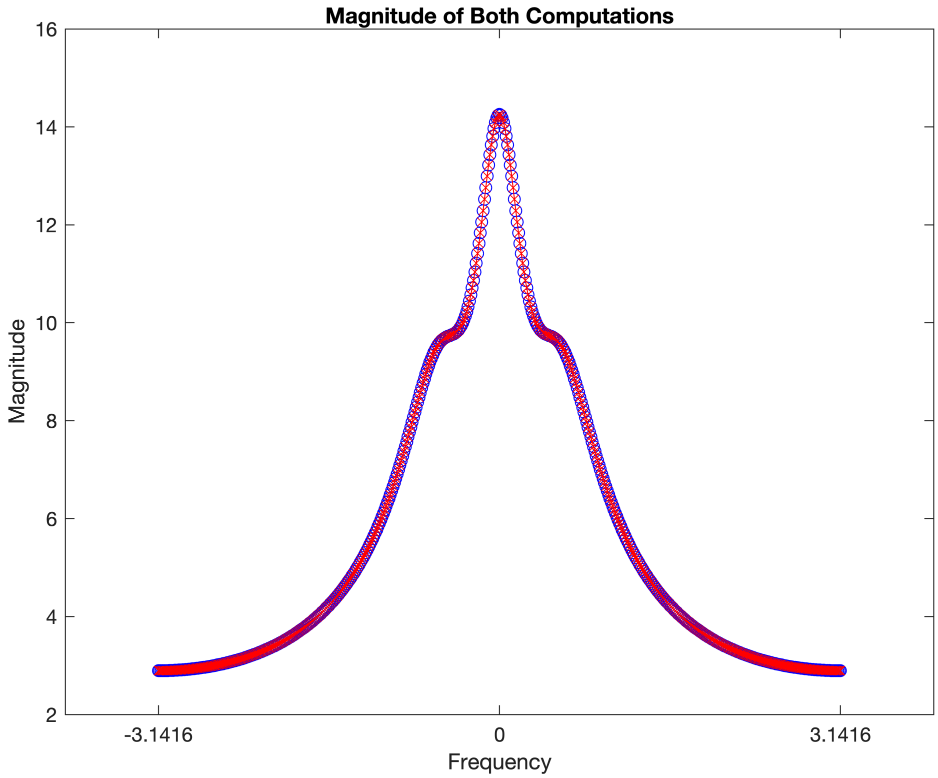

**3) Numerically computer $\tilde{Z}\left(e^{j\omega_n}\right)$ using the truncated sum in (2) with $x[n]$**

```
%Pick a large enough N to satisify 0.9^N ~ 0.
N = 100;
n = 0:N;
for k = 1:K+1
    z(k) = sum((2*(0.8.^(n)) + 3*(0.7.^(n).*cos((pi.*n)/6))).*exp(-1i*w_k(k).*n));
end
plot(w_k, angle(z))
set(gca, 'XTick', -2*pi:pi:2*pi);
title('Angle for Numerical Computation of X')
xlabel('Frequency')
ylabel('Phase')
```




**4) Plot $\left|Z\left(e^{j\omega_k}\right)\right|$ and $\left|\tilde{Z}\left(e^{j\omega_k}\right)\right|$ on the same graph. Do they look same**

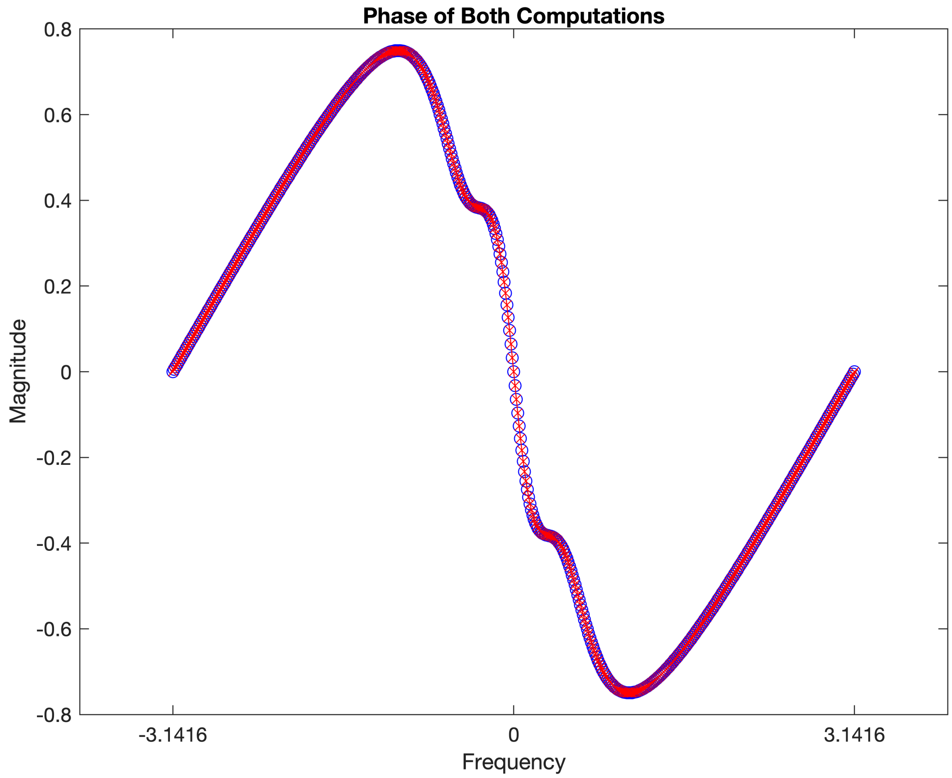
```
plot(w_k,abs(Z), 'b-o')
hold on
plot(w_k,abs(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Magnitude of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```




Yes, the graphs looks the same

**5) Plot $|\angle Z\left(e^{j\omega_k}\right)$ and $\angle\tilde{Z}\left(e^{j\omega_k}\right)$ on the same graph. Do they look the same?**

