ASSIGNMENT-10 EE17B109

April 15, 2019

1 Introduction

In this experiment we will be trying to do convolution operation on various signals and using both methods of linear convolution and circular convolution.In the theory class we have ana- lyzed the advantages of using circular convolution over using linear convolution when we are recieving continuos samples of inputs.We will also be analysing the effect of passing the signal x = cos(0.2 pi n) + cos(0.85 pi n) through a given filter.At last we will be analysing the cross- correllation output of the Zadoff–Chu sequence.

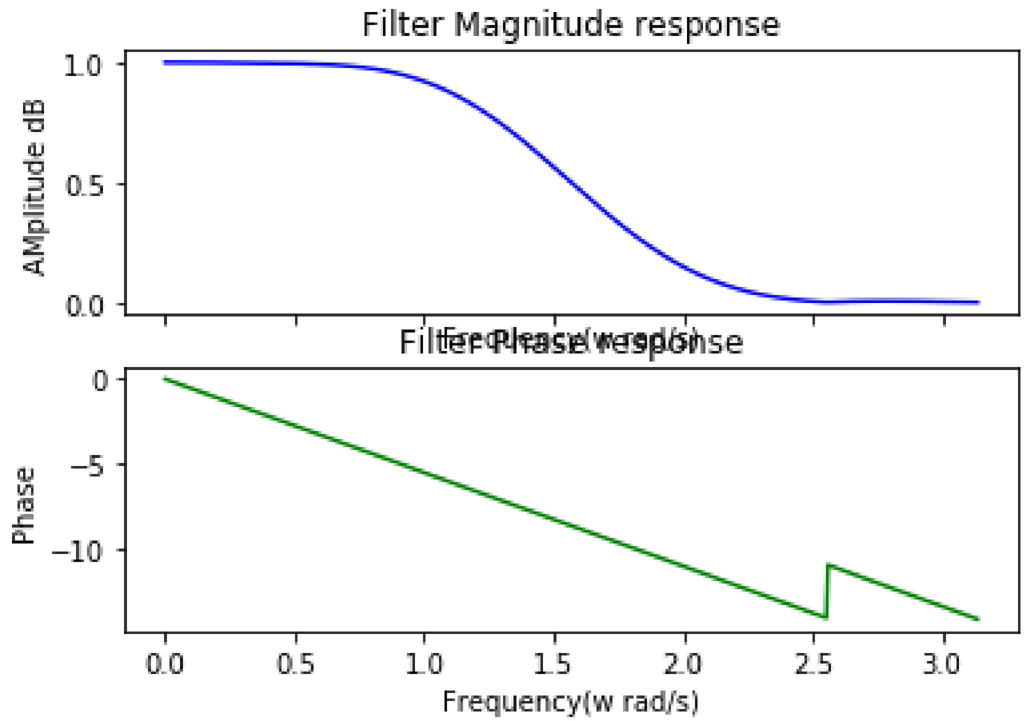
2 Importing packages

```
In [1]: import numpy as np
        import csv
        from scipy import signal
        import matplotlib.pyplot as plt
        from math import *
        import pandas as pd
```

3 Filter sequence

Now we will use the signal.freqz function to visuaize the filter in frequency domain.

