In [119]:

```
%matplotlib inline

from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, recall_score, precision_score, f1_score
from scipy.signal import butter, lfilter, find_peaks_cwt, find_peaks, periodogram
from scipy.stats import kurtosis, skew
from sklearn.svm import SVC
from sklearn.ensemble import RandomForestClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import cross_val_score, KFold, cross_val_score, cross_valida
te
from sklearn.metrics import confusion_matrix
from sklearn.metrics import plot_confusion_matrix
from sklearn.metrics import classification_report
from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve
from sklearn.metrics import make_scorer
from sklearn.preprocessing import normalize
from sklearn.preprocessing import StandardScaler
from sklearn.tree import DecisionTreeClassifier

import pickle
import numpy as np
import matplotlib.pyplot as plt

import antropy as ent

import random
import os
```

In [2]:

```
SEED = 57
SAMPLING_FREQUENCY = 173.6
```

In [3]:

```
random.seed(SEED)
os.environ['PYTHONHASHSEED'] = str(SEED)
np.random.seed(SEED)
```

In [4]:

```
x = pickle.load(open('../data/x.pkl', 'rb'))
y = pickle.load(open('../data/y.pkl', 'rb'))
```

In [5]:

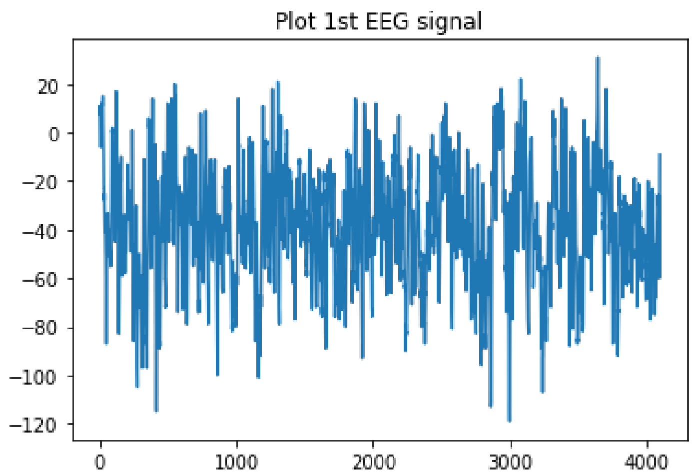
```
x_normal = np.concatenate((x[:300], x[400:]), axis=0)
x_seizure = x[300:400]

print(x_normal.shape)
print(x_seizure.shape)

b, a = butter(3, [0.5,40], btype='bandpass',fs=SAMPLING_FREQUENCY)

x_normal_filtered = np.array([lfilter(b,a,x_normal[index,:]) for index in range(x_normal
.shape[0])])
x_seizure_filtered = np.array([lfilter(b,a,x_seizure[index,:]) for index in range(x_seiz
ure.shape[0])])

print(x_normal.shape)
print(x_seizure.shape)

x = np.concatenate((x_normal, x_seizure))
y = np.concatenate((np.zeros((400, 1)), np.ones((100, 1))))
```

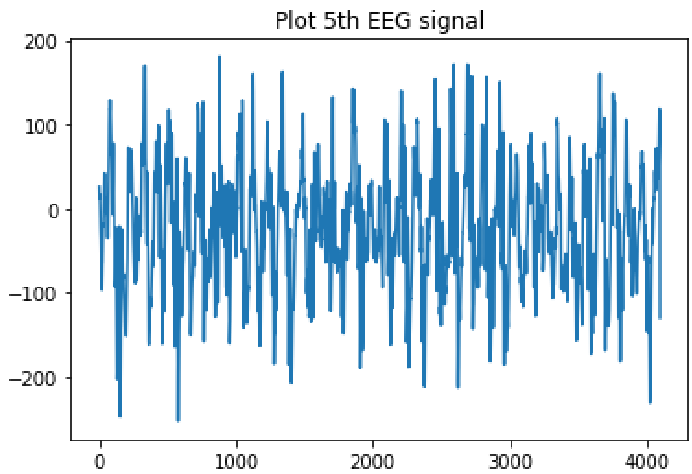
```
print(x.shape)
print(y.shape)
```

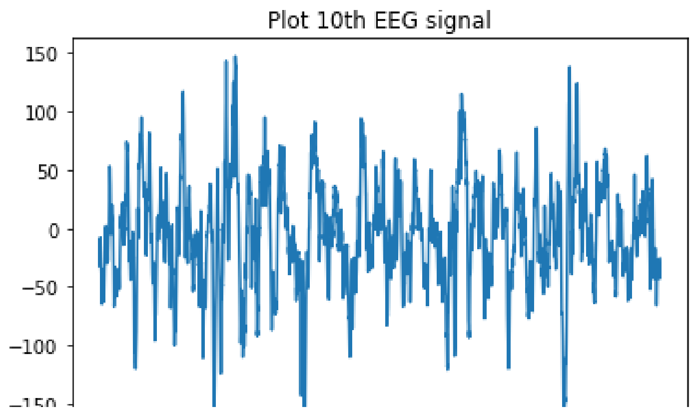
```
(400, 4097)
(100, 4097)
(400, 4097)
(100, 4097)
(500, 4097)
(500, 1)
```

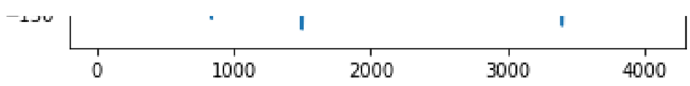
In [6]:

```
# plot some of the signals and their y values
plt.title('Plot 1st EEG signal')
plt.plot(x[0])
plt.show()

plt.title('Plot 5th EEG signal')
plt.plot(x[5])
plt.show()

plt.title('Plot 10th EEG signal')
plt.plot(x[10])
plt.show()
```









Statistical analysis

In order to visualize out data, we begin with the statistical analysis of our data, which we perform with the help of NumPy. Our statistical data are as follows:

- **Mean**
- **Median**
- **Max**
- **Min**
- **Std**
- **Var**
- **Sqrt**
- **Arg Min**
- **Arg Max**

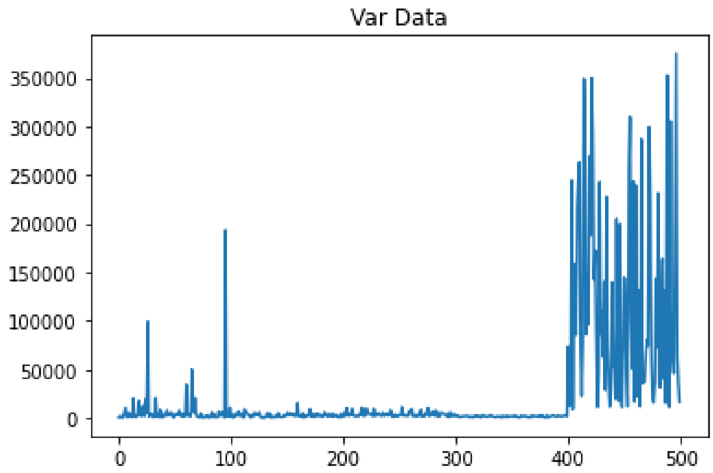
In [7]:

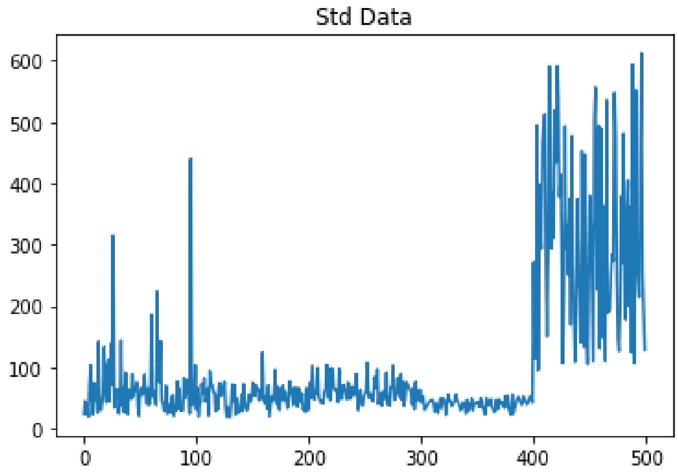
```
def mean(data):
    return np.mean(data, axis=1)

def median(data):
    return np.median(data, axis=1)

def std(data):
    return np.std(data, axis=1)

def var(data):
    return np.var(data, axis=1)

def minimum(data):
    return np.min(data, axis=1)

def maximum(data):
    return np.max(data, axis=1)

def arg_min(data):
    return np.argmin(data, axis=1)

def arg_max(data):
    return np.argmax(data, axis= 1)

def sqrt(data):
    return np.sqrt(np.mean(data**2, axis=-1))

var = var(x)
std = std(x)
mean = mean(x)
median = median(x)
maximum = maximum(x)
minimum = minimum(x)
arg_min = arg_min(x)
arg_max = arg_max(x)
sqrt = sqrt(x)
```

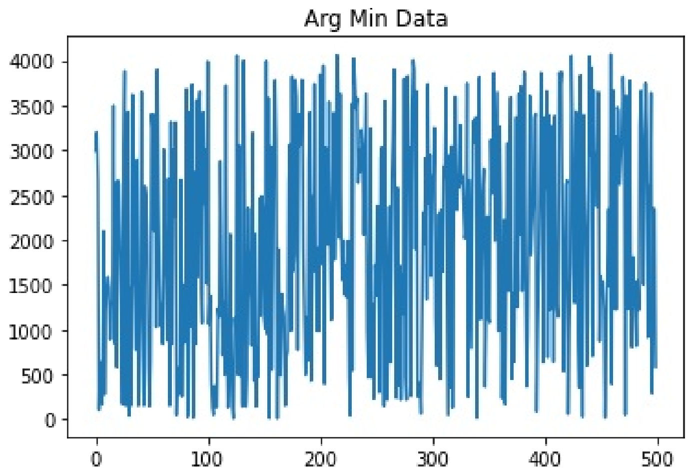
In [8]:

```
plt.title("Var Data")
plt.plot(var)
plt.show()

plt.title("Std Data")
plt.plot(std)
plt.show()
```

```
plt.title("Arg Min Data")
plt.plot(arg_min)
plt.show()
```







Let's build our new x based on statistical features calculated before.