```
plot(w_k,angle(Z), 'b-o')
hold on
plot(w_k,angle(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Phase of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```

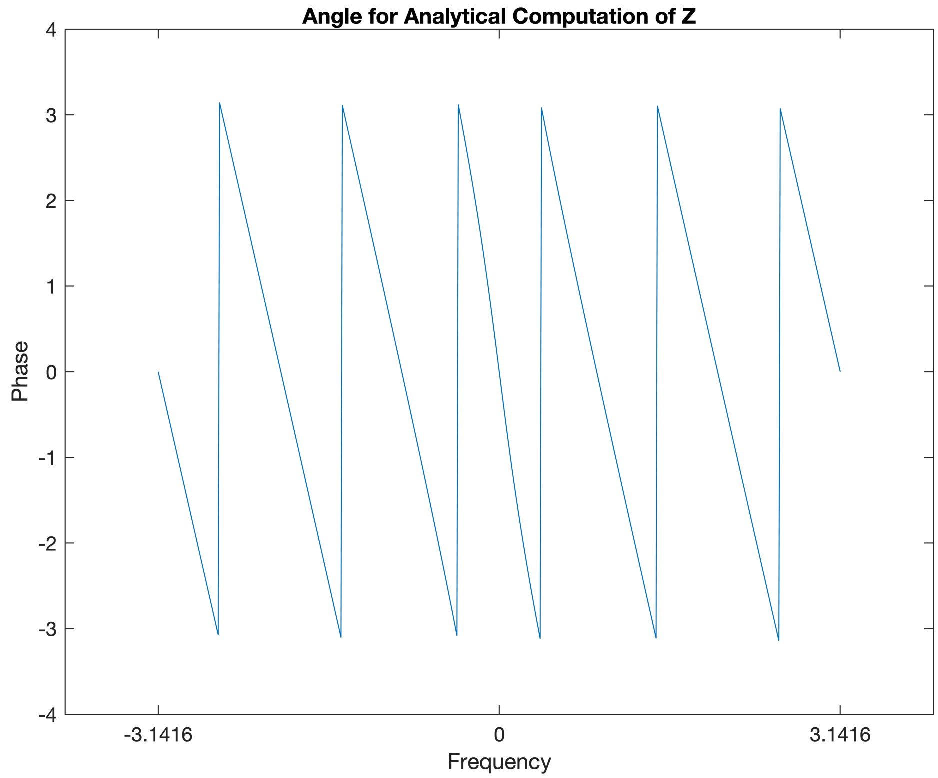



Yes the graphs look the same

### f) Repeat e with $z[n] = x[n-6]$.

**1) Analytically compute $Z(e^{j\omega})$ using $X(e^{j\omega}), Y(e^{j\omega})$, and the relevant property of DTFT.**

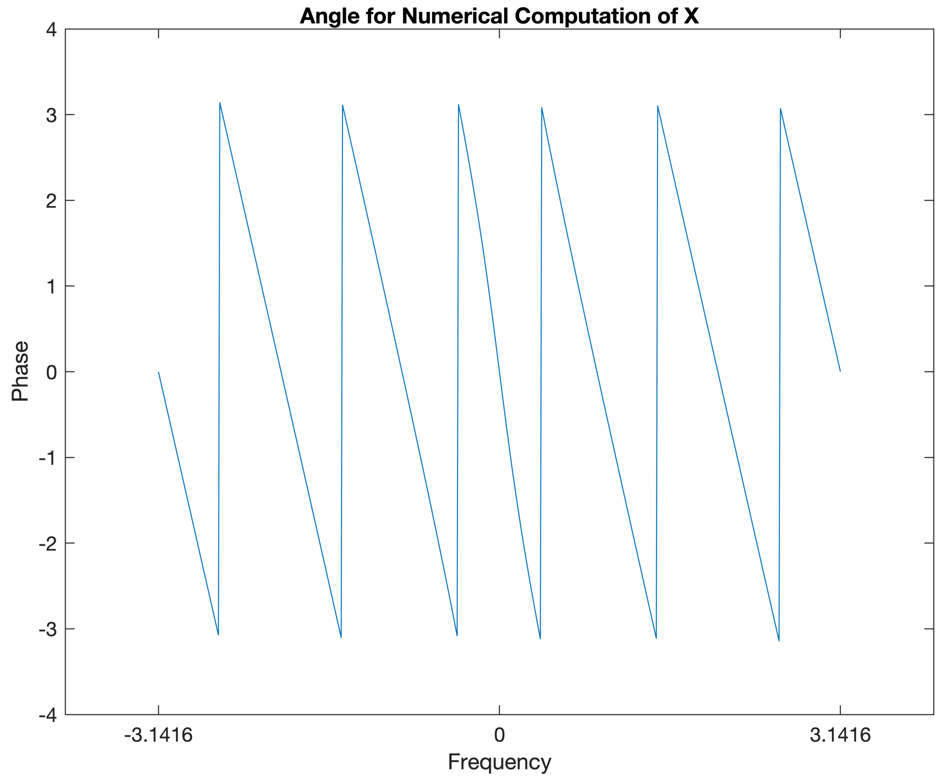
```
K = 500;
w_k = -pi:(2*pi/K):pi;
N = 100;
n = 6:N;
X = 1./(1-0.8.*exp(-1i*w_k));
Z = X.*exp(-1i*w_k*6);
plot(w_k,angle(Z))
set(gca,'XTick',-2*pi:pi:2*pi)
title('Angle for Analytical Computation of Z')
xlabel('Frequency');
ylabel('Phase');
```