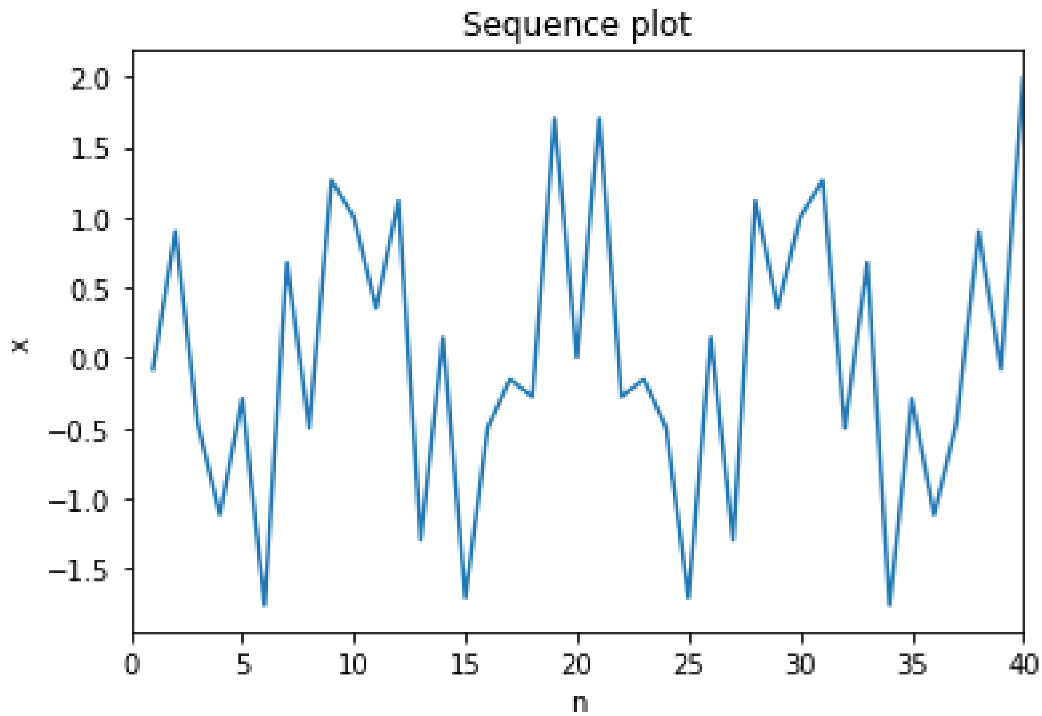
```
In [2]: a = np.genfromtxt('h.csv',delimiter=',')
        w,h = signal.freqz(a)
        fig,ax = plt.subplots(2,sharex=True)
        plt.grid(True,which="all")
        ax[0].plot(w,(abs(h)),"b")
        ax[0].set_title("Filter Magnitude response")
        ax[0].set_xlabel("Frequency(w rad/s)")
        ax[0].set_ylabel("AMplitude dB")
        angle = np.unwrap(np.angle(h))
        ax[1].plot(w,angle,"g")
        ax[1].set_title("Filter Phase response")
        ax[1].set_xlabel("Frequency(w rad/s)")
        ax[1].set_ylabel("Phase")
        plt.show()
```



Here I have plotted both the magnitude and phase response of the filter in the appropriate frequency range. It is clear from the plot that the given filter is a low-pass filter with a cutoff frequency of about 0.75 rad/s.

