In [1]:
```
%pylab inline
import numpy as np
import wave
import matplotlib.pyplot as plt
import scipy.io.wavfile
import operator
from IPython.display import Audio
```

```
Populating the interactive namespace from numpy and matplotlib
```

Audio File Matching

This notebook continues the audio file matching problem. Be sure to have song.wav and clip.wav in the same directory as the notebook.

In this notebook, we will look at the problem of searching for a small audio clip inside a song.

The song "Mandelbrot Set" by Jonathan Coulton is licensed under CC BY-NC 3.0 (http://creativecommons.org/licenses/by-nc/3.0/)

If you have trouble playing the audio file in IPython, try opening it in a different browser. I encountered problem with Safari but Chrome works for me.

In [2]:

```
import numpy as np
import wave
import matplotlib.pyplot as plt
import scipy.io.wavfile
import operator
from IPython.display import Audio
%matplotlib inline

given_file = 'song.wav'
target_file = 'clip.wav'
rate_given,  given_signal  = scipy.io.wavfile.read(given_file)
rate_target, target_signal = scipy.io.wavfile.read(target_file)
given_signal  = given_signal[:2000000].astype(float)
target_signal = target_signal.astype(float)
def play_clip(start, end, signal=given_signal):
    scipy.io.wavfile.write('temp.wav', rate_given, signal[start:end].astype(np.int16))
    return Audio(url='temp.wav', autoplay=True)

def run_comparison(target_signal, given_signal, idxs=None):
    # Run everything if not called with idxs set to something
    if idxs is None:
        idxs = [i for i in range(len(given_signal)-len(target_signal))]
    return idxs, [vector_compare(target_signal, given_signal[i:i+len(target_signal)])
                  for i in idxs]

play_clip(0, len(given_signal))

#scipy.io.wavfile.write(target_file, rate_given, (-0.125*given_signal[1380000:1380000+70000]).astype(np.int16))
```

Out[2]: 0:00

We will load the song into the variable `given_signal` and load the short clip into the variable `target_signal`. Your job is to finish code that will identify the short clip's location in the song. The clip we are trying to find will play after executing the following block.

In [3]:

```
Audio(url=target_file, autoplay=True)
```

Out[3]: 0:01 / 0:01

Your task is to define the function 'vector_compare' and run the following code. Because the song has a lot of data, you should use the provided examples from the previous parts of the problem before running the later code. Do you results here make sense given your answers to previous parts of the problem?

In [23]:
```
def vector_compare(desired_vec, test_vec):
    """This function compares two vectors, returning a number.
    The test vector with the highest return value is regarded as being c
losest to the desired vector."""
    # The transpose is a gotcha! Stupid numpy
    # your code here
    """diff = 0
    for x in range(len(test_vec)):
        diff += abs(desired_vec[x] - test_vec[x])
    if diff == 0:
        return 1.01
    else:
        return 1/diff""" #THIS DOESNT WORK, SO TRYING NEW THING BELOW:
    if np.array_equal(desired_vec, test_vec):
        return 1
    else:
        return
np.dot(desired_vec,test_vec)/(np.linalg.norm(desired_vec)*np.linalg.norm(
est_vec))*(1/np.linalg.norm(desired_vec-test_vec))


print("PART A:")
print(vector_compare(np.array([1,1,1]), np.array([1,1,1])))
print(vector_compare(np.array([1,1,1]), np.array([-1,-1,-1])))
print("PART C:")
print(vector_compare(np.array([1,2,3]), np.array([1,2,3])))
print(vector_compare(np.array([1,2,3]), np.array([2,3,4])))
print(vector_compare(np.array([1,2,3]), np.array([3,4,5])))
print(vector_compare(np.array([1,2,3]), np.array([4,5,6])))
print(vector_compare(np.array([1,2,3]), np.array([5,6,7])))
print(vector_compare(np.array([1,2,3]), np.array([6,7,8])))
```