**3) Numerically computer $\widetilde{Z}\left(e^{j\omega_n}\right)$ using the truncated sum in (2) with $x[n]$**

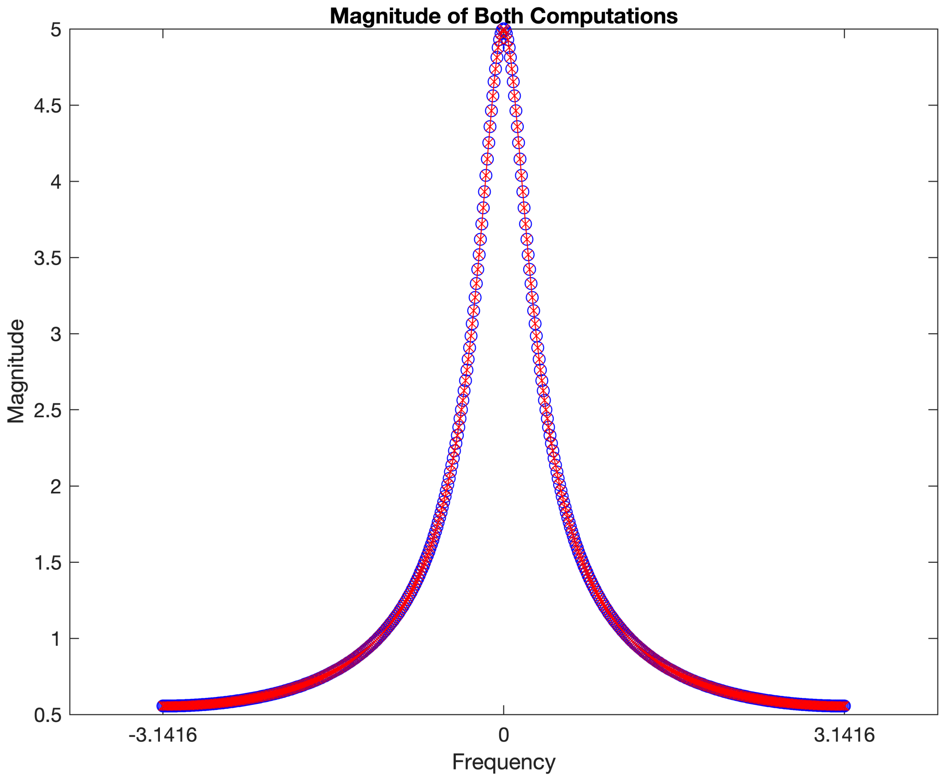
```
%Pick a large enough N to satisify 0.9^N ~ 0.
N = 100;
n = 6:N;
for k = 1:K+1
    z(k) = sum((0.8.^(n-6).*exp(-1i*w_k(k).*n)));
end

plot(w_k, angle(z))
set(gca, 'XTick', -2*pi:pi:2*pi);
title('Angle for Numerical Computation of X')
xlabel('Frequency')
ylabel('Phase')
```




**4) Plot $\left|Z\left(e^{j\omega_k}\right)\right|$ and $\left|\widetilde{Z}\left(e^{j\omega_k}\right)\right|$ on the same graph. Do they look same**