In [9]:

```
var = var.reshape(-1, 1)
std = std.reshape(-1, 1)
maximum = maximum.reshape(-1, 1)
minimum = minimum.reshape(-1, 1)
mean = mean.reshape(-1, 1)
median = median.reshape(-1, 1)
sqrt = sqrt.reshape(-1, 1)
arg_min = arg_min.reshape(-1, 1)
arg_max = arg_max.reshape(-1, 1)

new_x = np.concatenate((var, std, maximum, minimum, mean, median, sqrt, arg_max, arg_min
), axis=1)
new_x.shape
```

Out[9]:

```
(500, 9)
```

In [10]:

```
x_train, x_test, y_train ,y_test = train_test_split(new_x, y, random_state=SEED, test_si
ze=0.2)

print(x_train.shape)
print(x_test.shape)
print(y_train.shape)
print(y_test.shape)
```

```
(400, 9)
(100, 9)
(400, 1)
(100, 1)
```

In [11]:

```
clf = SVC(kernel='linear', max_iter=30000000)
clf.fit(x_train, y_train)

y_prediction = clf.predict(x_test)

print(accuracy_score(y_test, y_prediction))
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

```
0.93
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\svm\_base
.py:301: ConvergenceWarning: Solver terminated early (max_iter=30000000).  Consider pre-p
rocessing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
```

Entropy analysis

Entropy is proportional to the degree of disorder in a thermodynamic process. The higher the degree of disorder, the higher the entropy. We continue with the entropy analysis of our data, which we perform with the help of [AntroPy](). Our entropic data are as follows:

- **Permutation**
- **Specular**
- **Single Value Decomposition**
- **Approximate**
- **Sample**
- **Lempel Ziv**

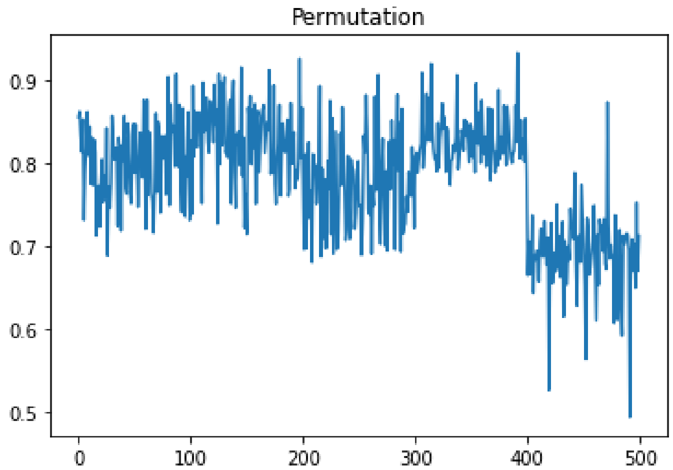
In [12]:

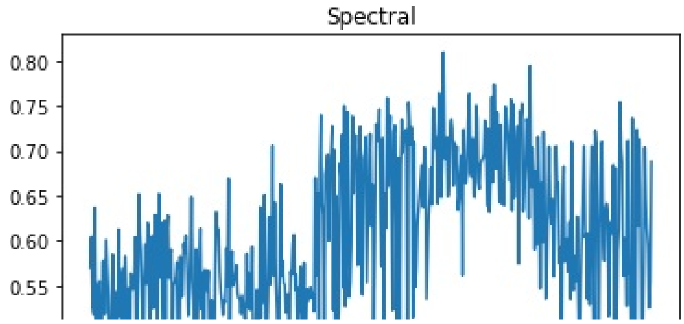
```
# Permutation entropy
def permutation(data):
    return ent.perm_entropy(data, normalize=True)

# Spectral entropy
def spectral(data):
    return ent.spectral_entropy(data, sf=100, method='welch', normalize=True)

# Singular value decomposition entropy
def singular_value_decomposition(data):
    return ent.svd_entropy(data, normalize=True)

# Approximate entropy
```

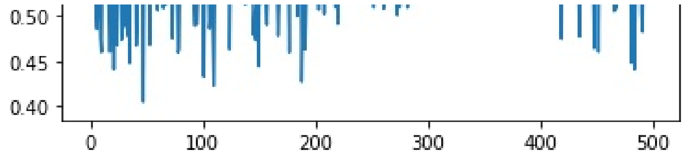
```
def approximate(data):
    return ent.app_entropy(data)

# Sample entropy
def sample(data):
    return ent.sample_entropy(data)

# Lempel-Ziv complexity
def lempel_ziv(data):
    return ent.lziv_complexity('01111000011001', normalize=True)

permutation = np.array([permutation(x[i, :]) for i in range(x.shape[0])])
spectral = np.array([spectral(x[i, :]) for i in range(x.shape[0])])
singular_value_decomposition = np.array([singular_value_decomposition(x[i, :]) for i in
range(x.shape[0])])
approximate = np.array([approximate(x[i, :]) for i in range(x.shape[0])])
lempel_ziv = np.array([lempel_ziv(x[i, :]) for i in range(x.shape[0])])
sample = np.array([sample(x[i, :]) for i in range(x.shape[0])])
```

In [13]:

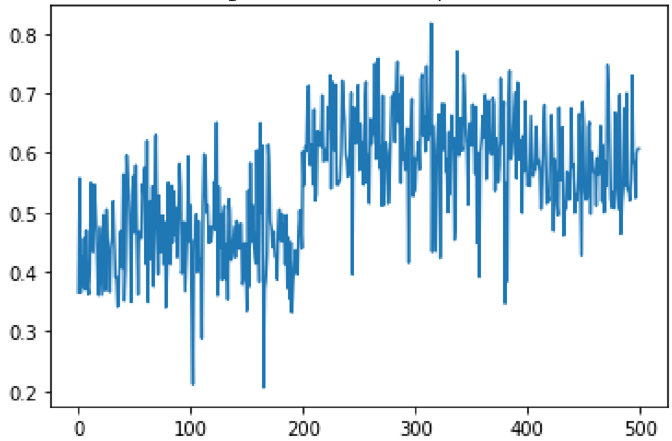
```
plt.title('Permutation')
plt.plot(permutation)
plt.show()

plt.title('Spectral')
plt.plot(spectral)
plt.show()

plt.title('Singular Value Decomposition')
plt.plot(singular_value_decomposition)
plt.show()

plt.title('Approximate')
plt.plot(approximate)
plt.show()

plt.title('Lempel Ziv')
plt.plot(lempel_ziv)
plt.show()

plt.title('Sample')
plt.plot(sample)
plt.show()
```



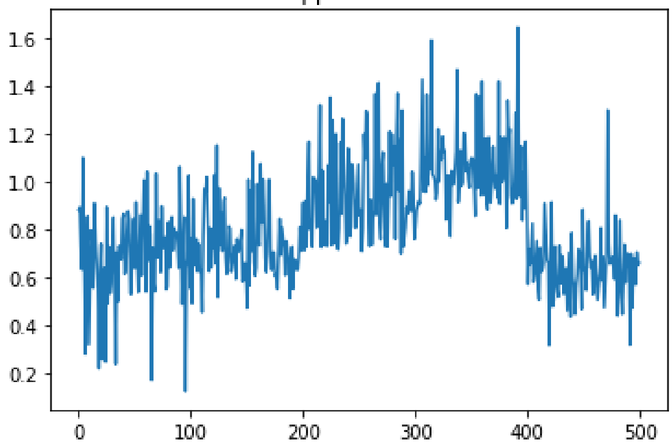




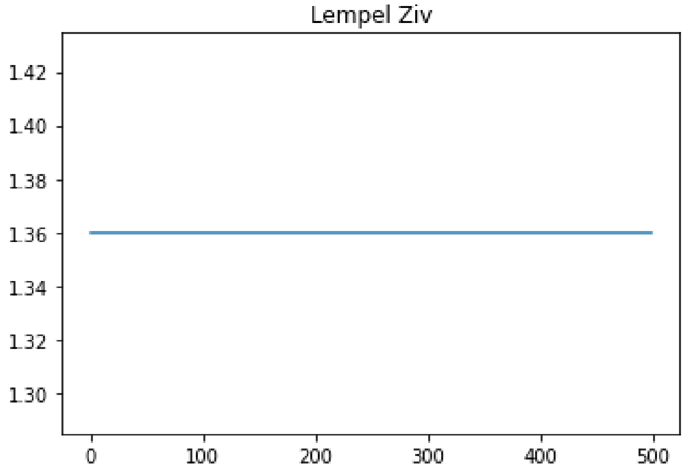
Singular Value Decomposition



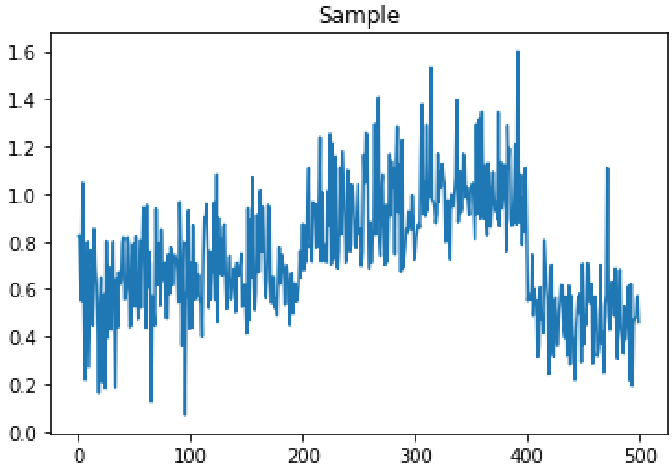
Approximate



Lempel Ziv



Sample



Let's build our new x based on fast fourier transform features calculated before.

In [14]:

```
permutation = permutation.reshape(-1, 1)
spectral = spectral.reshape(-1, 1)
approximate = approximate.reshape(-1, 1)
singular_value_decomposition = singular_value_decomposition.reshape(-1, 1)
lempel_ziv = lempel_ziv.reshape(-1, 1)
sample = sample.reshape(-1, 1)

new_x = np.concatenate((permutation, spectral, approximate, singular_value_decomposition
, lempel_ziv, sample), axis=1)
new_x.shape
```

Out[14]:

```
(500, 6)
```

In [15]:

```
x_train, x_test, y_train ,y_test = train_test_split(new_x, y, random_state=SEED, test_si
ze=0.2)

print(x_train.shape)
print(x_test.shape)
print(y_train.shape)
print(y_test.shape)
```

```
(400, 6)
(100, 6)
(400, 1)
(100, 1)
```

In [16]:

```
clf = SVC(kernel='linear', max_iter=20000000)
clf.fit(x_train, y_train)

y_prediction = clf.predict(x_test)

print(accuracy_score(y_test, y_prediction))
```

```
0.91
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

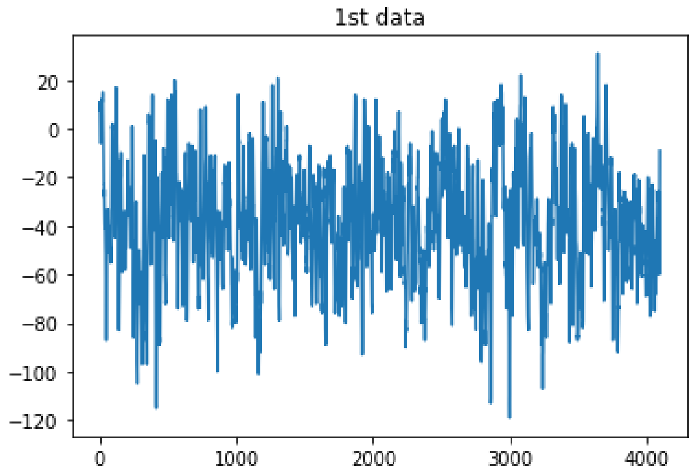
What is FFT?