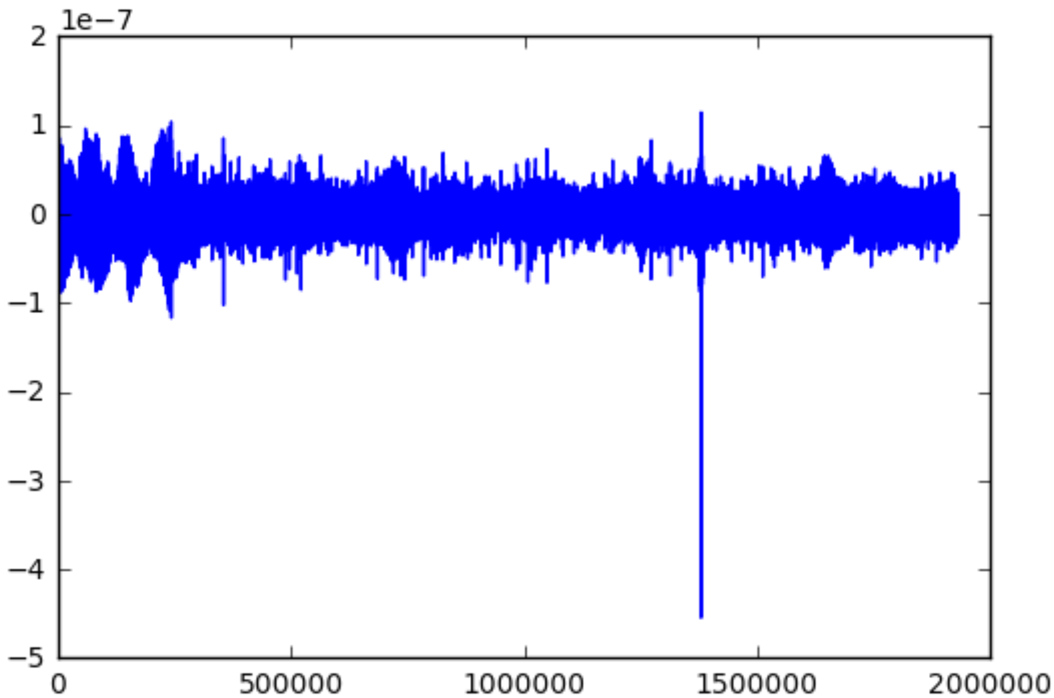
```
PART A:
1
-0.288675134595
PART C:
1
0.573068255061
0.283683257307
0.187567986254
0.139766348005
0.111241002164
```

Problem 1

Run the following code that runs `vector_compare` on every subsequence in the song- it will probably take at least 5 minutes. How do you interpret this plot to find where the clip is in the song?

In [24]:
```python
import time

t0 = time.time()
idxs, song_compare = run_comparison(target_signal, given_signal)
t1 = time.time()
plt.plot(idxs, song_compare)
print ("That took %(time).2f minutes to run" % {'time':(t1-t0)/60.0} )
```

```
That took 4.26 minutes to run
```



Problem 2

In the space below, write code that uses `song_compare` to print the index of `given_signal` where `target_signal` begins. Then, verify that your answer is correct by playing the song at that index using the `play_clip` function.

In [27]:
```python
# your code here
#Print index
max_corr = np.argmax(song_compare)
print(max_corr)
print(len(target_signal)+ max_corr)

#Play it
play_clip(max_corr,len(target_signal)+ max_corr, target_signal )
```

```
1380284
1450284
```

Out[27]:

0:00

GPS Locationing

In [5]:
```
%pylab inline
import numpy as np
import matplotlib.pyplot as plt
import scipy.io
import sys
```

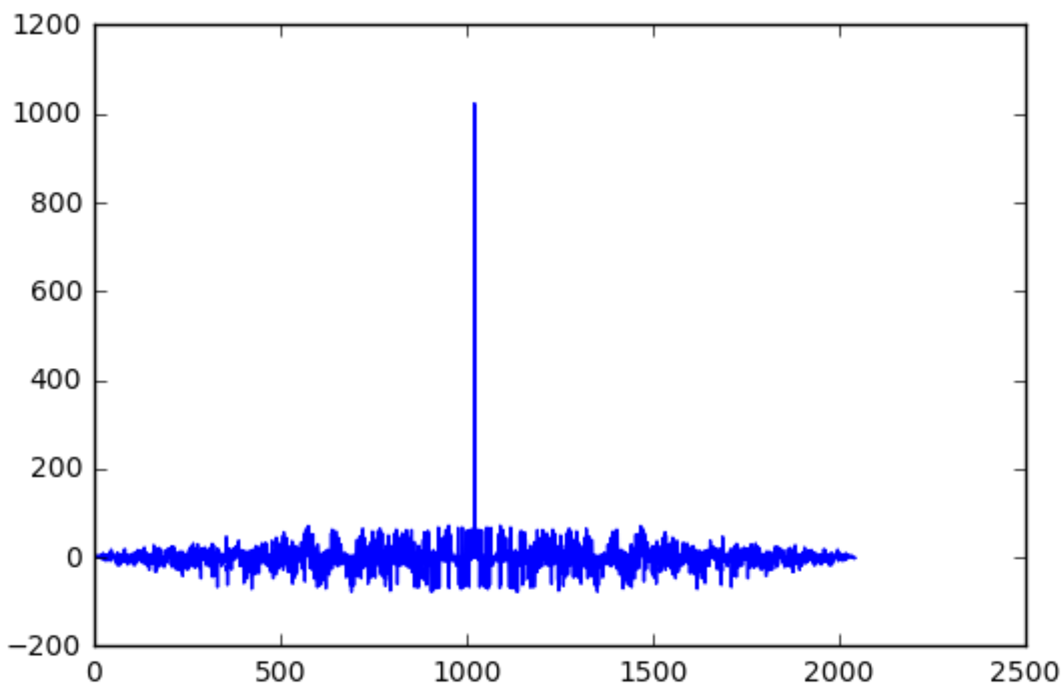
```
Populating the interactive namespace from numpy and matplotlib
```