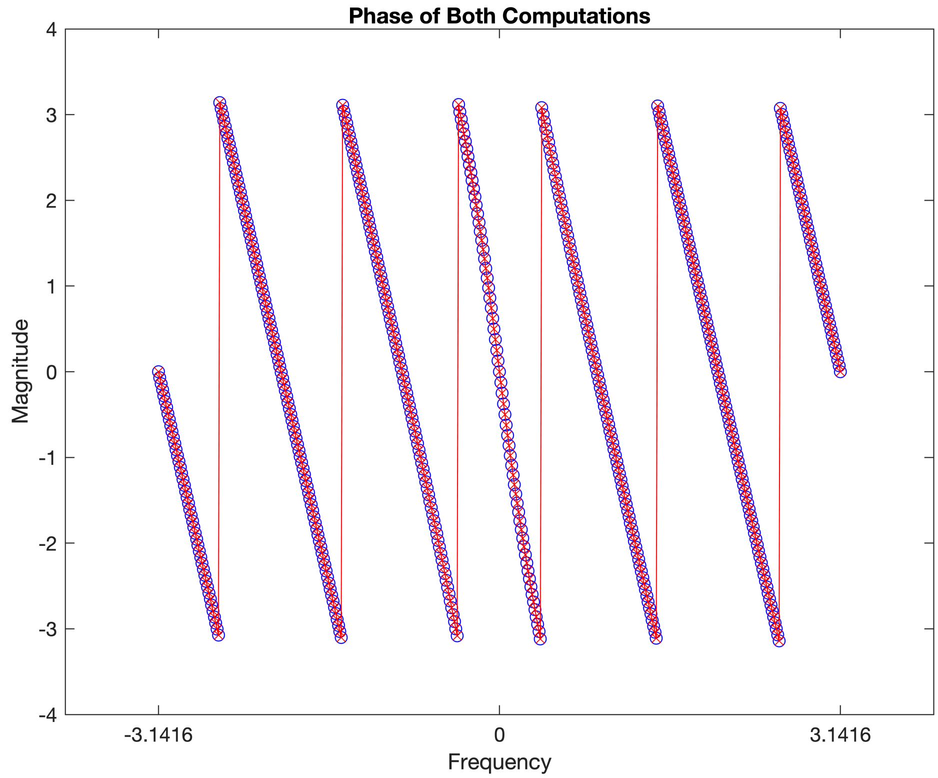
```
plot(w_k,abs(Z), 'b-o')
hold on
plot(w_k,abs(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Magnitude of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```




Yes, the graphs looks the same

**5) Plot** $|\angle Z\left(e^{j\omega_k}\right)$ **and** $\angle \widetilde{Z}\left(e^{j\omega_k}\right)$ **on the same graph. Do they look the same?**

```
plot(w_k,angle(Z), 'b-o')
hold on
plot(w_k,angle(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Phase of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```