4 Given Signal:

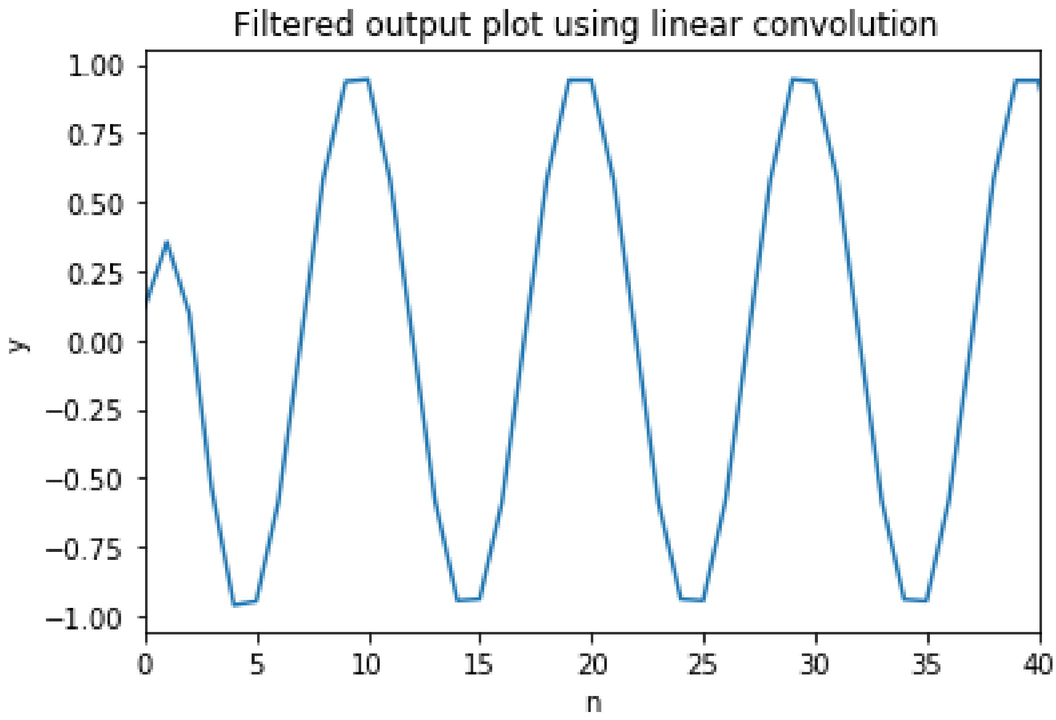
In [3]:
```
n = np.linspace(1,2**10,2**10)
x = np.cos(0.2*pi*n) + np.cos(0.85*pi*n)
fig2,bx = plt.subplots(1,sharex=True)
bx.plot(n,x)
bx.set_title("Sequence plot")
bx.set_xlabel("n")
bx.set_ylabel("x")
bx.set_xlim(0,40)
plt.show()
```



Clearly the input seqence has frequency components of 0.2pi = 0.628 rad/s and 0.85pi = 2.669 rad/s.

5 Passing signal through Filter

In [4]:
```
y = np.convolve(x,a,mode="same")
fig3,cx = plt.subplots(1,sharex=True)
cx.plot(y)
cx.set_title("Filtered output plot using linear convolution ")
cx.set_xlabel("n")
cx.set_ylabel("y")
cx.set_xlim(0,40)
plt.show()
```