In [6]:
```
## RUN THIS FUNCTION BEFORE YOU START THIS PROBLEM
## This function will generate the gold code associated with the satelli
te ID using linear shift registers
## The satellite_ID can be any integer between 1 and 24
def Gold_code_satellite(satellite_ID):
    codelength = 1023
    registerlength = 10

    # Defining the MLS for G1 generator
    register1 = -1*np.ones(registerlength)
    MLS1 = np.zeros(codelength)
    for i in range(codelength):
        MLS1[i] = register1[9]
        modulo = register1[2]*register1[9]
        register1 = np.roll(register1,1)
        register1[0] = modulo

    # Defining the MLS for G2 generator
    register2 = -1*np.ones(registerlength)
    MLS2 = np.zeros(codelength)
    for j in range(codelength):
        MLS2[j] = register2[9]
        modulo = register2[1]*register2[2]*register2[5]*register2[7]*reg
ister2[8]*register2[9]
        register2 = np.roll(register2,1)
        register2[0] = modulo

    delay =
np.array([5,6,7,8,17,18,139,140,141,251,252,254,255,256,257,258,469,470,4
71,472,473,474,509,512,513,514,515,516,859,860,861,862])
    G1_out = MLS1;
    shamt = delay[satellite_ID - 1]
    G2_out = np.roll(MLS2,shamt)

    CA_code = G1_out * G2_out

    return CA_code
```

In [17]:
```
## PART A CODE HERE
def array_correlation(array1,array2):
    """ This function should return two arrays or a matrix with one row
 corresponding to
    the offset and other to the correlation value
    """
    ## INSERT YOUR CODE HERE
    ## Use np.correlate with "FULL". Check out the helper page for it
    offset_array = list(range(len(array1)+len(array2)-1))
    correlation_value = np.correlate(array1, array2, mode="full")
    return(offset_array, correlation_value)

# Plot the auto-correlation of satellite 10 with itself. Your signal sho
uld be centered
# at offset = 0.
# Use plt.plot or plt.stem to plot.
_, corr = array_correlation(Gold_code_satellite(10),
Gold_code_satellite(10))
print(corr)
plt.plot(np.arange(len(corr)), corr)
```

```
[-1. -2. -1. ..., -1. -2. -1.]
```

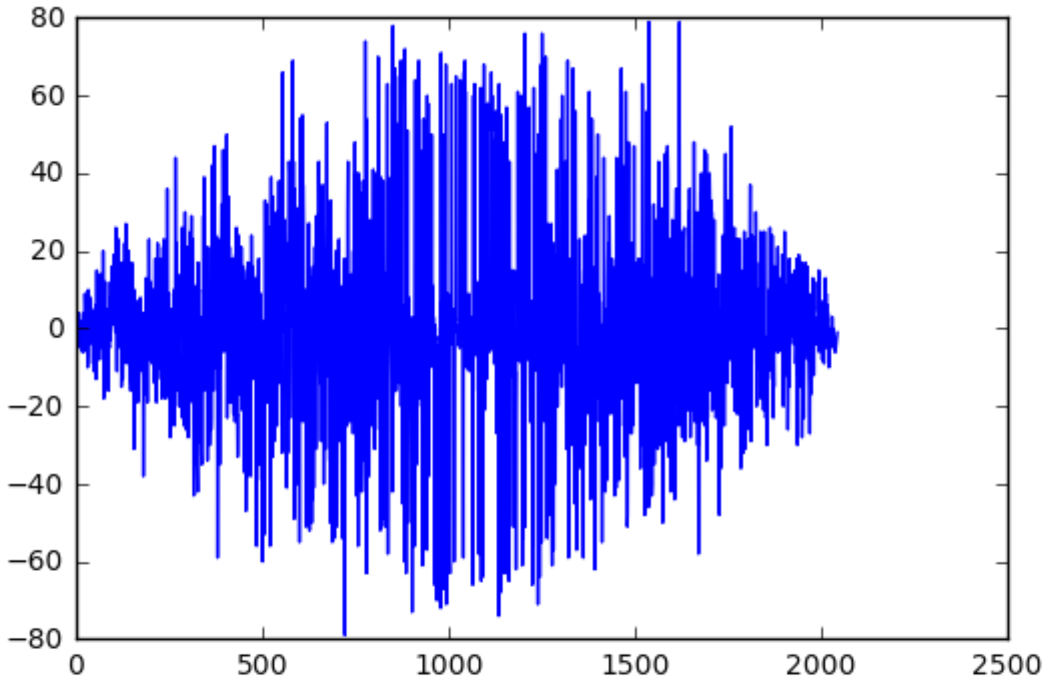
Out[17]: [<matplotlib.lines.Line2D at 0x112e71780>]



In [18]:
```
## PART B CODE HERE
_, corr = array_correlation(Gold_code_satellite(10),
Gold_code_satellite(13))
print(corr)
plt.plot(np.arange(len(corr)), corr)
```

```
[-1. -2. -1. ..., -3. -2. -1.]
```