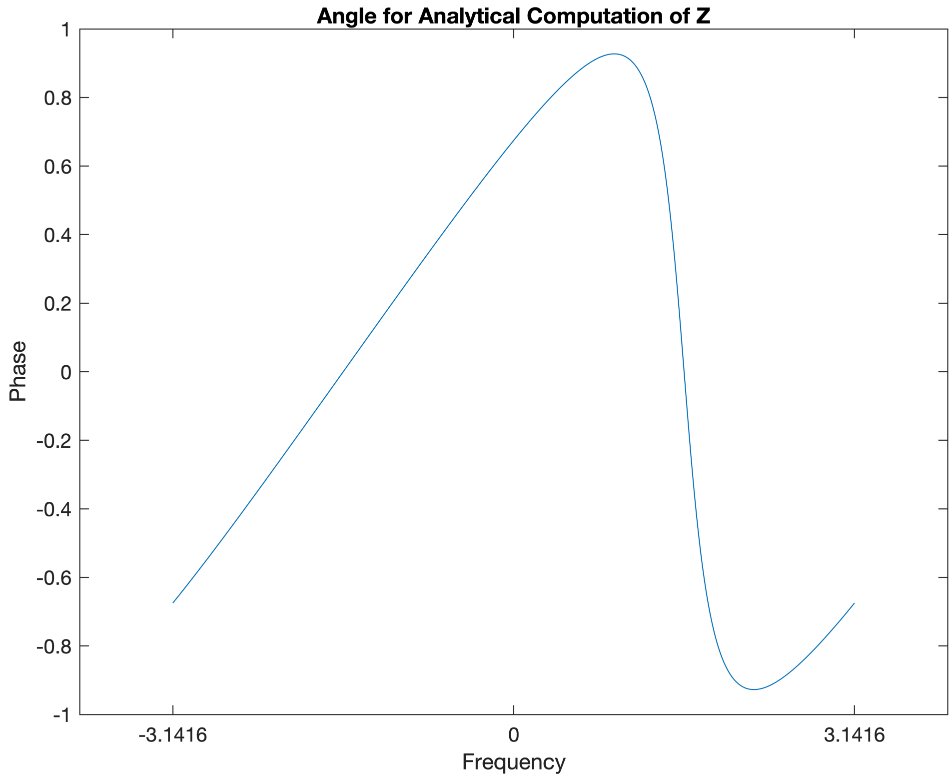



Yes the graphs look the same

### g) Repeat e with $z[n] = e^{j\frac{\pi}{2}n}x[n]$

#### 1) Analytically compute $Z(e^{j\omega})$ using $X(e^{j\omega}), Y(e^{j\omega})$, and the relevant property of DTFT.

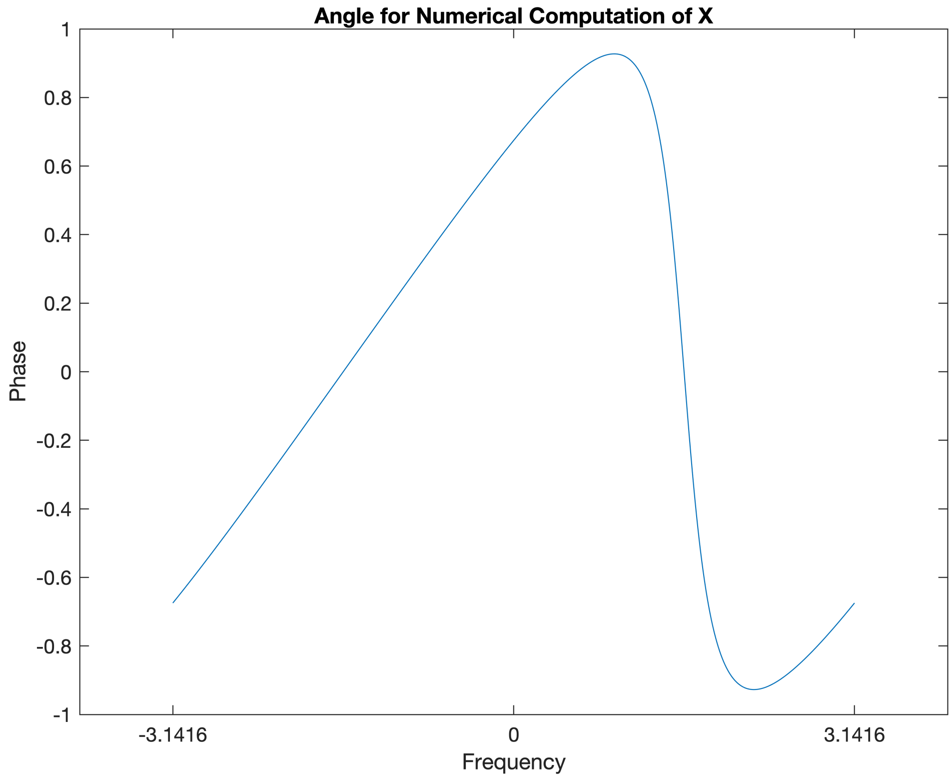
```
X = 1./(1-0.8.*exp(-1i*(w_k-pi/2)));
Z = X;
plot(w_k,angle(Z))
set(gca,'XTick',-2*pi:pi:2*pi)
title('Angle for Analytical Computation of Z')
xlabel('Frequency');
ylabel('Phase');
```




**3) Numerically computer $\widetilde{Z}\left(e^{j\omega_n}\right)$ using the truncated sum in (2) with $x[n]$**

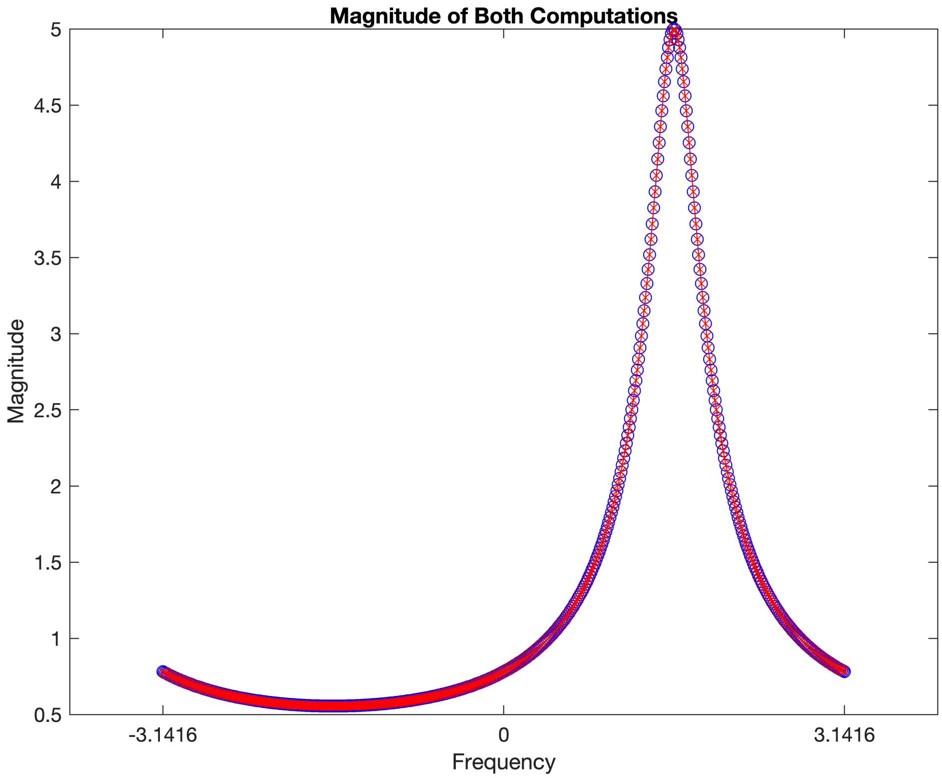
```
%Pick a large enough N to satisify 0.9^N ~ 0.
N = 100;
n = 0:N;
for k = 1:K+1
    z(k) = sum((0.8.^(n).*exp(1i*(pi/2.*n)).*exp(-1i*w_k(k).*n)));
end

plot(w_k, angle(z))
set(gca, 'XTick', -2*pi:pi:2*pi);
title('Angle for Numerical Computation of X')
xlabel('Frequency')
ylabel('Phase')
```




