# REPORT

Zajęcia: Analog and digital electronic circuits

Teacher: prof. dr hab. Vasyl Martsenyuk

**Lab 3**

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**Topic:** Random signals

**Variant 1**

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## 1. Problem statement:

Generate ensemble of random signals of the form

$$x_n(k)=A\cos(2f\pi/k)+BW_n(k)$$

where

$$W_n(k)$$

is normally distributed in [0,1] numbers,

$$A,f,B$$

are determined in the table below.

1. Estimate the linear mean as ensemble average

2. Estimate the linear mean and squared linear mean

3. Estimate the quadratic mean and variance.

4. Plot 1-4 graphically.

5. Estimate and plot the auto-correlation function (ACF)

## 2. Input data:

| No | $f$ | $A$ | $B$ | $N$ |
|---|---|---|---|---|
| 1 | 300 | 300.25 | 299.75 | 2000 |
| 2 | 400 | 400.25 | 399.75 | 3000 |
| 3 | 500 | 500.25 | 499.75 | 1800 |
| 4 | 600 | 600.25 | 599.75 | 2000 |
| 5 | 300 | 300.25 | 299.75 | 2000 |
| 6 | 600 | 600.25 | 599.75 | 2000 |
| 7 | 400 | 400.25 | 399.75 | 3000 |
| 8 | 500 | 500.25 | 499.75 | 1800 |
| 9 | 600 | 600.25 | 599.75 | 2000 |
| 10 | 300 | 300.25 | 299.75 | 2000 |
| 11 | 200 | 200.25 | 199.75 | 2000 |
| 12 | 400 | 400.25 | 399.75 | 3000 |
| 13 | 500 | 500.25 | 499.75 | 1800 |
| 14 | 600 | 600.25 | 599.75 | 2000 |
| 15 | 500 | 500.25 | 499.75 | 2000 |

Table 1: Variants

## 3. Commands used (or GUI):

In [1]:
```
import numpy as np
import matplotlib as mpl
from matplotlib import pyplot as plt
from numpy.random import Generator, PCG64
from scipy import signal
from scipy import stats
from scipy.stats import truncnorm
```

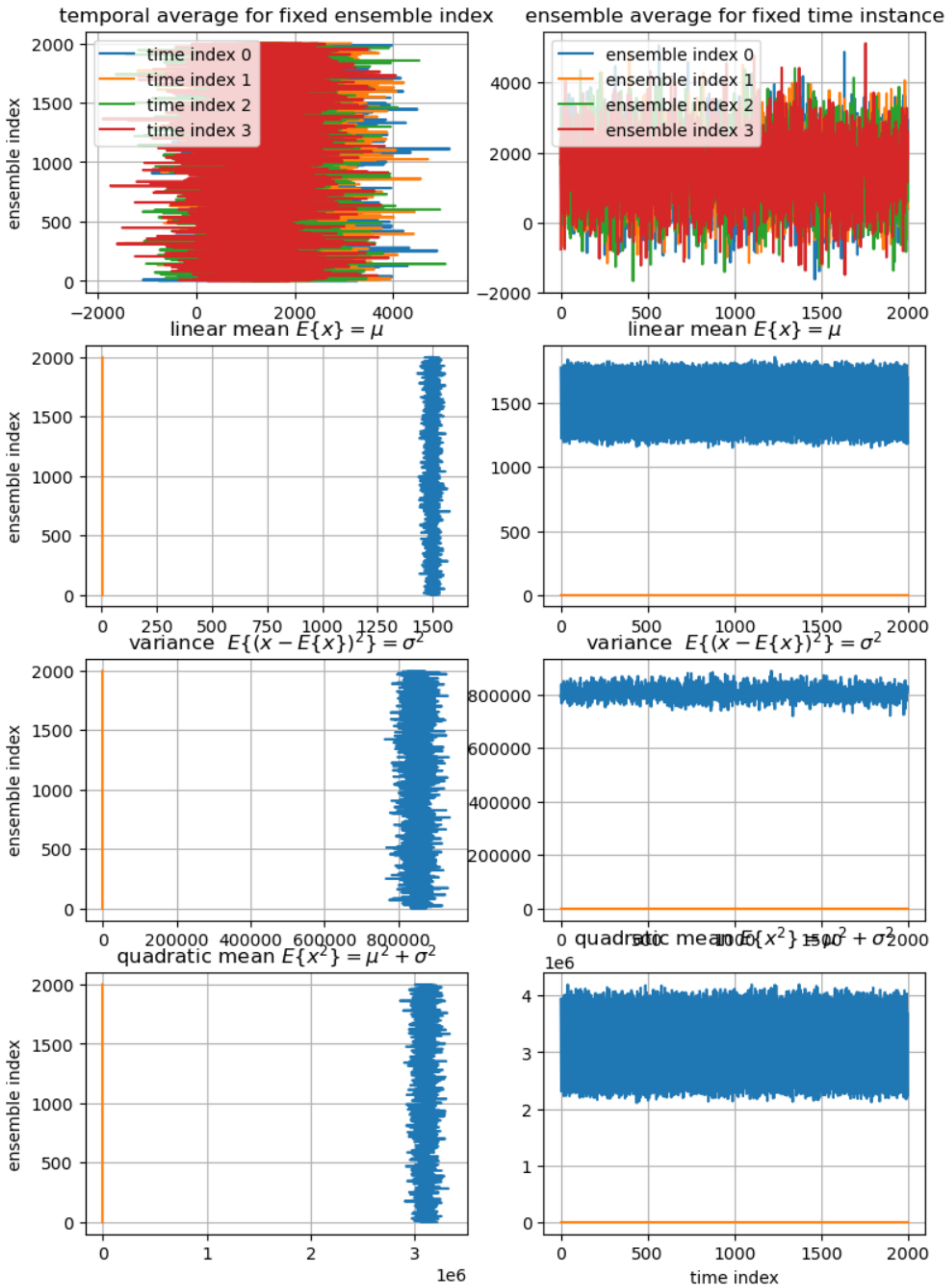
In [2]:
```
a = 300.25
b = 299.75
f = 300
N = 2000

# create random process based on normal distribution
Ns = N  # number of samples to set up an ensemble
Nt = N  # number of time steps to set up 'ensemble over time'-characteristics
np.random.seed(1)

s = np.arange(Ns)  # ensemble index (s to indicate sample function)
t = np.arange(Nt)  # time index

loc, scale = 5, 3  # mu, sigma
x = np.random.normal(loc=loc, scale=scale, size=[Ns, Nt]) * b

tmp = a*np.cos(2 * f*np.pi/Nt * np.arange(0, Nt))
x = x + np.tile(tmp, (Ns, 1))

fig, axs = plt.subplots(4, 2, figsize=(9, 13))
# plot signals
for i in range(4):
    axs[0, 0].plot(x[:, i], s, label='time index '+str(i))
    axs[0, 1].plot(t, x[i, :], label='ensemble index '+str(i))
# plot means
axs[1, 0].plot(np.mean(x, axis=1), s)
axs[1, 1].plot(t, np.mean(x, axis=0))
axs[1, 0].plot([loc, loc], [0, Ns])
axs[1, 1].plot([0, Nt], [loc, loc])
# plot variance
axs[2, 0].plot(np.var(x, axis=1), s)
axs[2, 1].plot(t, np.var(x, axis=0))
axs[2, 0].plot([scale**2, scale**2], [0, Ns])
axs[2, 1].plot([0, Nt], [scale**2, scale**2])
# plot quadratic mean
axs[3, 0].plot(np.mean(x**2, axis=1), s)
axs[3, 1].plot(t, np.mean(x**2, axis=0))
axs[3, 0].plot([loc**2+scale**2, loc**2+scale**2], [0, Ns])
axs[3, 1].plot([0, Nt], [loc**2+scale**2, loc**2+scale**2])
# labeling
axs[3, 1].set_xlabel('time index')
for i in range(4):
    #axs[i,1].set_xlabel('time index')
    axs[i, 0].set_ylabel('ensemble index')
    for j in range(2):
        axs[i, j].grid(True)
axs[0, 0].set_title(r'temporal average for fixed ensemble index')
axs[0, 1].set_title(r'ensemble average for fixed time instance')
for i in range(2):
    axs[0, i].legend(loc='upper left')
    axs[1, i].set_title(r'linear mean $E\{x\} = \mu$')
    axs[2, i].set_title(r'variance  $E\{(x -E\{x\} )^2\} = \sigma^2$')
    axs[3, i].set_title(r'quadratic mean $E\{x^2\} = \mu^2+\sigma^2$')
```