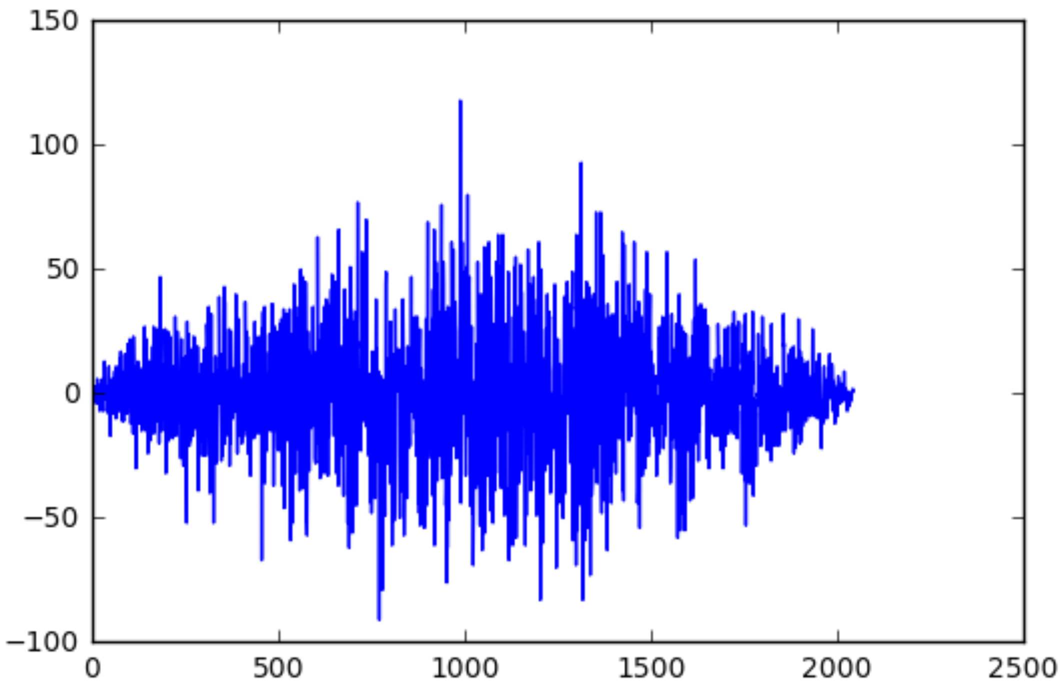
Out[18]:
```
[<matplotlib.lines.Line2D at 0x112f131d0>]
```



In [19]:
```
## PART C CODE HERE
## THIS IS A HELPER FUNCTION FOR PART C
def integernoise_generator(length_of_noise):
    noise_array = np.random.randint(2,size = length_of_noise)
    noise_array = 2*noise_array - np.ones(size(noise_array))
    return noise_array

ten = Gold_code_satellite(10)
_, corr = array_correlation(ten, integernoise_generator(len(ten)))
print(corr)
plt.plot(np.arange(len(corr)), corr)
```

```
[-1. -2. -1. ...,  1.  2.  1.]
```

Out[19]: [<matplotlib.lines.Line2D at 0x112faf7b8>]

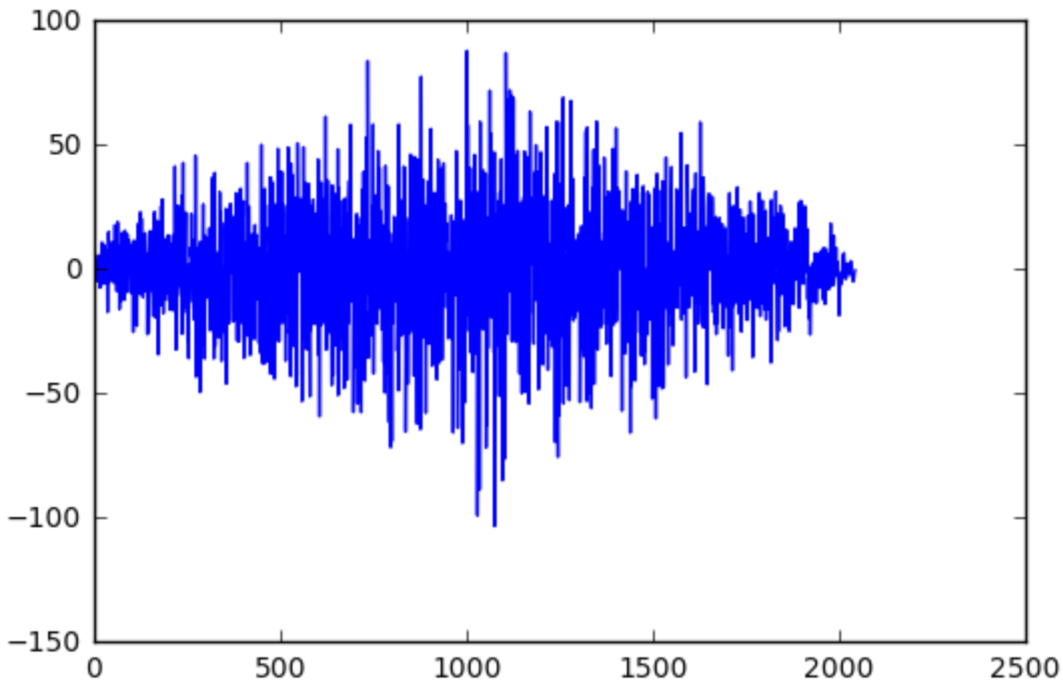


In [21]:

```
## PART D CODE HERE
## THIS IS A HELPER FUNCTION FOR PART D
def gaussiannoise_generator(length_of_noise):
    noise_array = np.random.normal(0,1,length_of_noise)
    return noise_array

_, corr = array_correlation(Gold_code_satellite(10), gaussiannoise_gener
ator(1023))
print(corr)
plt.plot(np.arange(len(corr)), corr)
```