**4) Plot $\left|Z\left(e^{j\omega_k}\right)\right|$ and $\left|\tilde{Z}\left(e^{j\omega_k}\right)\right|$ on the same graph. Do they look same**

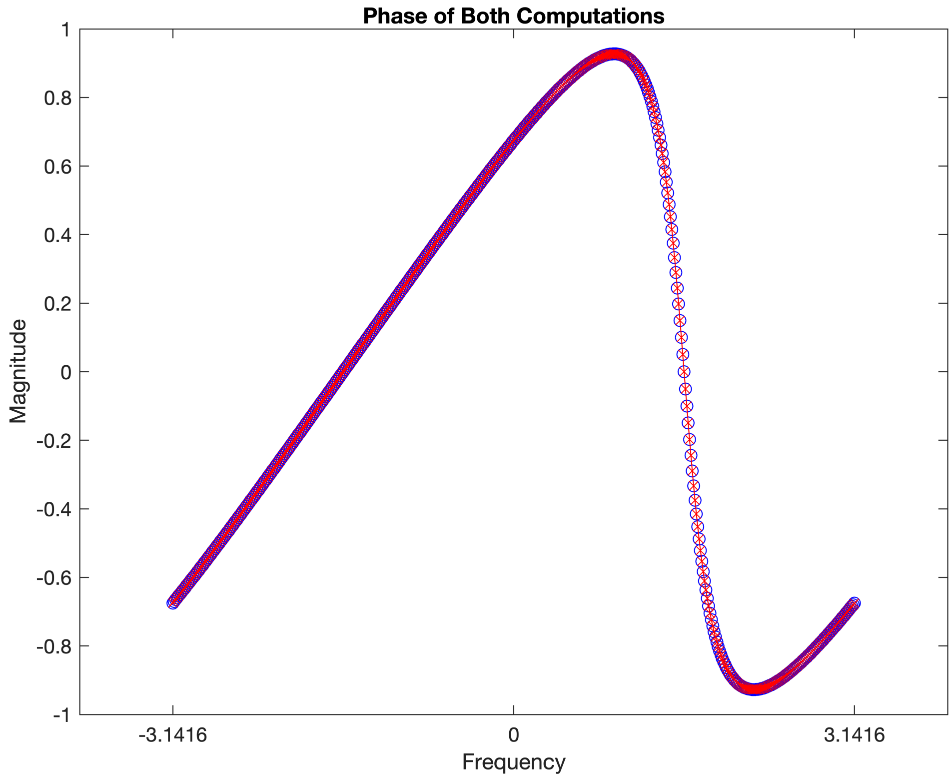
```
plot(w_k,abs(Z), 'b-o')
hold on
plot(w_k,abs(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Magnitude of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```




Yes, the graphs looks the same

**5) Plot** $|\angle Z\left(e^{j\omega_k}\right)$ **and** $\angle \widetilde{Z}\left(e^{j\omega_k}\right)$ **on the same graph. Do they look the same?**

```
plot(w_k,angle(Z), 'b-o')
hold on
plot(w_k,angle(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Phase of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```

