Method 2

First deblur the signal using dtft and then remove the additive noise

In [27]:

```
# importing required libraries for basic mathematics and manupulation

import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import math
```

In [28]:

```
#reads the csv and stores it in a dataframe

df = pd.read_csv('data.csv')
```

In [29]:

```
#displays first five rows
df.head()
```

Out[29]:

	x[n]	y[n]
0	35.4312	33.3735
1	35.1511	34.3744
2	34.8284	35.7514
3	34.4656	35.5869
4	34.0656	36.0826

In [30]:

```
# removing headers

df = df.rename(columns={col: "" for col in df})
df.head()
```

Out[30]:

0	35.4312	33.3735
1	35.1511	34.3744
2	34.8284	35.7514
3	34.4656	35.5869
4	34.0656	36.0826

In [31]:

```
# converting data into 1D lists
x = df.iloc[:,0]
y = df.iloc[:,1]
y.head()
```

Out[31]:

```
0    33.3735
1    34.3744
2    35.7514
3    35.5869
4    36.0826
Name: , dtype: float64
```

In [32]:

```
# converts to numpy array which supports complex number manipulation
x = np.array(x)
y = np.array(y)
```

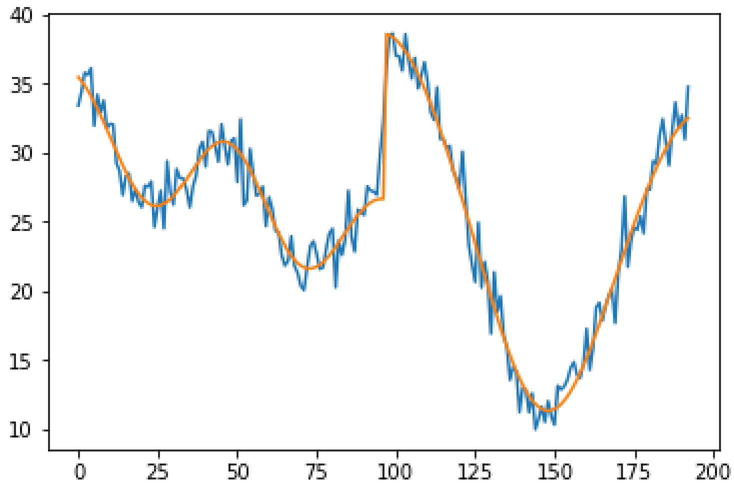
Representation of Initial signals

In [33]:

```
plt.plot(range(0,193),y)
plt.plot(range(0,193),x)
```

Out[33]:

```
[<matplotlib.lines.Line2D at 0x1a92d274370>]
```



Step 1 : Deblurring the signal using Discrete time fourier transform

In [34]:

```
# dtft algorithm for y[n]

N = len(y)
w = np.linspace(0,2*math.pi,N)                    # taking 193 samples of w between 0

X = np.zeros(N,dtype = 'complex_')                # array to store dtft

for k in range(0,N-1):                            # outer loop to change the value of
    X[k] = 0

    for n in range(0,N-1):                        # inner loop to change the value of

        X[k] = X[k] + y[n]* math.e**(-1j *w[k] *n)        # formula for dtft
```

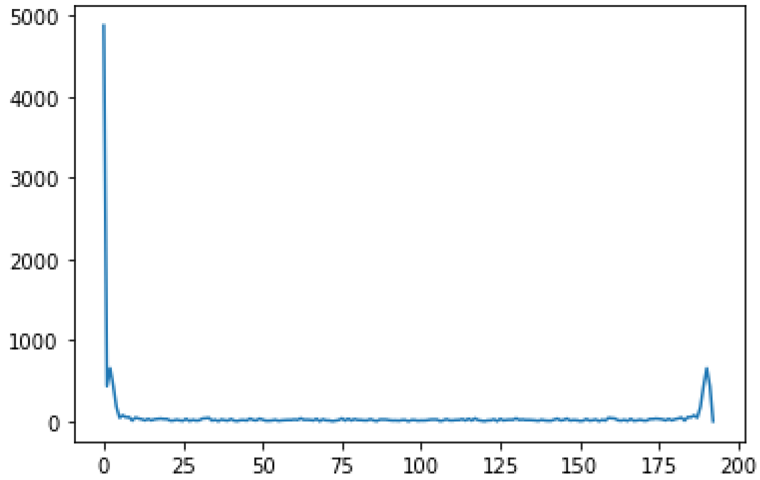
Plot for DTFT

In [35]:

```
plt.plot(range(0,193),abs(X))
```

Out[35]:

```
[<matplotlib.lines.Line2D at 0x1a92d2a6bb0>]
```



In [36]:

```
# dtft for h[n]

h = np.array([1/16, 1/4, 3/8, 1/4, 1/16])

N = 193

w=[]
for i in range (193):
    w.append(2*math.pi*i/193)

H = np.zeros(N,dtype = 'complex_')

for k in range(0,N-1):
    H[k-2] = 0

    for n in range(0,5):

        H[k-2] = H[k-2] + h[n]* math.e**(-1j *w[k-2] *n)
```