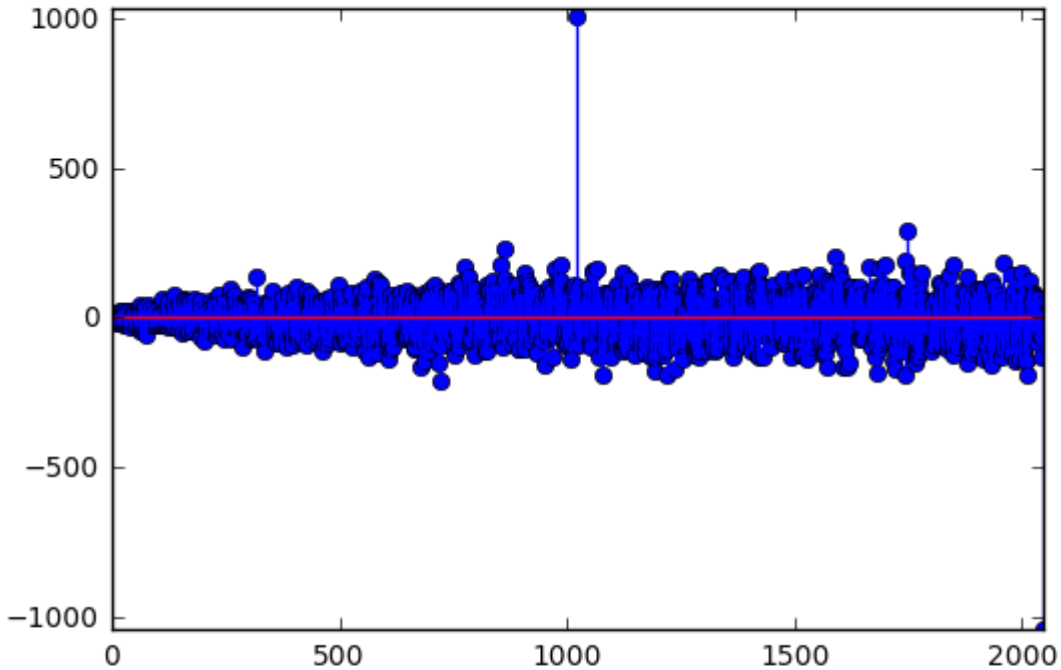
```
[-0.26832599 -0.22721151  1.01258948 ..., -1.87434826 -0.57010434
 -0.34232715]
```

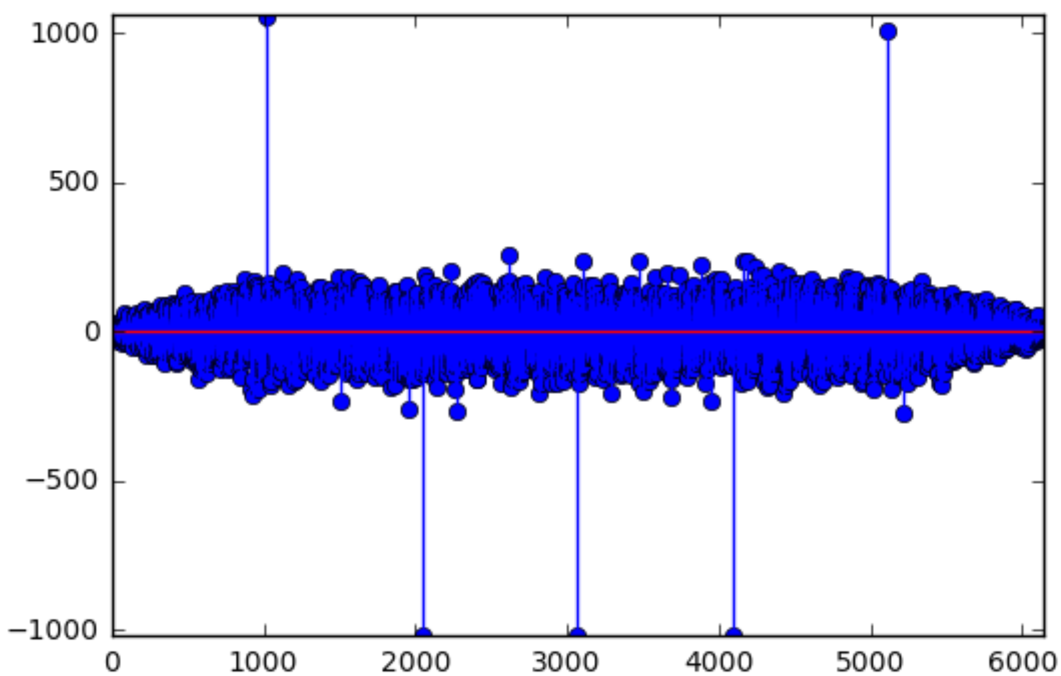
Out[21]: [<matplotlib.lines.Line2D at 0x112f1fcf8>]