A fast Fourier transform is an algorithm that computes the discrete Fourier transform of a sequence, or its inverse. Fourier analysis converts a signal from its original domain to a representation in the frequency domain and vice versa.

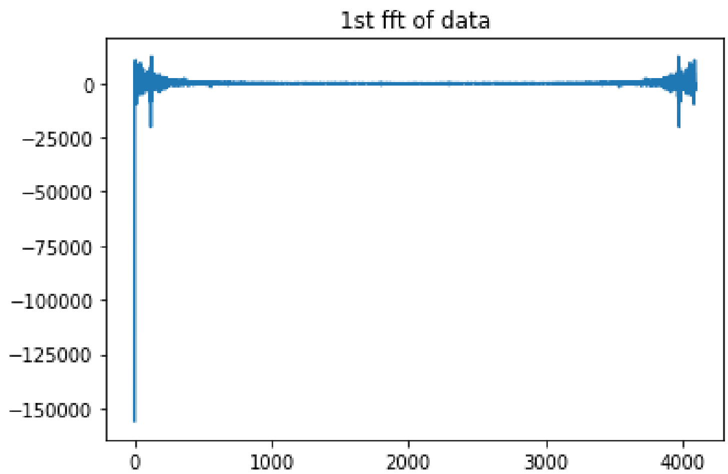
In [17]:

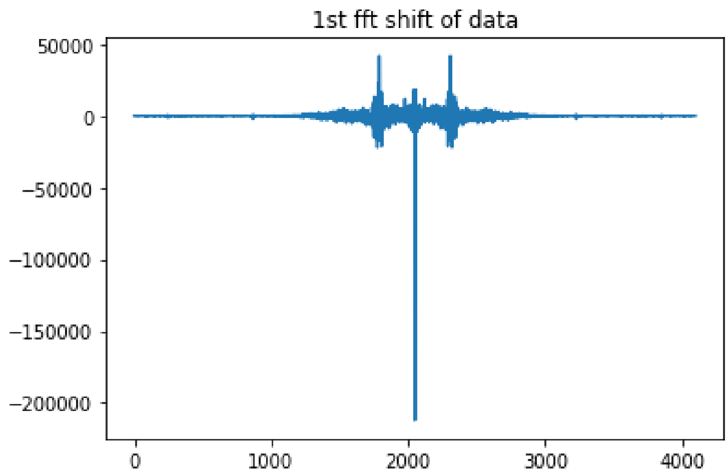
```
fft = np.fft.fft(x)
fft_shift = np.fft.fftshift(fft)

plt.title('1st data')
plt.plot(x[0])
plt.show()

plt.title('1st fft of data')
plt.plot(fft[0])
plt.show()
```

```
plt.title('1st fft shift of data')
plt.plot(fft_shift[0])
plt.show()
```




```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\matplotlib\cbook\
__init__.py:1298: ComplexWarning: Casting complex values to real discards the imaginary p
art
  return np.asarray(x, float)
```

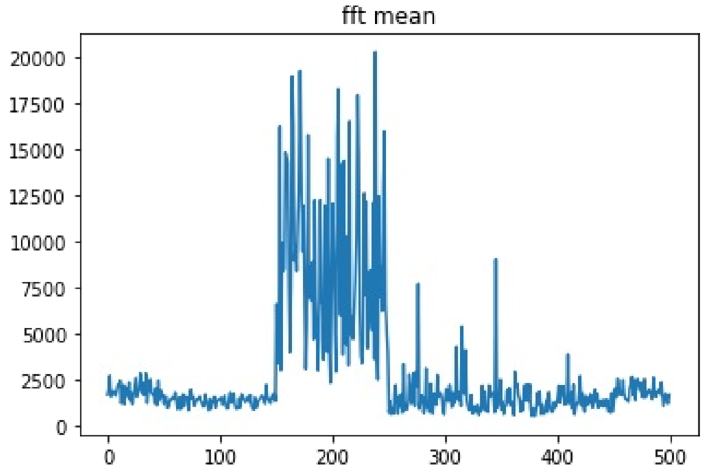


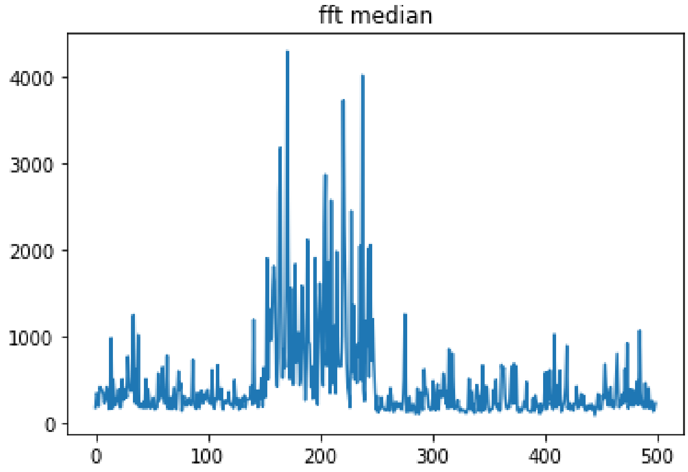


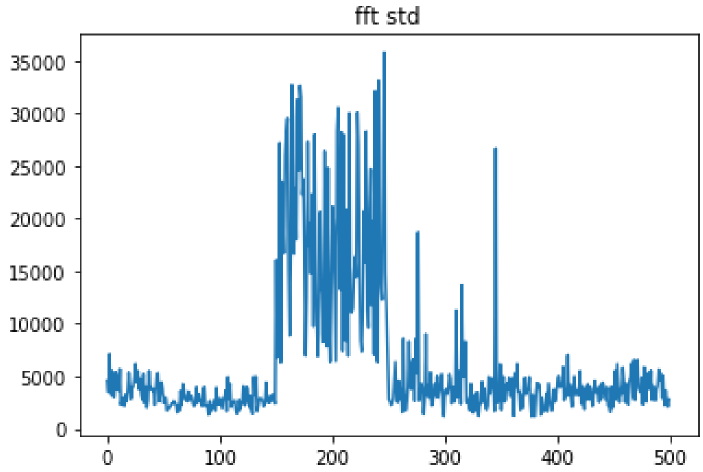
In [18]:

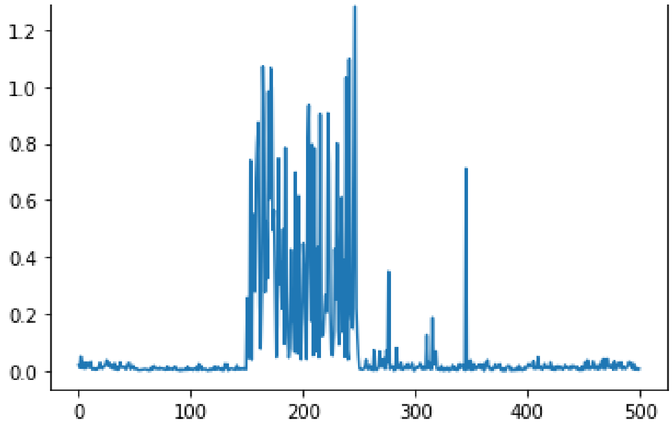
```
fft_abs = np.abs(fft_shift)
fft_mean = np.mean(fft_abs, axis=1)
fft_var = np.var(fft_abs, axis=1)
fft_median = np.median(fft_abs, axis=1)
fft_std = np.std(fft_abs, axis=1)
fft_max = np.max(fft_abs, axis=1)
fft_min = np.min(fft_abs, axis=1)

plt.title('fft mean')
plt.plot(fft_mean)
plt.show()
```

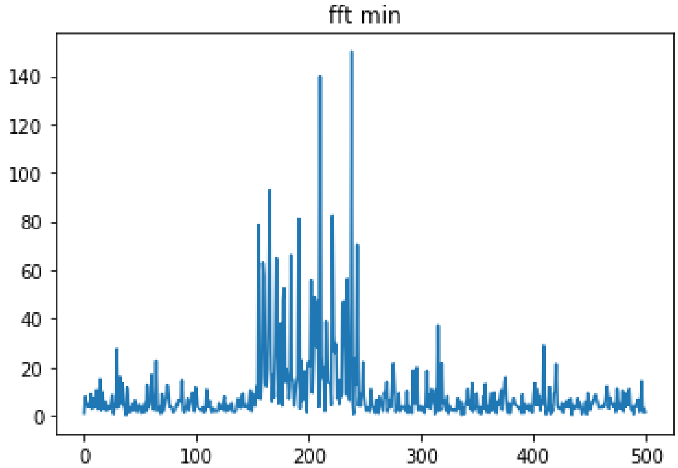
```
plt.title('fft median')
plt.plot(fft_median)
plt.show()

plt.title('fft std')
plt.plot(fft_std)
plt.show()

plt.title('fft var')
plt.plot(fft_var)
plt.show()

plt.title('fft min')
plt.plot(fft_min)
plt.show()

plt.title('fft max')
plt.plot(fft_max)
plt.show()
```

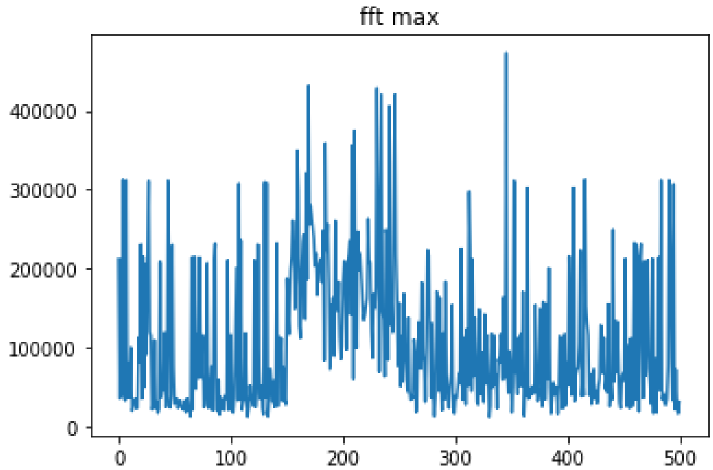












Let's build our new x based on fast fourier transform features calculated before.