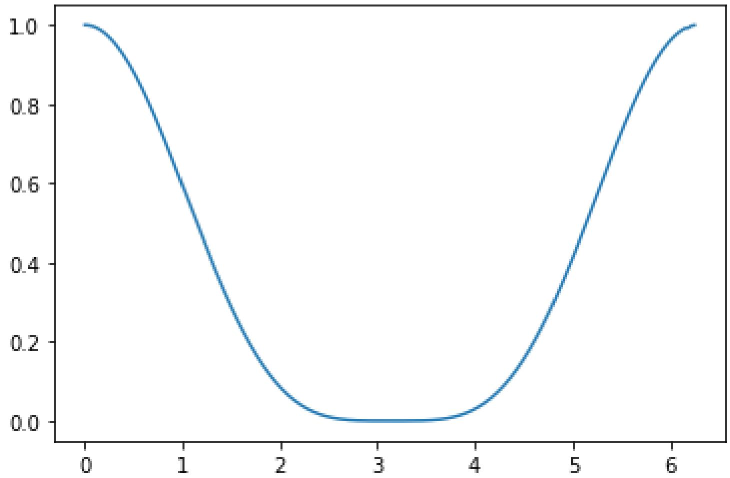
Plot for DTFT of h[n]

In [37]:

```
H[190] = (H[191] + H[189]) /2

plt.plot(range(0,193),abs(H))
```

Out[37]:

```
[<matplotlib.lines.Line2D at 0x1a92d16b310>]
```



In [38]:

```
# In the above plot we see that H(e^jw) approches zero at certain values and thus X_final(e
# To avoid this senario we clip the graph at an appropriate value which is determined by tr
# value to all the values below the threshold

H_mod = list(abs(H))

for n, i in enumerate(H_mod):
    if i < 0.8:
        H_mod[n] = 0.8
```

In [39]:

```
print(H_mod.index(0.8))

print(H[21])
```

```
21
(0.15920910143656403-0.7716376423250288j)
```

In [40]:

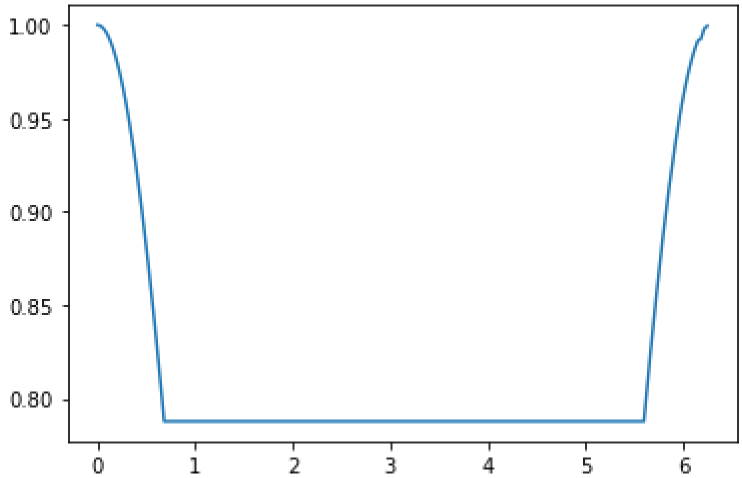
```
for i in range(22,172):                  # assigns the given to all the numbers in this range

    H[i] = 0.15920910143656403-0.7716376423250288j
```

In [41]:

```
plt.plot(range(0,193),abs(H))
```

Out[41]:

```
[<matplotlib.lines.Line2D at 0x1a92e2e46d0>]
```



In [42]:

```
X_final = X/H                                      # dtft for the X_final
```

In [43]:

```
# using inverse fourier transform on X_final

N = len(X_final)
w = np.linspace(0,2*math.pi,N)                     # taking 193 samples of w between 0 and 2*p

X1 = np.zeros(N,dtype = 'complex_')

# Applying the summation formula for inverse dtft

for k in range(0,N-1):
    X1[k] = 0

    for n in range(0,N-1):

        X1[k] = ( X1[k] + X_final[n]* math.e**(1j * w[k] *n))

X1 = X1 / 193
```