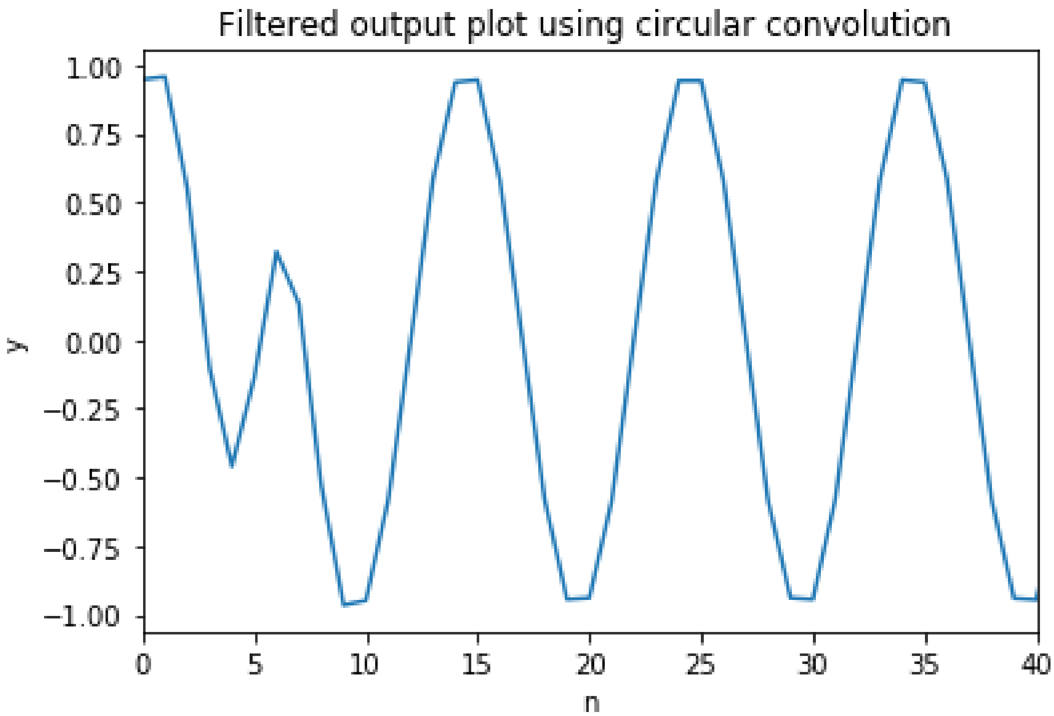


We can clearly see that it acted as a low pass filter

6 Using Circular Convolution

```
In [5]: a_adjusted = np.pad(a,(0,len(x)-len(a)),"constant")
        y1 = np.fft.ifft(np.fft.fft(x) * np.fft.fft(a_adjusted))
        fig4,dx = plt.subplots(1,sharex=True)
        dx.plot(y1)
        dx.set_title("Filtered output plot using circular convolution ")
        dx.set_xlabel("n")
        dx.set_ylabel("y")
        dx.set_xlim(0,40)
        plt.show()
```

```
/home/suhas/anaconda3/lib/python3.6/site-packages/numpy/core/numeric.py:492: ComplexWarning: Ca
  return array(a, dtype, copy=False, order=order)
```

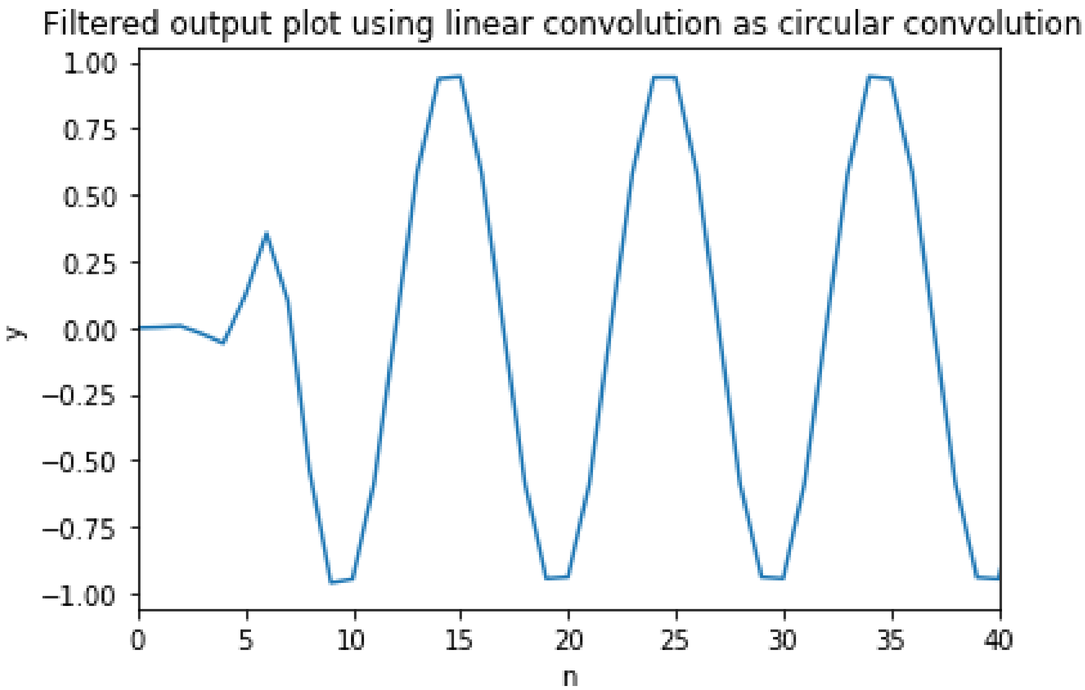


norder to compute the output using circular-convolution I am imitially padding my signals in to avoid overlapping of the output over itself.By doing this we will be getting the output seqence just like linear convolution.