In [19]:

```
fft_mean = fft_mean.reshape(-1, 1)
fft_median = fft_median.reshape(-1, 1)
fft_var = fft_var.reshape(-1, 1)
fft_std = fft_std.reshape(-1, 1)
fft_max = fft_max.reshape(-1, 1)
fft_min = fft_min.reshape(-1, 1)

new_x = np.concatenate((fft_mean, fft_median, fft_std, fft_var, fft_max, fft_min), axis=
1)
print(new_x.shape)
```

```
(500, 6)
```

In [20]:

```
x_train, x_test, y_train ,y_test = train_test_split(new_x, y, random_state=SEED, test_si
ze=0.2)

print(x_train.shape)
```

```
print(x_test.shape)
print(y_train.shape)
print(y_test.shape)
```

```
(400, 6)
(100, 6)
(400, 1)
(100, 1)
```

In [21]:

```
clf = SVC(kernel='linear', max_iter=20000000)
clf.fit(x_train, y_train)

y_prediction = clf.predict(x_test)

print(accuracy_score(y_test, y_prediction))
```

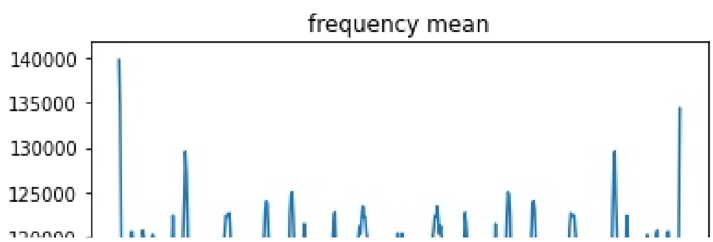
```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

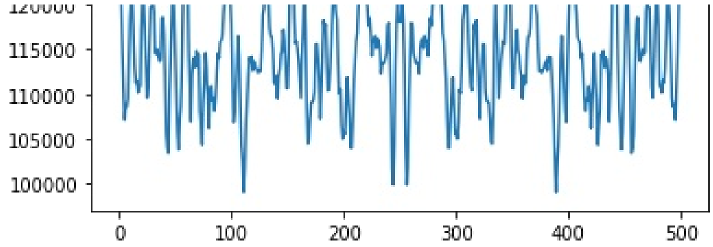
```
0.74
```

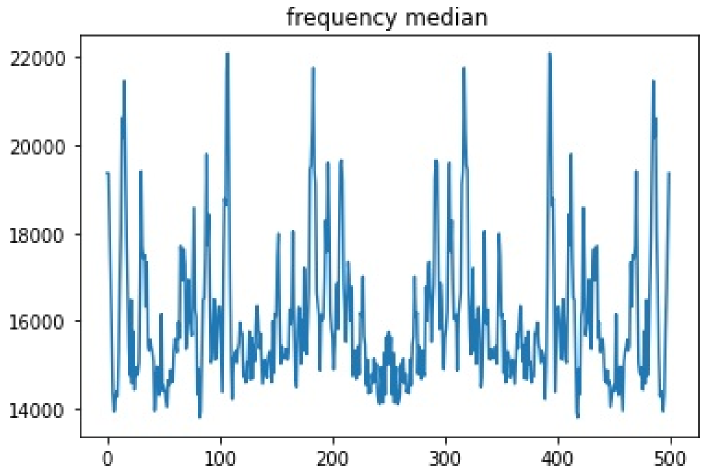
```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\svm\_base
.py:301: ConvergenceWarning: Solver terminated early (max_iter=20000000).  Consider pre-p
rocessing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
```

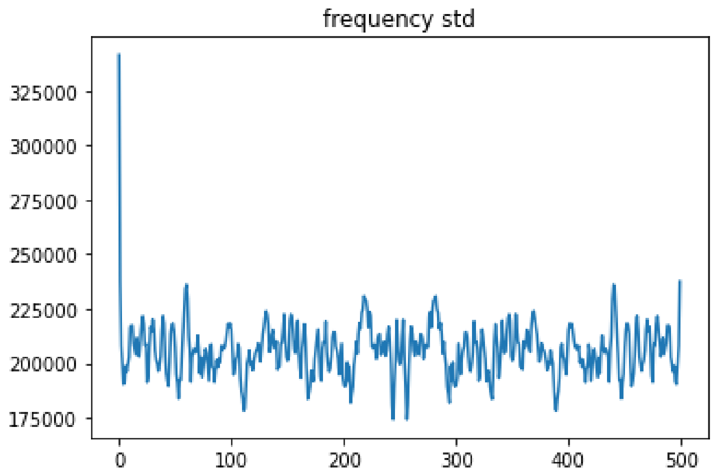
In [22]:

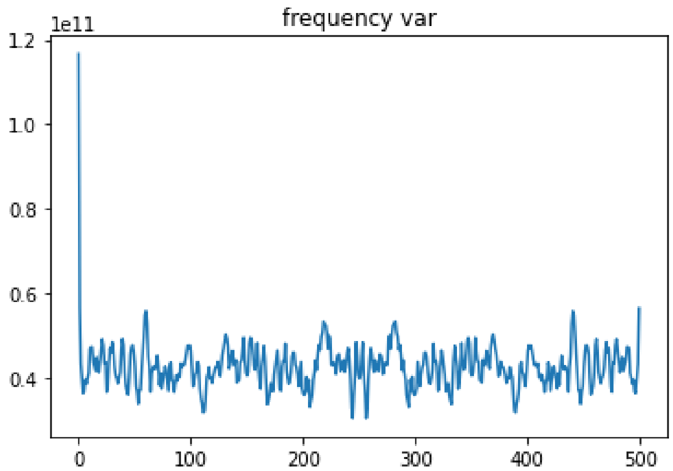
```
frequency = np.fft.fft2(x)
frequency_abs = np.abs(frequency)
frequency_mean = np.mean(frequency_abs, axis=1)
frequency_median = np.median(frequency_abs, axis=1)
frequency_var = np.var(frequency_abs, axis=1)
frequency_std = np.std(frequency_abs, axis=1)
frequency_min = np.min(frequency_abs, axis=1)
frequency_max = np.max(frequency_abs, axis=1)

plt.title('frequency mean')
plt.plot(frequency_mean)
plt.show()

plt.title('frequency median')
plt.plot(frequency_median)
plt.show()

plt.title('frequency std')
plt.plot(frequency_std)
plt.show()

plt.title('frequency var')
plt.plot(frequency_var)
plt.show()

plt.title('frequency min')
plt.plot(frequency_min)
plt.show()

plt.title('frequency max')
plt.plot(frequency_max)
plt.show()
```

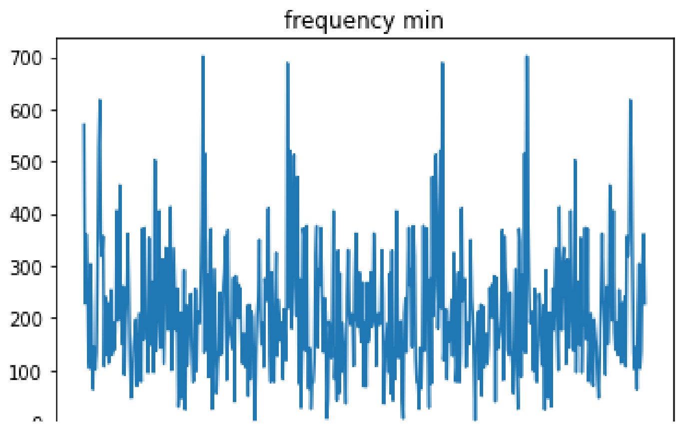


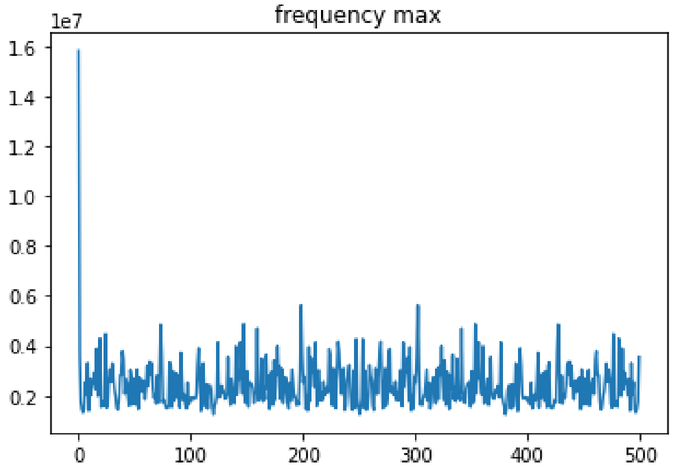



frequency median


frequency std


frequency var
1e11


frequency min



Let's build our new x based on fast fourier transform features calculated before.

In [23]:

```
frequency_mean = frequency_mean.reshape(-1, 1)
frequency_median = frequency_median.reshape(-1, 1)
frequency_var = frequency_var.reshape(-1, 1)
frequency_std = frequency_std.reshape(-1, 1)
frequency_max = frequency_max.reshape(-1, 1)
frequency_min = frequency_min.reshape(-1, 1)

new_x = np.concatenate((frequency_mean, frequency_median, frequency_std, frequency_var,
frequency_max, frequency_min), axis=1)
print(new_x.shape)
```