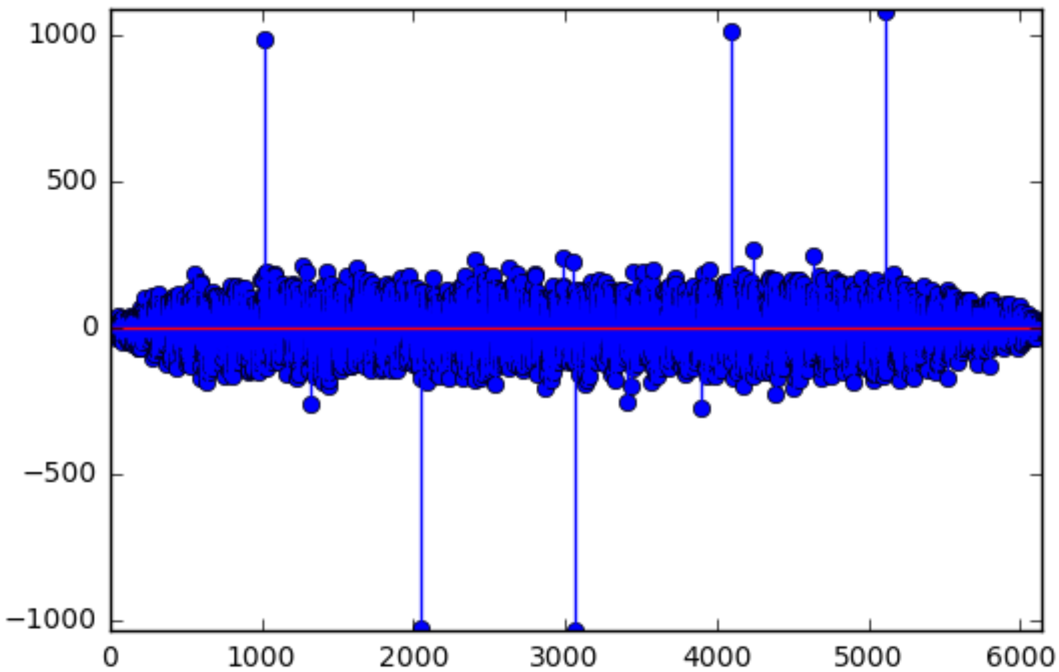


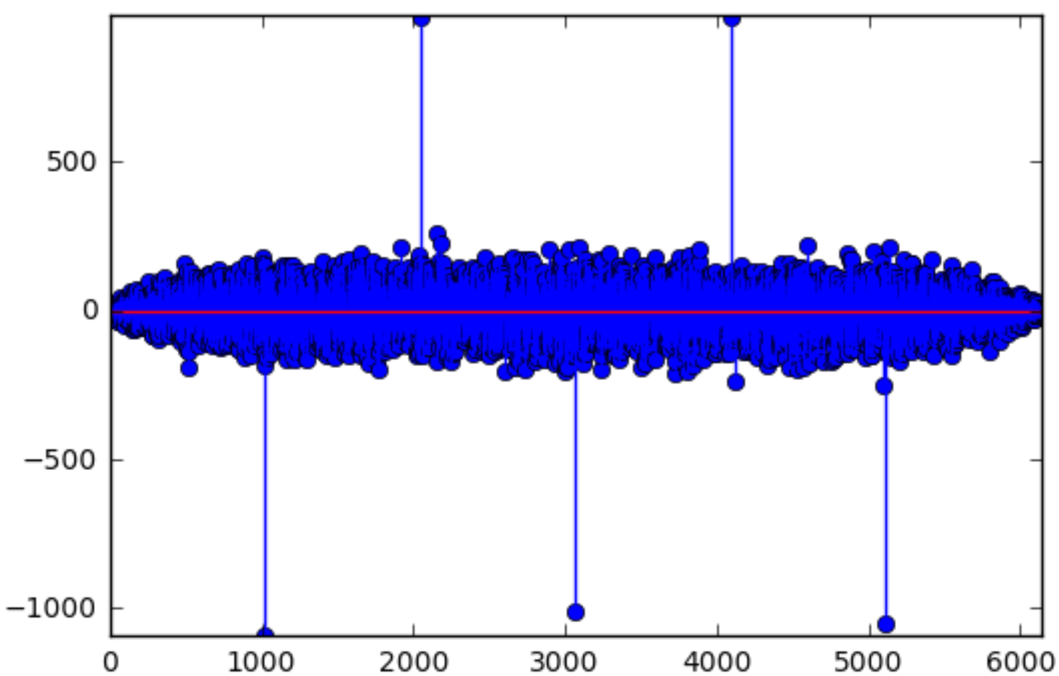
In [23]:

```
## PART E CODE HERE
## USE 'np.load' FUNCTION TO LOAD THE DATA
## USE DATA1.NPY AS THE SIGNAL ARRAY

satellites = []
signal = np.load("data1.npy")
for i in range(1, 25):
    _, corr = array_correlation(signal, Gold_code_satellite(i))
    if min(corr) < -500 or max(corr) > 500: #if a peak
        satellites.append(i)
        #plt.plot(np.arange(len(corr)), corr)
        plt.axis([-1, len(x), min(corr) - 1, max(corr) + 1])
        x = np.arange(len(corr))
        plt.stem(x, corr, "b-", "bo")
        plt.show()

print(satellites)
```