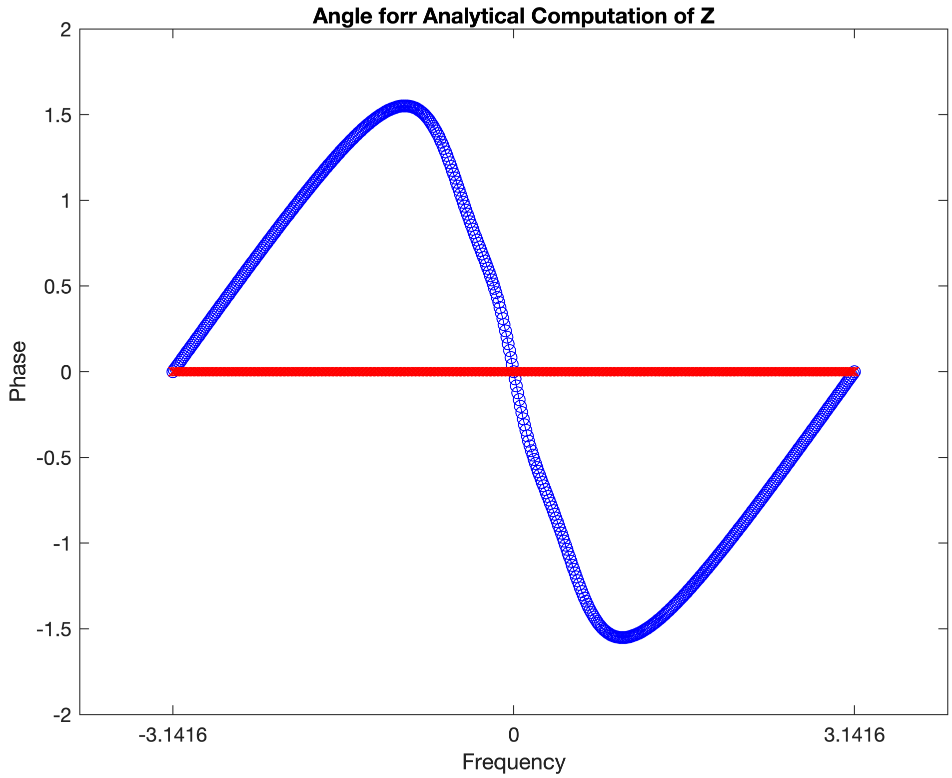



Yes the graphs look the same

## h) Repeate e with $z[n] = x[n] \star y[n]$

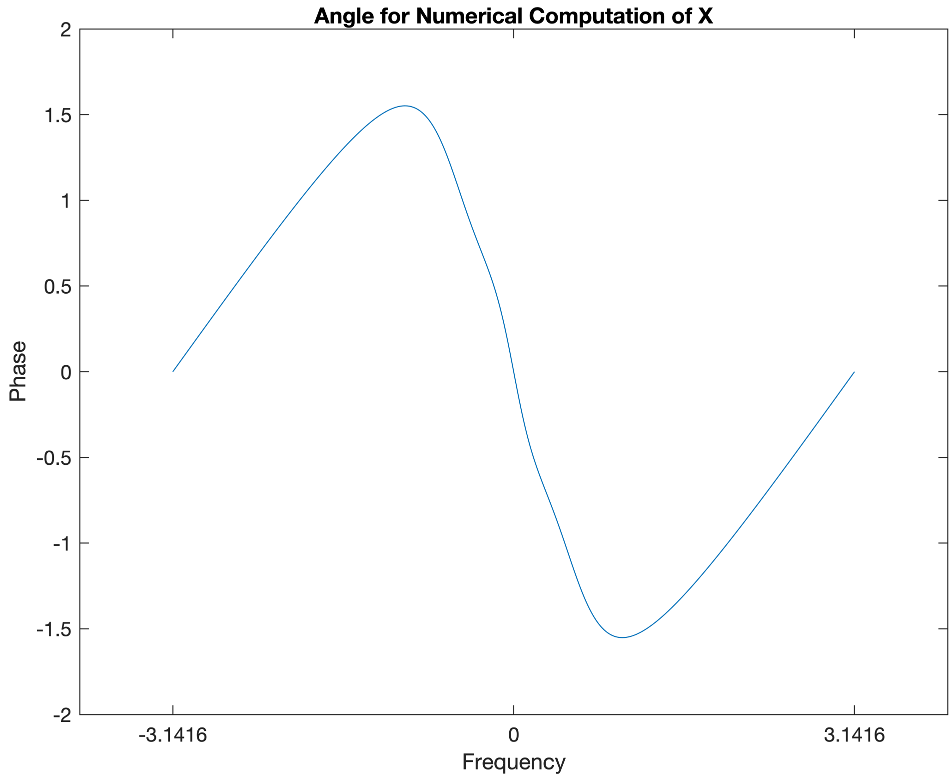
### 1) Analytically compute $Z(e^{j\omega})$ using $X(e^{j\omega}), Y(e^{j\omega})$, and the relevant property of DTFT.

```
X = 1./(1-0.8.*exp(-1i*w_k));
Z = X.*Y;
%plot(w_k,angle(Z))
set(gca,'XTick',-2*pi:pi:2*pi)
title('Angle forr Analytical Computation of Z')
xlabel('Frequency');
ylabel('Phase');
```