```
(500, 6)
```

In [24]:

```
x_train, x_test, y_train ,y_test = train_test_split(new_x, y, random_state=SEED, test_si
ze=0.2)

print(x_train.shape)
print(x_test.shape)
print(y_train.shape)
print(y_test.shape)
```

```
(400, 6)
(100, 6)
(400, 1)
(100, 1)
```

In [25]:

```
clf = SVC(kernel='linear', max_iter=30000000)
clf.fit(x_train, y_train)

y_prediction = clf.predict(x_test)

print(accuracy_score(y_test, y_prediction))
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

```
0.26
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\svm\_base
.py:301: ConvergenceWarning: Solver terminated early (max_iter=30000000).  Consider pre-p
rocessing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
```

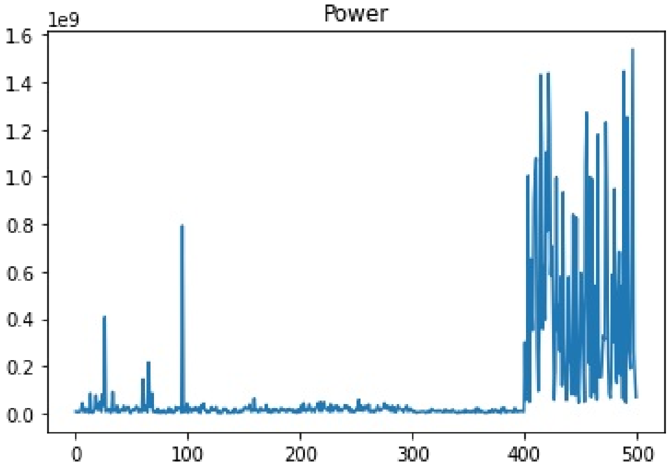
In [26]:

```
#calculate the energy of each signal
energy = np.sum(x**2, axis=1)
print(energy.shape)
```

```
(500,)
```

In [27]:

```
plt.title('Power')
plt.plot(energy)
plt.show()

energy = energy.reshape(-1, 1)
```



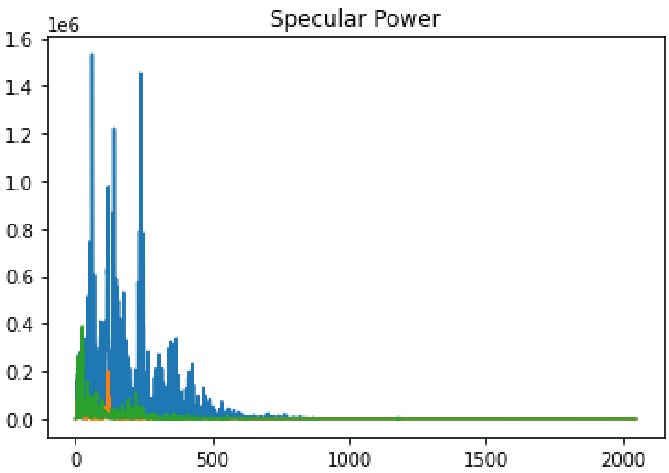
In [28]:

```
# calculate power spectral density for each signal
power_specular = np.array([periodogram(x[ind, :])[1] for ind in range(x.shape[0])])
print(power_specular.shape)
```

```
(500, 2049)
```

In [29]:

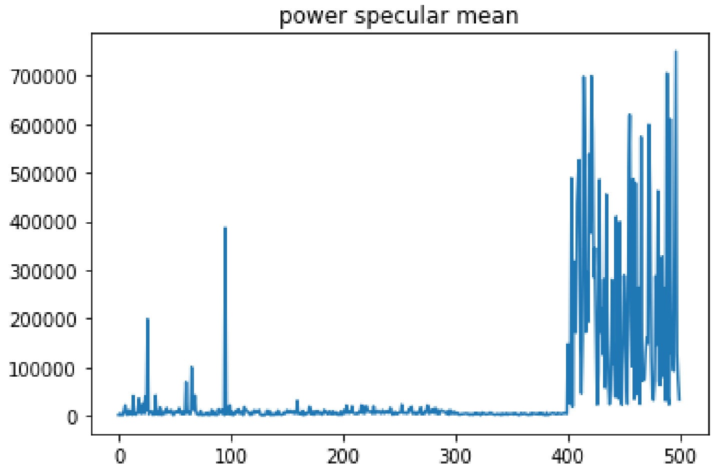
```
plt.title('Specular Power')
plt.plot(power_specular[-1])
plt.plot(power_specular[0])
plt.plot(power_specular[1])
plt.show()
```

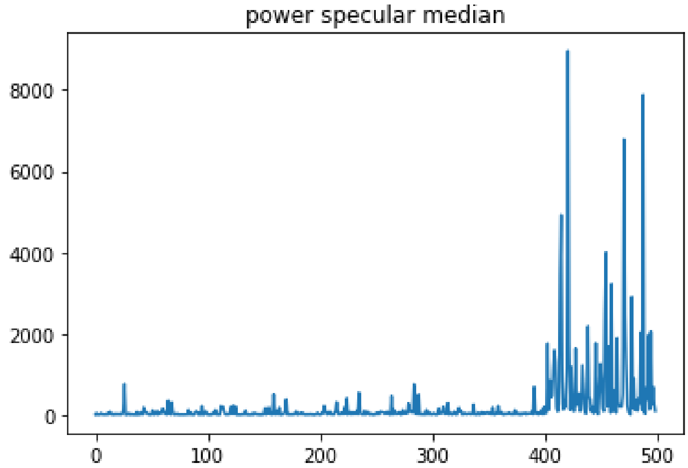


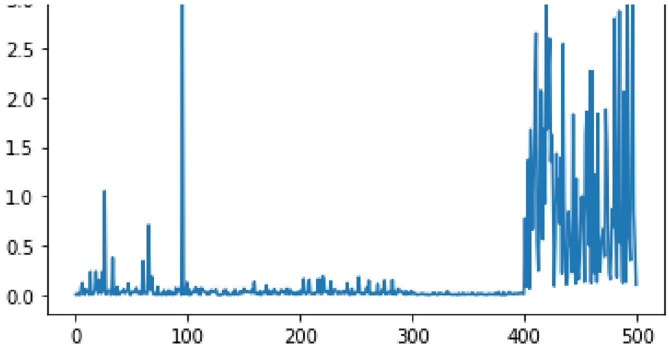
In [30]:

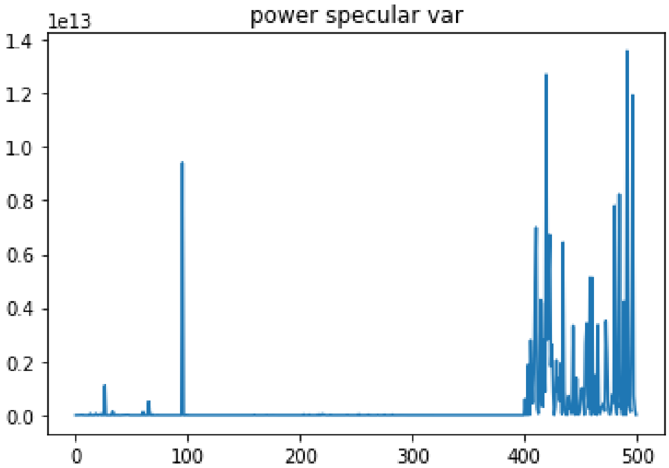
```
power_specular_mean = np.mean(power_specular, axis=1)
power_specular_median = np.median(power_specular, axis=1)
power_specular_std = np.std(power_specular, axis=1)
```

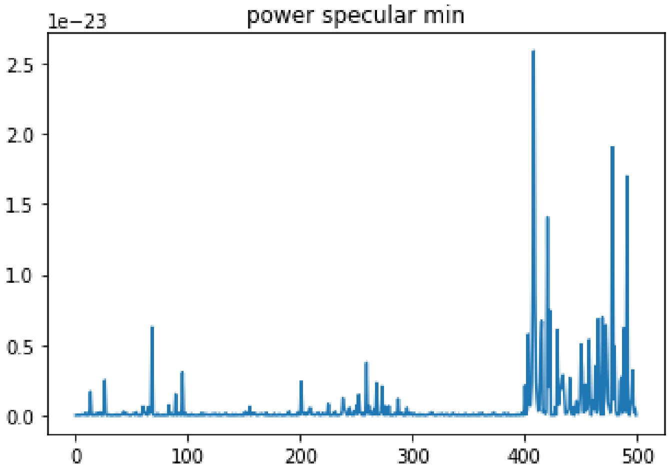
```
power_specular_var = np.var(power_specular, axis=1)
power_specular_min = np.min(power_specular, axis=1)
power_specular_max = np.max(power_specular, axis=1)

plt.title('power specular mean')
plt.plot(power_specular_mean)
plt.show()

plt.title('power specular median')
plt.plot(power_specular_median)
plt.show()

plt.title('power specular std')
plt.plot(power_specular_std)
plt.show()

plt.title('power specular var')
plt.plot(power_specular_var)
plt.show()

plt.title('power specular min')
plt.plot(power_specular_min)
plt.show()

plt.title('power specular max')
plt.plot(power_specular_max)
plt.show()

power_specular_mean = power_specular_mean.reshape(-1, 1)
power_specular_median = power_specular_median.reshape(-1, 1)
power_specular_std = power_specular_std.reshape(-1, 1)
power_specular_var = power_specular_var.reshape(-1, 1)
power_specular_min = power_specular_min.reshape(-1, 1)
power_specular_max = power_specular_max.reshape(-1, 1)
```