In [3]:
```
def my_xcorr(x, y):
    N, M = len(x), len(y)
    kappa = np.arange(N+M-1) - (M-1)
    ccf = signal.correlate(x, y, mode='full', method='auto')
    return kappa, ccf
```

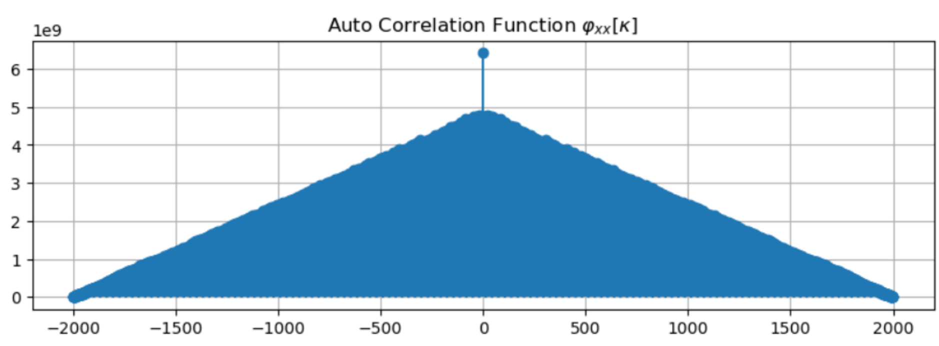
In [4]:
```
plt.figure(figsize=(10, 3))
plt.subplot(1, 1, 1)
kappa, ccf = my_xcorr(x[0, :], x[0, :])
plt.stem(kappa, ccf, basefmt='C0:')
plt.xlabel(r'$\kappa$')
plt.title(r'Auto Correlation Function $\varphi_{xx}[\kappa]$')
plt.grid(True)
```

Link to remote repozytorium : https://github.com/TomaszSteblik/Aadec_3

## 4. Outcomes:



temporal average for fixed ensemble index
ensemble average for fixed time instance
time index 0
time index 1
time index 2
time index 3
ensemble index 0
ensemble index 1
ensemble index 2
ensemble index 3
ensemble index
linear mean $E\{x\} = \mu$
variance $E\{(x - E\{x\})^2\} = \sigma^2$
quadratic mean $E\{x^2\} = \mu^2 + \sigma^2$
time index
1e6

Auto Correlation Function $\varphi_{xx}[\kappa]$
1e9

## 5. Conclusions:

In general, performing these tasks provides a better understanding of the characteristics of a random process, including its averages, quadratic moments and autocorrelation functions. Graphical analysis provides an intuitive view of changes over time.