7 Circular Convolution using linear stiching

```
In [6]: N = len(a) + len(x) - 1
        fil = np.concatenate([a,np.zeros(N-len(a))])
        y_modified = np.concatenate([x,np.zeros(N-len(x))])
        y2 = np.fft.ifft(np.fft.fft(y_modified) * np.fft.fft(fil))
        fig5,fx = plt.subplots(1,sharex=True)
        fx.plot(y2)
        fx.set_title("Filtered output plot using linear convolution as circular convolution ")
        fx.set_xlabel("n")
        fx.set_ylabel("y")
        fx.set_xlim(0,40)
        plt.show()
```

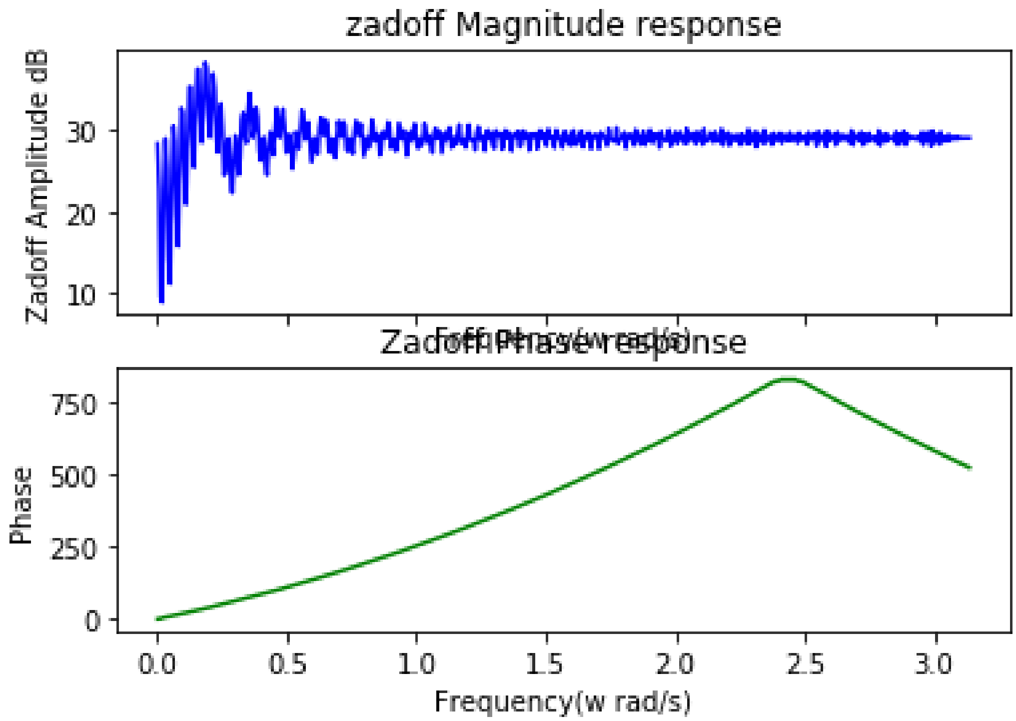
```
/home/suhas/anaconda3/lib/python3.6/site-packages/numpy/core/numeric.py:492: ComplexWarning: Ca
  return array(a, dtype, copy=False, order=order)
```



We clearly see that the output is exactly similar to the one which we got by linear convolution.Hence it is seen that by padding the sequence appropriately we will be able to achieve the output using circular convolution.

8 Zadoff Sequence

```
In [7]: zadoff = pd.read_csv("x1.csv").values[:,0]
        zadoff = np.array([complex(zadoff[i].replace("i","j")) for i in range(len(zadoff))])
        zw,zh = signal.freqz(zadoff)
        fig5,ex = plt.subplots(2,sharex=True)
        plt.grid(True,which="all")
        ex[0].plot(zw,(abs(zh)),"b")
        ex[0].set_title("zadoff Magnitude response")
        ex[0].set_xlabel("Frequency(w rad/s)")
        ex[0].set_ylabel("Zadoff Amplitude dB")
        angle_z = np.unwrap(np.angle(zh))
        ex[1].plot(zw,angle_z,"g")
        ex[1].set_title("Zadoff Phase response")
        ex[1].set_xlabel("Frequency(w rad/s)")
        ex[1].set_ylabel("Phase")
        plt.show()
```