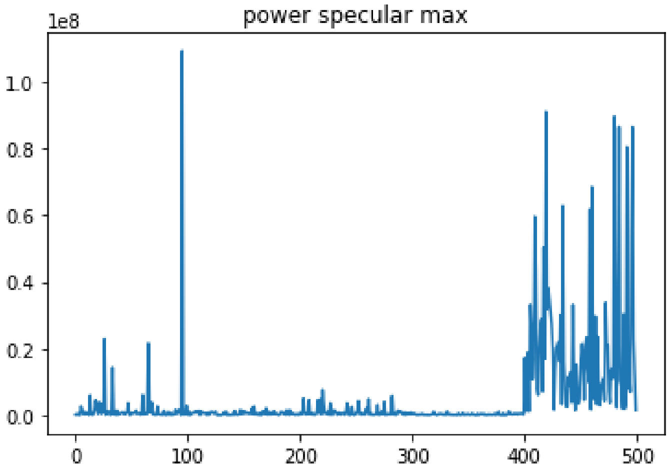






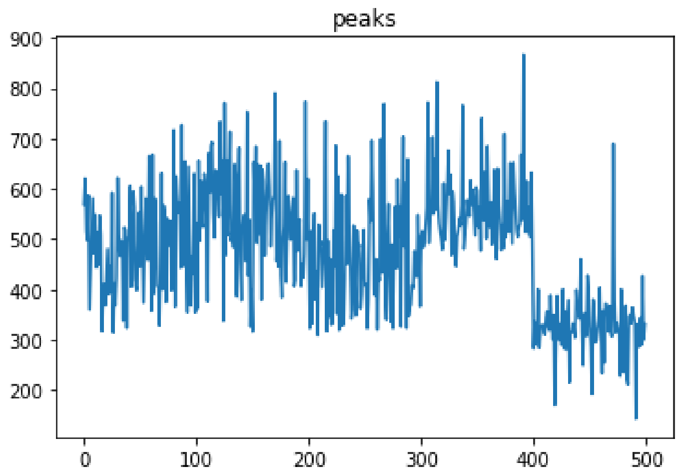






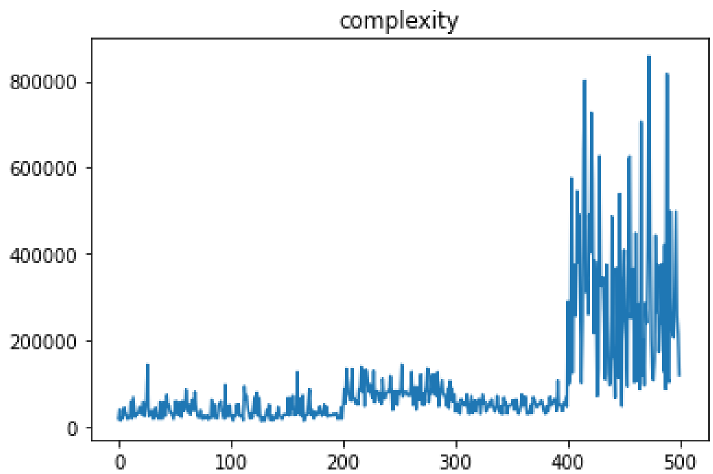
In [31]:

```
#detect peaks
peaks = np.array([find_peaks(x[i, :])[0].shape[0] for i in range(x.shape[0])])

plt.title('peaks')
plt.plot(peaks)
plt.show()

peaks = peaks.reshape(-1, 1)
```



In [32]:

```
#calculate complexity
complexity = np.array([np.sum(np.abs(np.diff(x[i, :]))) for i in range(x.shape[0])])

plt.title('complexity')
plt.plot(complexity)
plt.show()

complexity = complexity.reshape(-1, 1)
```



In [33]:

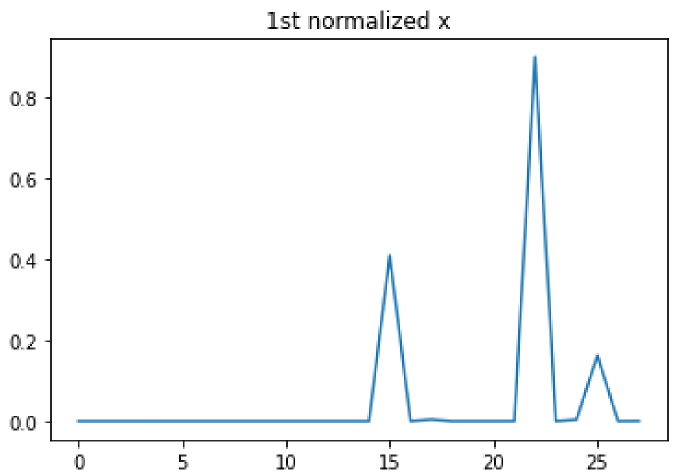
```
new_x = np.concatenate((var,
                        mean,
                        maximum,
                        minimum,
                        median,
                        std,
                        var,
                        permutation,
                        spectral,
                        singular_value_decomposition,
                        approximate,
                        sample,
                        lempel_ziv,
                        fft_mean,
                        fft_median,
                        fft_var,
                        fft_std,
                        fft_max,
                        fft_min,
                        power_specular_mean,
                        power_specular_median,
                        power_specular_std,
                        power_specular_var,
                        power_specular_min,
```

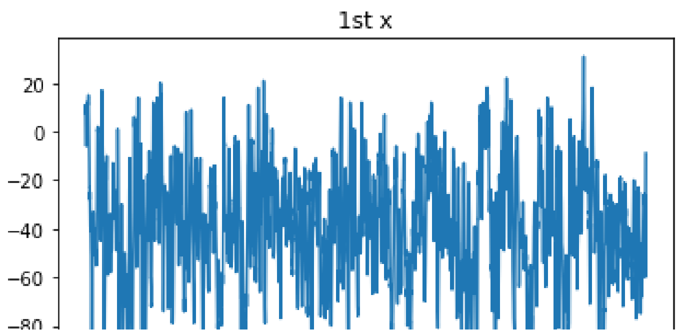
```
                        power_specular_max,
                        energy,
                        peaks,
                        complexity), axis=1)

x_train, x_test, y_train, y_test = train_test_split(new_x, y, random_state=SEED, test_si
ze=0.2)
print(new_x.shape)
print(new_x)
```

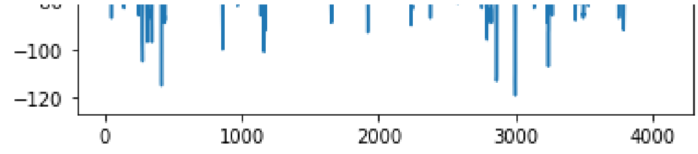
```
(500, 28)
[[ 5.85240101e+02 -3.80785941e+01  3.10000000e+01 ...  8.33829400e+06
   5.69000000e+02  1.86870000e+04]
 [ 2.04747837e+03 -1.23775934e+01  1.92000000e+02 ...  9.01619900e+06
   6.21000000e+02  4.03000000e+04]
 [ 5.58204044e+02  2.78664877e+01  9.20000000e+01 ...  5.46845100e+06
   5.15000000e+02  1.48300000e+04]
 ...
 [ 6.41967333e+04 -5.22089334e-01  6.83000000e+02 ...  2.63015133e+08
   4.27000000e+02  2.57480000e+05]
 [ 3.73167473e+04 -1.50078106e+01  5.55000000e+02 ...  1.53809499e+08
   3.00000000e+02  2.16483000e+05]
 [ 1.64935065e+04 -1.86465707e+01  3.99000000e+02 ...  6.89984010e+07
   3.31000000e+02  1.19561000e+05]]
```

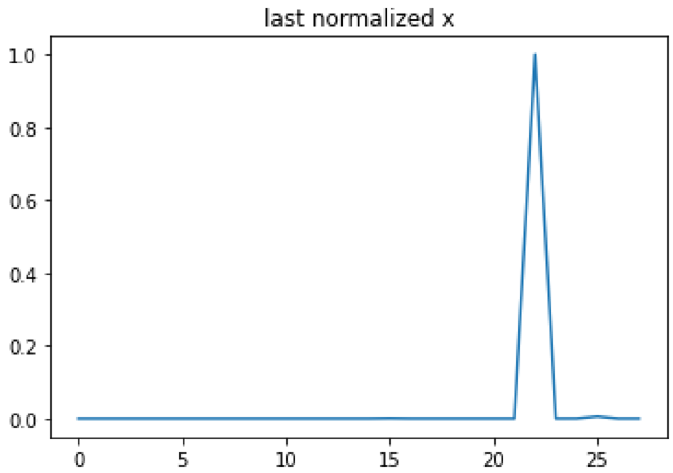
In [34]:

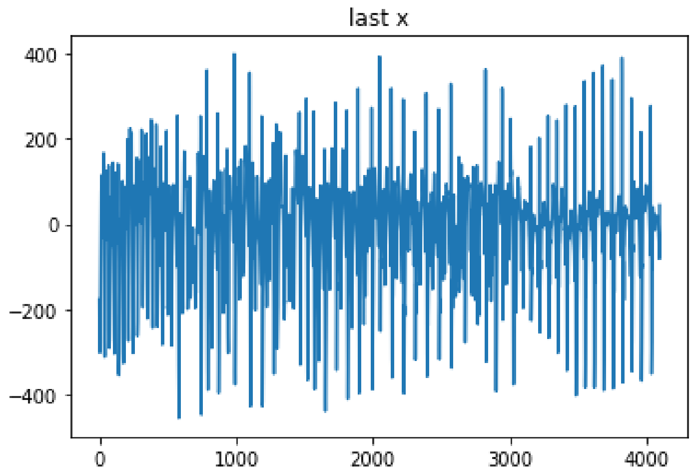
```
normalized_x = normalize(new_x)

plt.title('1st normalized x')
plt.plot(normalized_x[0])
plt.show()

plt.title('1st x')
plt.plot(x[0])
plt.show()

plt.title('last normalized x')
plt.plot(normalized_x[-1])
plt.show()

plt.title('last x')
plt.plot(x[-1])
plt.show()
```











RANDOM FOREST CLASSIFIER

- **n_estimators: The number of trees in the forest.**
- **max_depth: The maximum depth of the tree. If None, then nodes are expanded until all leaves are pure or until all leaves contain less than min_samples_split samples.**
- **min_samples_split: The minimum number of samples required to split an internal node: If int, then consider min_samples_split as the minimum number. If float, then min_samples_split is a fraction and ceil(min_samples_split * n_samples) are the minimum number of samples for each split.**
- **random_state: Controls both the randomness of the bootstrapping of the samples used when building trees (if bootstrap=True) and the sampling of the features to consider when looking for the best split at each node (if max_features < n_features). See Glossary for details.**