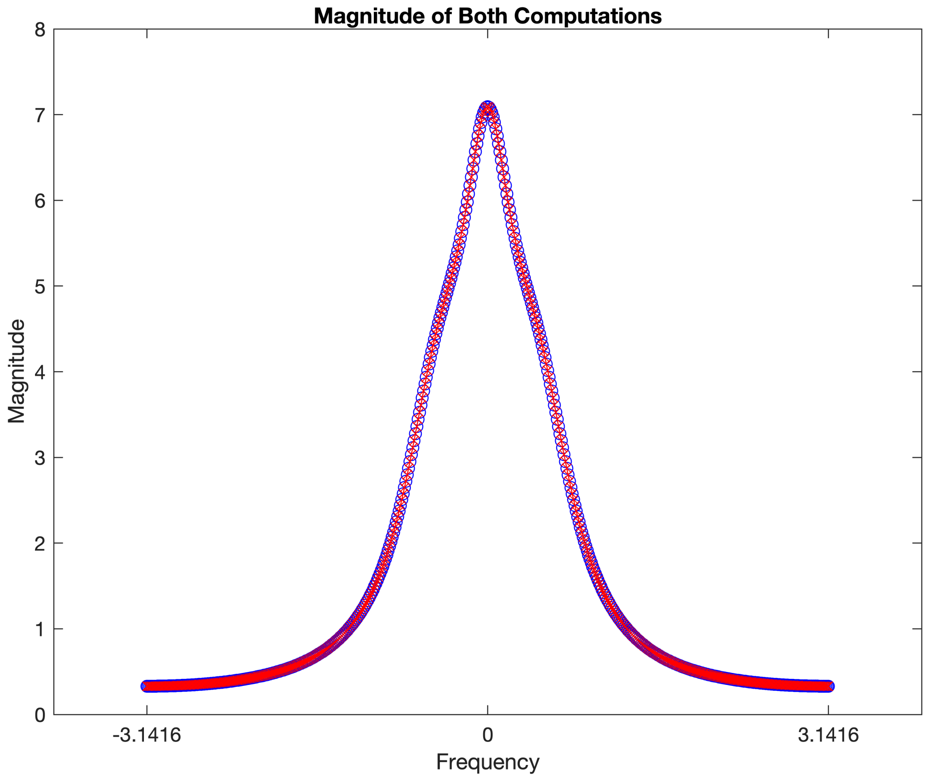

**3) Numerically computer $\widetilde{Z}\left(e^{j\omega_n}\right)$ using the truncated sum in (2) with $x[n]$**

```
%Pick a large enough N to satisify 0.9^N ~ 0.
N = 100;
n = 0:N;
for k = 1:K+1
    x = 0.8.^(n).*exp(-1i*w_k(k).*n);
    y = 0.7.^(n).*cos((pi.*n)/6).*exp(-1i*w_k(k).*n);
    z(k) = sum(conv(x,y,'full'));
end
plot(w_k, angle(z))
set(gca, 'XTick', -2*pi:pi:2*pi);
title('Angle for Numerical Computation of X')
xlabel('Frequency')
ylabel('Phase')
```




**4) Plot $\left|Z\left(e^{j\omega_k}\right)\right|$ and $\left|\tilde{Z}\left(e^{j\omega_k}\right)\right|$ on the same graph. Do they look same**

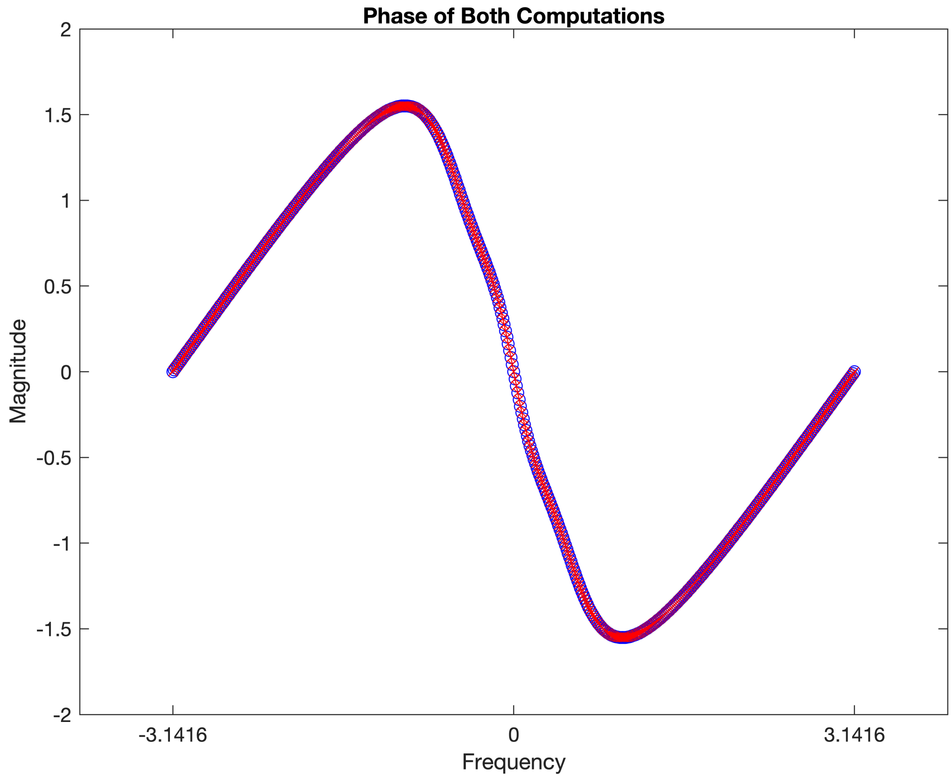
```
plot(w_k,abs(Z), 'b-o')
hold on
plot(w_k,abs(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Magnitude of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```




Yes, the graphs looks the same

**5) Plot $|\angle Z\left(e^{j\omega_k}\right)$ and $\angle\widetilde{Z}\left(e^{j\omega_k}\right)$ on the same graph. Do they look the same?**

```
plot(w_k,angle(Z), 'b-o')
hold on
plot(w_k,angle(z), 'r-x')
hold off
set(gca, 'XTick', -2*pi:pi:2*pi)
title('Phase of Both Computations')
xlabel('Frequency')
ylabel('Magnitude')
```




Yes the graphs look the same

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