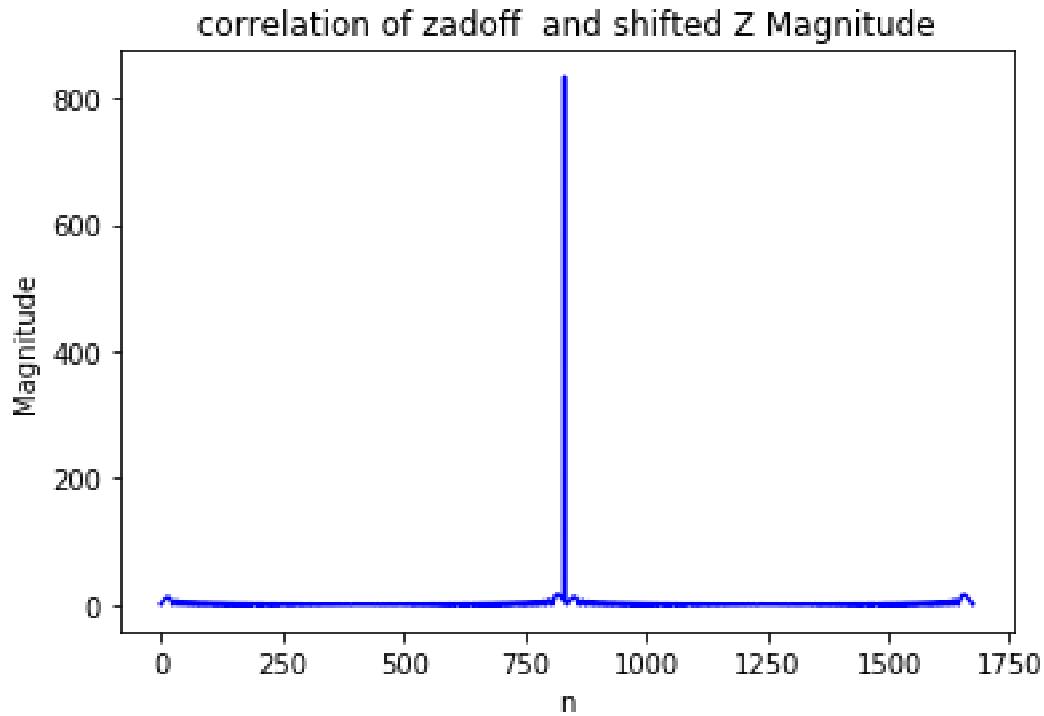


Properties of Zadoff-Chu sequence: *(a)Itisacomplexsequence.*
(b)Itisaconstantamplitudesequence. *(c)TheautocorrelationofaZadoffChusequencewithacyclicallyshiftedversionofi*
(d)CorrelationofZadoffChusequencewiththedelayedversionofitselfwillgiveapeakatthatdelay.

9 Co-relation with shifting with itself

```
In [10]: zadoff_modified = np.concatenate([zadoff[-5:],zadoff[:-5]])

         z_out = np.correlate(zadoff,zadoff_modified,"full")
         fig7,gx = plt.subplots(1,sharex=True)
         plt.grid(True,which="all")
         gx.plot((abs(z_out)),"b")
         gx.set_title(" correlation of zadoff  and shifted Z Magnitude ")
         gx.set_xlabel("n")
         gx.set_ylabel("Magnitude")
         plt.show()
```



We clearly see a peak at shited magnitude frequency correspondent

10 Conclusion

Hence through this assignment we are able to take the output of a system for a given signal using convolution. We approached convolution using linear method and circular method.We use padding to make the filter of appropriate size before we do the circular convolution.Later we analysed the crosscorrelation function of Zadoff–Chu sequence with its circularly shifted version of itself.We observe a sharp peak in appropriate location according to the circular shift done.