1000
500
0
−500
−1000
0
500
1000
1500
2000


1000
500
0
−500
−1000
0
1000
2000
3000
4000
5000
6000

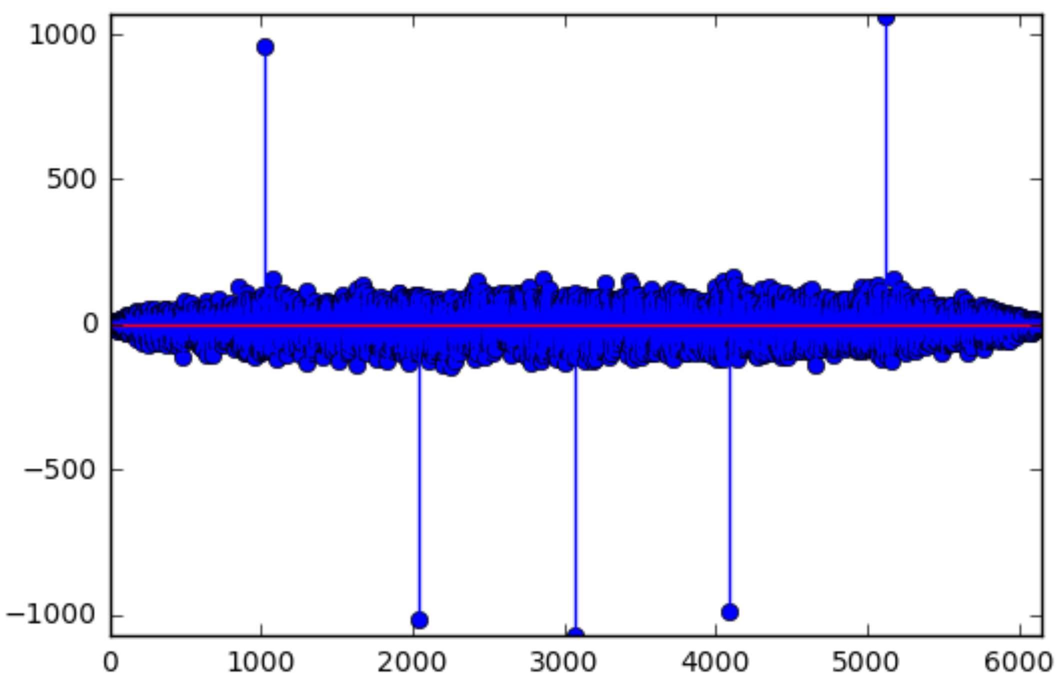

1000
500
0
−500
−1000
0
1000
2000
3000
4000
5000
6000


500
0
−500
−1000
0
1000
2000
3000
4000
5000
6000

```
[4, 7, 13, 19]
```

In [24]:
```
## PART F CODE HERE
## USE DATA2.NPY AS THE SIGNAL ARRAY
satellites, signal = [], np.load("data2.npy")
print(signal)
for i in range(1, 25):
    offset, y = array_correlation(signal, Gold_code_satellite(i))
    if min(y) < -500 or max(y) > 500:
        satellites.append(i)
        plt.axis([0, len(x) + 10, min(y) - 1, max(y) + 1])
        x = np.arange(len(y))
        plt.stem(x, y, "b-", "bo")
        plt.show()
print("Satellite:", satellites[0])
```

```
[ 0.1823331  -0.14363724 -0.93911872 ..., -0.26802293  1.41068829
 -1.46613957]
```