In [35]:

```
clf = RandomForestClassifier(n_estimators=100, max_depth=2, random_state=0)
clf.fit(x_train, y_train)
y_prediction = clf.predict(x_test)

print(accuracy_score(y_test, y_prediction))
print(recall_score(y_test, y_prediction))
print(precision_score(y_test, y_prediction))
```

```
C:\Users\SQ-PC\AppData\Local\Temp\ipykernel_16060\1168402667.py:2: DataConversionWarning:
A column-vector y was passed when a 1d array was expected. Please change the shape of y t
o (n_samples,), for example using ravel().
  clf.fit(x_train, y_train)
```

```
0.98
0.9230769230769231
1.0
```

1.0

In [36]:

```
scoring = {
    'accuracy': make_scorer(accuracy_score),
    'recall': make_scorer(recall_score),
    'precision': make_scorer(precision_score),
    'f1': make_scorer(f1_score),
}

cv = KFold(n_splits=5, random_state=SEED, shuffle=True)
cross_validate = cross_validate(estimator=clf, X=new_x, y=y, cv=cv)
cross_validate
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
```

Out[36]:

```
{'fit_time': array([0.33897591, 0.30395746, 0.38918424, 0.45299053, 0.37788701]),
 'score_time': array([0.0239563 , 0.03697276, 0.03643537, 0.02108312, 0.02253556]),
 'test_score': array([0.98, 0.95, 1.  , 0.98, 0.97])}
```

In [37]:

```
scores = cross_val_score(clf, new_x, y, cv=5)
print("k-fold cross validation accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std(
) * 2))
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
```

```
k-fold cross validation accuracy: 0.97 (+/- 0.07)
```

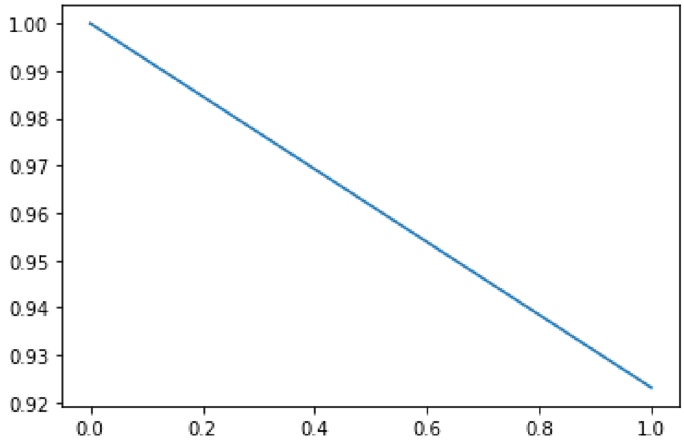
```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\model_sel
ection\_validation.py:686: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example using ravel
().
  estimator.fit(X_train, y_train, **fit_params)
```

In [38]:

```
#recall plot
plt.plot(recall_score(y_test, y_prediction, average=None))
```

Out[38]:

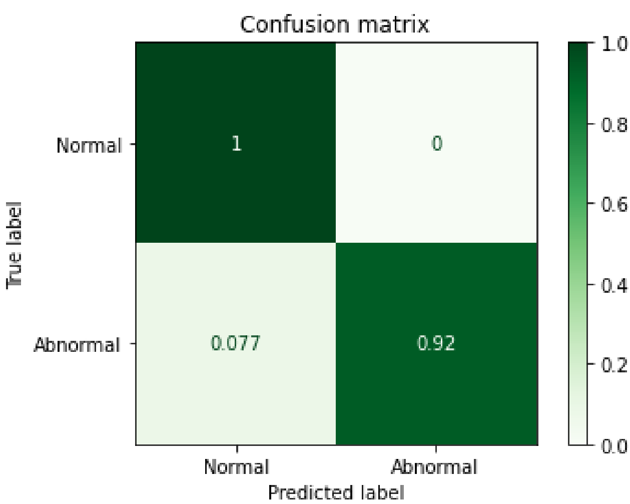
```
[<matplotlib.lines.Line2D at 0x1c01ff7ccd0>]
```



In [39]:

```
#confusion matrix plot
display = plot_confusion_matrix(clf, x_test, y_test, display_labels=['Normal', 'Abnormal
'], cmap=plt.cm.Greens, normalize='true')
display.ax_.set_title('Confusion matrix')

plt.show()

print(confusion_matrix(y_test, y_prediction))
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\dep
recation.py:87: FutureWarning: Function plot_confusion_matrix is deprecated; Function `pl
ot_confusion_matrix` is deprecated in 1.0 and will be removed in 1.2. Use one of the clas
s methods: ConfusionMatrixDisplay.from_predictions or ConfusionMatrixDisplay.from_estimat
or.
  warnings.warn(msg, category=FutureWarning)
```




```
[[74  0]
 [ 2 24]]
```

K Nearest Neighbors Classifier

n_neighbors: n_neighbors is the number of neighbors that we are going to use to classify our data which here is 2

- **weights: weights is the weight function used in prediction. possible values are:**
- **uniform: uniform weights. all points in each neighborhood are weighted equally.**
- **distance : weight points by the inverse of their distance. in this case, closer neighbors of a query point will have a greater influence than neighbors which are further away.**

In [40]:

```
clf = KNeighborsClassifier(n_neighbors=2,
                               weights='distance',
                               algorithm='auto',
                               leaf_size=30,
                               p=2,
                               metric='minkowski',
                               metric_params=None,
                               n_jobs=None)
clf.fit(x_train, y_train)
y_prediction = clf.predict(x_test)

print(accuracy_score(y_test, y_prediction))
print(recall_score(y_test, y_prediction))
print(precision_score(y_test, y_prediction))
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\neighbors
\_classification.py:200: DataConversionWarning: A column-vector y was passed when a 1d ar
ray was expected. Please change the shape of y to (n_samples,), for example using ravel()
.
  return self._fit(X, y)
```

```
0.93
0.7307692307692307
1.0
```

In [41]:

```
# scoring = {
#     'accuracy': make_scorer(accuracy_score),
#     'recall': make_scorer(recall_score),
#     'precision': make_scorer(precision_score),
#     'f1': make_scorer(f1_score),
# }

# cv = KFold(n_splits=5, random_state=SEED, shuffle=True)
# cross_validate = cross_validate(estimator=clf, X=new_x, y=y, cv=cv)
# cross_validate
```

In [42]:

```
scores = cross_val_score(clf, new_x, y, cv=5)
print("k-fold cross validation accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std(
) * 2))
```

```
k-fold cross validation accuracy: 0.93 (+/- 0.08)
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\neighbors
\_classification.py:200: DataConversionWarning: A column-vector y was passed when a 1d ar
ray was expected. Please change the shape of y to (n_samples,), for example using ravel()
.
  return self._fit(X, y)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\neighbors
\_classification.py:200: DataConversionWarning: A column-vector y was passed when a 1d ar
ray was expected. Please change the shape of y to (n_samples,), for example using ravel()
.
  return self._fit(X, y)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\neighbors
\_classification.py:200: DataConversionWarning: A column-vector y was passed when a 1d ar
```

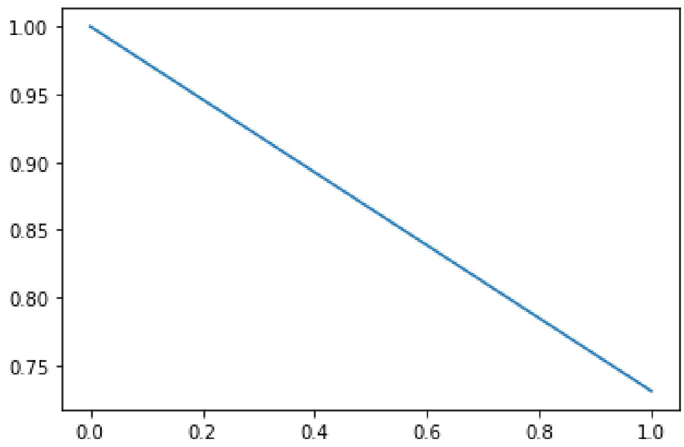
```
ray was expected. Please change the shape of y to (n_samples,), for example using ravel()
.
  return self._fit(X, y)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\neighbors
\_classification.py:200: DataConversionWarning: A column-vector y was passed when a 1d ar
ray was expected. Please change the shape of y to (n_samples,), for example using ravel()
.
  return self._fit(X, y)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\neighbors
\_classification.py:200: DataConversionWarning: A column-vector y was passed when a 1d ar
ray was expected. Please change the shape of y to (n_samples,), for example using ravel()
.
  return self._fit(X, y)
```

In [43]:

```
#recall plot
plt.plot(recall_score(y_test, y_prediction, average=None))
```

Out[43]:

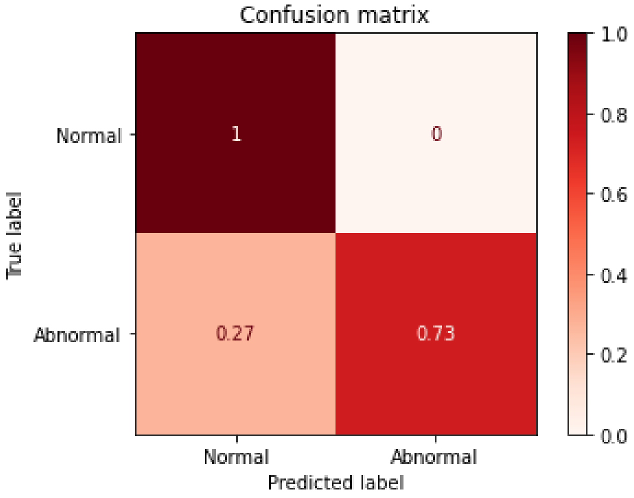
```
[<matplotlib.lines.Line2D at 0x1c01feac2b0>]
```



In [44]:

```
#confusion matrix plot
display = plot_confusion_matrix(clf, x_test, y_test, display_labels=['Normal', 'Abnormal
'], cmap=plt.cm.Reds, normalize='true')
display.ax_.set_title('Confusion matrix')

plt.show()

print(confusion_matrix(y_test, y_prediction))
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\dep
recation.py:87: FutureWarning: Function plot_confusion_matrix is deprecated; Function `pl
ot_confusion_matrix` is deprecated in 1.0 and will be removed in 1.2. Use one of the clas
s methods: ConfusionMatrixDisplay.from_predictions or ConfusionMatrixDisplay.from_estimat
or.
  warnings.warn(msg, category=FutureWarning)
```



```
[[74  0]
 [ 7 19]]
```

SVM

kernel: kernel type to be used in the algorithm. it must be one of 'linear', 'poly', 'rbf', 'sigmoid', 'precomputed' or a callable. if none is given, 'rbf' will be used. if a callable is given it is used to pre-compute the kernel matrix from data matrices; that matrix should be an array of shape (n_samples, n_samples).