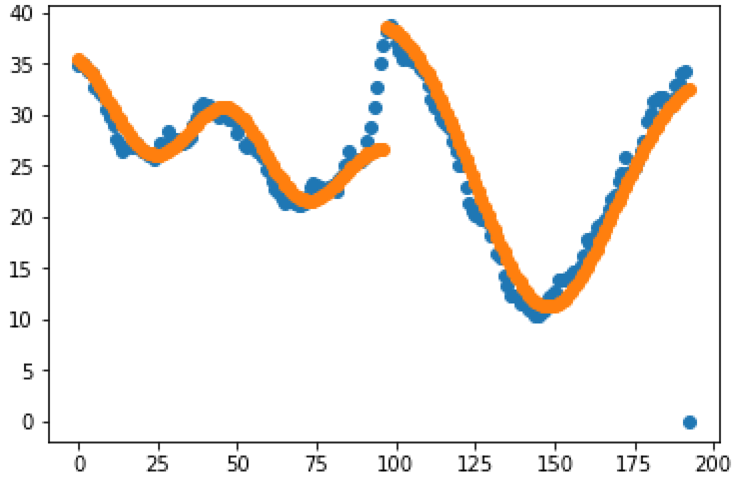
Plot after Deblur

In [44]:

```
plt.scatter(range(0,193),abs(X1))
plt.scatter(range(0,193),x)
#plt.plot(w,y)

plt.show
```

Out[44]:

```
<function matplotlib.pyplot.show(close=None, block=None)>
```



In [45]:

```
y_deblurred = np.array(abs(X1))
```

Denoising the blurred signal using moving averages

In [46]:

```
# denoising the signal using moving averages of window_size = 5 :

window_size = 5                    # indicates that we are taking average of 5 consecutive s

i = 0
X2 = []

while i < len(y) - window_size + 1:                     # while loop used untill the array
                                                        # one unit everytime the loop runs

    this_window = y_deblurred[i : i + window_size]


    window_average = sum(this_window) / window_size
    X2.append(window_average)
    i += 1

# we fall short of 4 values when window size is 5 and we add them
# manually by using the same method but averaging 3 values to ensure
# minimum deviation at the edges

X2.insert(-2,(y_deblurred[-2]+y_deblurred[-3]+y_deblurred[-4])/3)
X2.insert(-1,(y_deblurred[-1]+y_deblurred[-2]+y_deblurred[-3])/3)


X2.insert(0,(y_deblurred[0]+y_deblurred[1]+y_deblurred[2])/3)
X2.insert(1,(y_deblurred[1]+y_deblurred[2]+y_deblurred[3])/3)
```

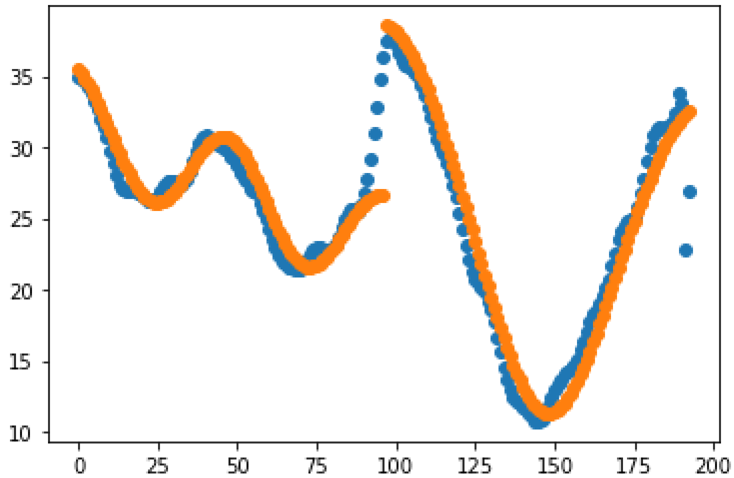
Final plot for X2[n] and comparison with original x[n]

In [47]:

```
plt.scatter(range(0,193),X2)
plt.scatter(range(0,193),x)
```

Out[47]:

```
<matplotlib.collections.PathCollection at 0x1a92e39ed90>
```



In [48]:

```
# for comparing these plots we can calculate the mean error between all the values
# As the value of error decreases, accuracy of determining x[n] increases.

abs_error = []

for i in range(0,191):                    # excluding last 2 values since they are way off
    abs_error.append(abs(X2[i]+x[i]))

mean_error = sum(abs_error)/191

print(mean_error)
```

```
50.622467196875064
```

By observing the mean_errors of both plots, we see that error in method 1 was less than error in method 2, although not by a significant margin. But in practical applications, the number of values are could be higher and that will only elevate the difference in errors between these methods.

Thus, we can conclude that method 1 is a better alternative to recover original signal from the transmitted signal.