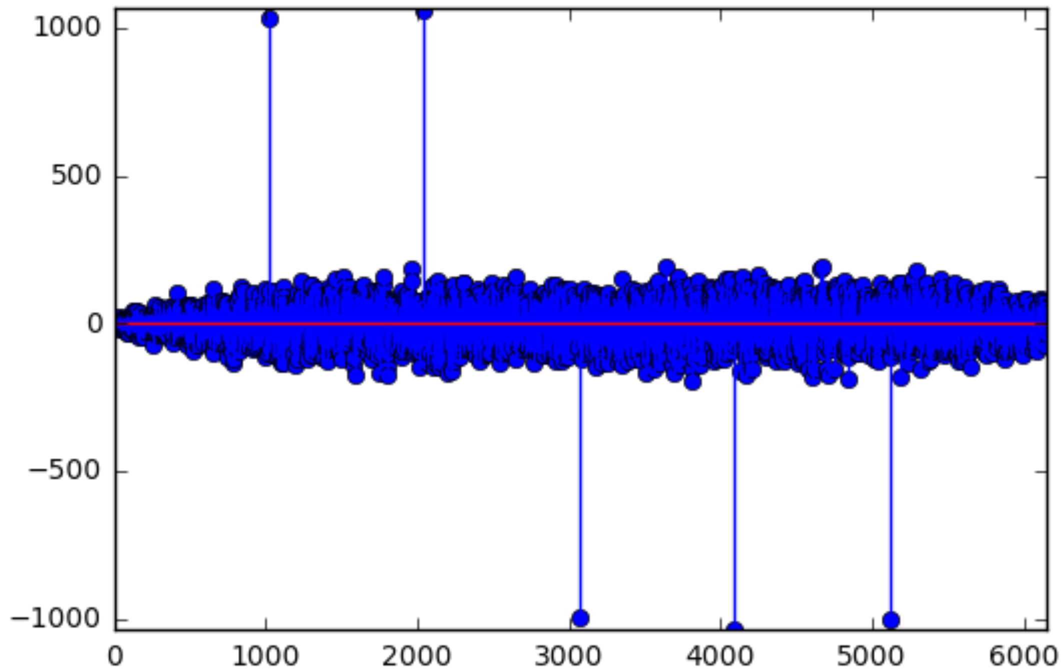


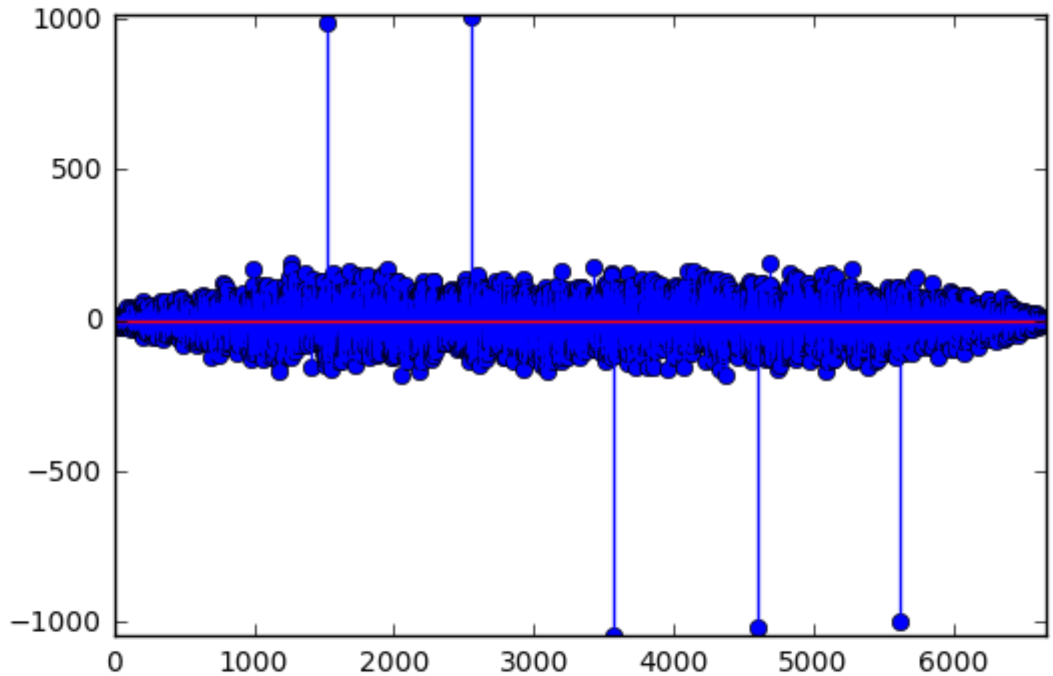

```
Satellite: 3
```

In [25]:

```python
## PART G CODE HERE
## USE DATA3.NPY AS THE SIGNAL ARRAY
satellites, signal = [], np.load("data3.npy")
print(signal)
for i in range(1, 25):
    offset, y = array_correlation(signal, Gold_code_satellite(i))
    if min(y) < -500 or max(y) > 500:
        satellites.append(i)
        plt.axis([0, len(x)+10, min(y)-1, max(y)+1])
        x = np.arange(len(y))
        plt.stem(x, y, "b-", "bo")
        plt.show()
print("Satellites:", satellites)


delays = []
for sat in satellites:
    rel_delay, y = array_correlation(signal, Gold_code_satellite(sat))
    for i in range(len(y)):
        if y[i] > 500 or y[i] < -500:
            delays.append(rel_delay[i])
print("Delays:", delays)
```

```
[-1.97847561  0.32305173  0.5788338  ..., -0.19858476 -1.50222466
 -0.68688047]
```






```
Satellites: [5, 20]
Delays: [1022, 2045, 3068, 4091, 5114, 1528, 2551, 3574, 4597, 5620]
```