In [45]:

```
#make svc faster
clf = SVC(kernel='rbf', max_iter=2000000000, C=10, random_state=0)
clf.fit(x_train, y_train)
y_prediction = clf.predict(x_test)

print(accuracy_score(y_test, y_prediction))
print(recall_score(y_test, y_prediction))
print(precision_score(y_test, y_prediction))
```

```
0.92
0.6923076923076923
1.0
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

In [46]:

```
# scoring = {
#     'accuracy': make_scorer(accuracy_score),
#     'recall': make_scorer(recall_score),
#     'precision': make_scorer(precision_score),
#     'f1': make_scorer(f1_score),
# }

# cv = KFold(n_splits=5, random_state=SEED, shuffle=True)
# cross_validate = cross_validate(estimator=clf, X=new_x, y=y, cv=cv)
# cross_validate
```

In [47]:

```
scores = cross_val_score(clf, new_x, y, cv=5)
print("k-fold cross validation accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std(
) * 2))
```

```
k-fold cross validation accuracy: 0.94 (+/- 0.02)
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
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expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\val
idation.py:1111: DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using ravel().
```

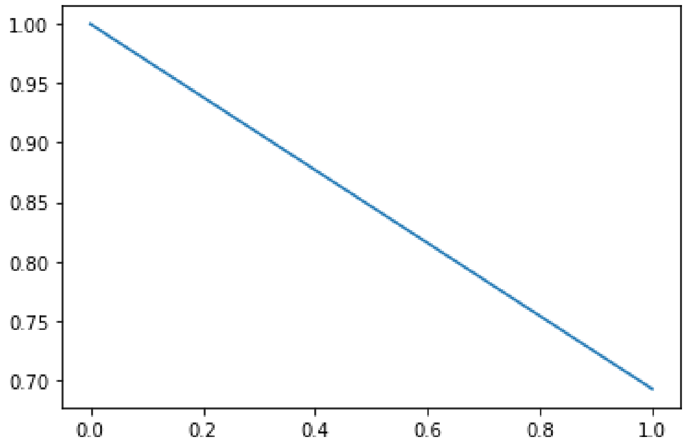
```
  y = column_or_1d(y, warn=True)
```

In [48]:

```
#recall plot
plt.plot(recall_score(y_test, y_prediction, average=None))
```

Out[48]:

```
[<matplotlib.lines.Line2D at 0x1c017aee490>]
```



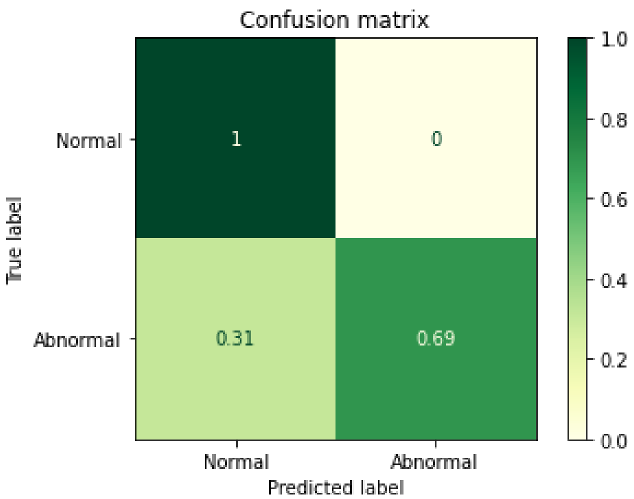
In [50]:

```
#confusion matrix plot
display = plot_confusion_matrix(clf, x_test, y_test, display_labels=['Normal', 'Abnormal
'], cmap=plt.cm.YlGn, normalize='true')
display.ax_.set_title('Confusion matrix')

plt.show()

print(confusion_matrix(y_test, y_prediction))
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\utils\dep
recation.py:87: FutureWarning: Function plot_confusion_matrix is deprecated; Function `pl
ot_confusion_matrix` is deprecated in 1.0 and will be removed in 1.2. Use one of the clas
s methods: ConfusionMatrixDisplay.from_predictions or ConfusionMatrixDisplay.from_estimat
or.
  warnings.warn(msg, category=FutureWarning)
```




```
[[74  0]
 [ 8 18]]
```

In [110]:

```
#calculate correlation of each feature and compare it with other features
correlation = np.corrcoef(new_x)

#compare each feature correlation with other features correlation and sort them to get th
e most correlated features
```

```
correlation = np.abs(correlation)
correlation = np.sort(correlation, axis=1)
```

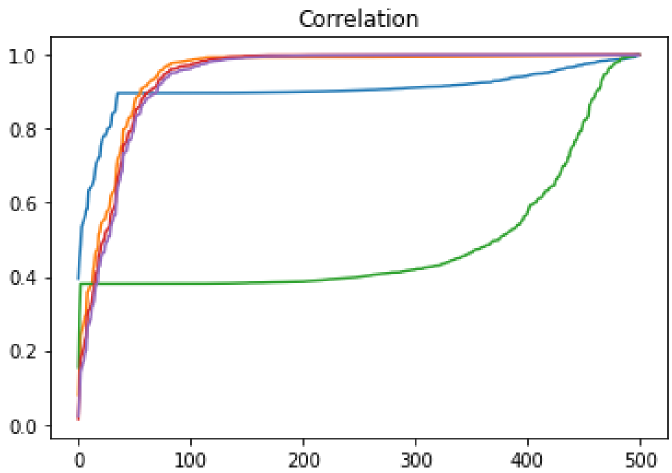
In [109]:

```
# ploy random correlations after sorting

plt.title("Correlation")

for i in range(0, correlation.shape[1], 100):
    plt.plot(correlation[i])

plt.show()
```



In [121]:

```
best_features = []
BEST_SCORE = 0.7

for i in range(0, new_x.shape[1]):
    x = new_x[:,i].reshape(-1, 1);
    x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.2, random_stat
e=SEED)

    clf = DecisionTreeClassifier()
    clf.fit(x_train, y_train)

    y_prediction = clf.predict(x_test)

    model_accuracy = accuracy_score(y_test, y_prediction)
    model_recall = recall_score(y_test, y_prediction)
    model_precision = precision_score(y_test, y_prediction)

    print(f'feature #{i} with accuracy: {model_accuracy}, recall: {model_recall}, precisi
on: {model_precision}')

    if model_accuracy > BEST_SCORE and model_recall > BEST_SCORE and model_precision > B
EST_SCORE:
        best_features.append(i)
```

```
feature #0 with accuracy: 0.93, recall: 0.7307692307692307, precision: 1.0
feature #1 with accuracy: 0.72, recall: 0.34615384615384615, precision: 0.45
feature #2 with accuracy: 0.92, recall: 0.7692307692307693, precision: 0.9090909090909091
feature #3 with accuracy: 0.91, recall: 0.7307692307692307, precision: 0.9047619047619048
feature #4 with accuracy: 0.89, recall: 0.6153846153846154, precision: 0.9411764705882353
feature #5 with accuracy: 0.93, recall: 0.7307692307692307, precision: 1.0
feature #6 with accuracy: 0.93, recall: 0.7307692307692307, precision: 1.0
feature #7 with accuracy: 0.84, recall: 0.5384615384615384, precision: 0.7777777777777778
feature #8 with accuracy: 0.7, recall: 0.46153846153846156, precision: 0.4285714285714285
5
feature #9 with accuracy: 0.71, recall: 0.23076923076923078, precision: 0.4
feature #10 with accuracy: 0.7, recall: 0.3076923076923077, precision: 0.4
feature #11 with accuracy: 0.77, recall: 0.5384615384615384, precision: 0.56
feature #12 with accuracy: 0.74, recall: 0.0, precision: 0.0
feature #13 with accuracy: 0.66, recall: 0.19230769230769232, precision: 0.27777777777777
78
```

```
78
feature #14 with accuracy: 0.65, recall: 0.2692307692307692, precision: 0.304347826086956
54
feature #15 with accuracy: 0.74, recall: 0.2692307692307692, precision: 0.5
feature #16 with accuracy: 0.74, recall: 0.2692307692307692, precision: 0.5
feature #17 with accuracy: 0.62, recall: 0.15384615384615385, precision: 0.2
feature #18 with accuracy: 0.66, recall: 0.19230769230769232, precision: 0.27777777777777
78
feature #19 with accuracy: 0.93, recall: 0.7307692307692307, precision: 1.0
feature #20 with accuracy: 0.83, recall: 0.6153846153846154, precision: 0.695652173913043
5
feature #21 with accuracy: 0.93, recall: 0.7307692307692307, precision: 1.0
feature #22 with accuracy: 0.93, recall: 0.7307692307692307, precision: 1.0
feature #23 with accuracy: 0.74, recall: 0.0, precision: 0.0
feature #24 with accuracy: 0.93, recall: 0.8076923076923077, precision: 0.913043478260869
5
feature #25 with accuracy: 0.95, recall: 0.8076923076923077, precision: 1.0
feature #26 with accuracy: 0.79, recall: 0.46153846153846156, precision: 0.63157894736842
1
feature #27 with accuracy: 0.92, recall: 0.8076923076923077, precision: 0.875
```

```
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\metrics\_
classification.py:1327: UndefinedMetricWarning: Precision is ill-defined and being set to
0.0 due to no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
c:\Users\SQ-PC\AppData\Local\Programs\Python\Python39\lib\site-packages\sklearn\metrics\_
classification.py:1327: UndefinedMetricWarning: Precision is ill-defined and being set to
0.0 due to no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

In [122]:

```
optimized_x = new_x[:, best_features]
print(optimized_x.shape)
```

```
(500, 11)
```

In [123]:

```
for i in range(optimized_x.shape[1]):
    plt.plot(optimized_x[i])

plt.show()
```