REPORT

Zajęcia: Analog and digital electronic circuits
Teacher: prof. dr hab. Vasyl Martsenyuk

Lab 2
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Topic: "Windowing"
Variant 2

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stacjonarne,
2 semestr,
Gr. 1a

1. Problem statement: Generate three sine signals of given f1, f2, and f3 and amplitude |x[k]|max
for the sampling frequency fs in the range of $0 \leq k < N$.
Plot: 1. the "normalized" level of the DFT spectra. 2. the window
DTFT spectra normalized to their mainlobe maximum. The intervals for f, Ω, and amplitudes should be chosen by yourself for the best interpretation purposes.
Interpret the results of the figures obtained regarding the best and worst case for the different windows. Why do the results for the signals with frequencies f1 and f2 differ?

2. Input data:

f1 = 400, f2 = 400.25, f3 = 399.75, |x[k]|max = 2, fs = 600, N = 3000

3. Commands used:

Source code:

```
import numpy as np
import matplotlib.pyplot as plt
from numpy.fft import fft, ifft, fftshift
from scipy.signal.windows import hann, flattop
f1 = 400 # Hz
f2 = 400.25 # Hz
f3 = 399.75 #Hz
fs = 600 # Hz
N = 3000
k = np.arange(N)
x1 = 2 * np.sin(2*np.pi*f1/fs*k)
x2 = 2 * np.sin(2*np.pi*f2/fs*k )
x3 = 2 * np.sin(2*np.pi*f3/fs*k )
wrect = np.ones(N)
whann = hann(N,sym=False)
wflattop = flattop(N, sym=False)
plt.plot(wrect, 'C0o-', ms=3, label='rect')
plt.plot(whann, 'C1o-', ms=3, label='hann')
plt.plot(wflattop, 'C2o-', ms=3, label='flattop')
plt.xlabel(r'$k$')
plt.ylabel(r'window $w [ k ] $')
plt.xlim(0, N)
plt.legend()
plt.grid(True)
X1wrect = fft(x1)
X2wrect = fft(x2)
X3wrect = fft(x3)
X1whann = fft(x1*whann)
X2whann = fft(x2*whann)
X3whann = fft(x3*whann)
X1wflattop = fft(x1*wflattop)
```

```
X2wflattop = fft(x2*wflattop)
X3wflattop = fft(x3*wflattop)
def fft2db(X):
    N = X.size
    Xtmp = 2/N*X
    Xtmp[0] *= 1/2
    if N%2 == 0:
        Xtmp[N//2] = Xtmp[N//2]/2
    return 20*np.log10(np.abs(Xtmp))
df = fs/N
f = np.arange(N)*df
plt.figure(figsize = (16/1.5, 10/1.5))
plt.subplot(3, 1, 1)
plt.plot(f, fft2db(X1wrect), 'C0o-', ms=3, label='x1')
plt.plot(f, fft2db(X2wrect), 'C3o-', ms=3, label='x2')
plt.plot(f, fft2db(X3wrect), 'C2o-', ms=3, label='x3')
plt.xlim(175, 225)
plt.ylim(-60, 0)
plt.xticks(np.arange(175, 230, 5))
plt.yticks(np.arange(-60, 10, 10))
plt.legend()
plt.ylabel('A / dB')
plt.grid(True)
plt.subplot(3, 1, 2)
plt.plot(f, fft2db(X1whann), 'C0o-', ms=3, label='x1')
plt.plot(f, fft2db(X2whann), 'C3o-', ms=3, label='x2')
plt.plot(f, fft2db(X3whann), 'C2o-', ms=3, label='x3')
plt.xlim(175, 225)
plt.ylim(-60, 0)
plt.xticks(np.arange(175, 230, 5))
plt.yticks(np.arange(-60, 10, 10))
plt.legend()
plt.ylabel('A / dB')
plt.grid(True)
plt.subplot(3, 1, 3)
plt.plot(f, fft2db(X1wflattop), 'C0o-', ms=3, label='x1')
plt.plot(f, fft2db(X2wflattop), 'C3o-', ms=3, label='x2')
plt.plot(f, fft2db(X3wflattop), 'C2o-', ms=3, label='x3')
plt.xlim(175, 225)
plt.ylim(-60, 0)
plt.xticks(np.arange(175, 230, 5))
plt.yticks(np.arange(-60, 10, 10))
plt.legend()
plt.xlabel('f / Hz')
plt.ylabel('A / dB')
plt.grid(True)
def winDTFTdB(w):
    N = w.size
    Nz = 100*N
    W = np.zeros(Nz)
    W[0:N] = w
    W = np.abs(fftshift(fft(W)))
    W /= np.max(W)
    np.seterr(divide = 'ignore')
    W = 20*np.log10(W)
    Omega = 2*np.pi/Nz*np.arange(Nz)-np.pi
    return Omega, W
plt.plot([-np.pi, +np.pi], [-3.01, -3.01], 'gray')
plt.plot([-np.pi, +np.pi], [-13.3, -13.3], 'gray')
```

```
plt.plot([-np.pi, +np.pi], [-31.5, -31.5], 'gray')
plt.plot([-np.pi, +np.pi], [-93.6, -93.6], 'gray')
Omega, W = winDTFTdB(wrect)
plt.plot(Omega, W, label='rect')
Omega, W = winDTFTdB(whann)
plt.plot(Omega, W, label='hann')
Omega, W = winDTFTdB(wflattop)
plt.plot(Omega, W, label='flattop')
plt.xlim(-np.pi, np.pi)
plt.ylim(-120, 10)
plt.xlim(-np.pi/100, np.pi/100)
plt.xlabel(r'$\Omega$')
plt.ylabel(r'|W($\Omega$)| / dB')
plt.legend()
plt.grid(True)
```

Link to remote repository:
https://github.com/BlazejMrzyglod/AADEC/tree/main/lab2

4. Outcomes:

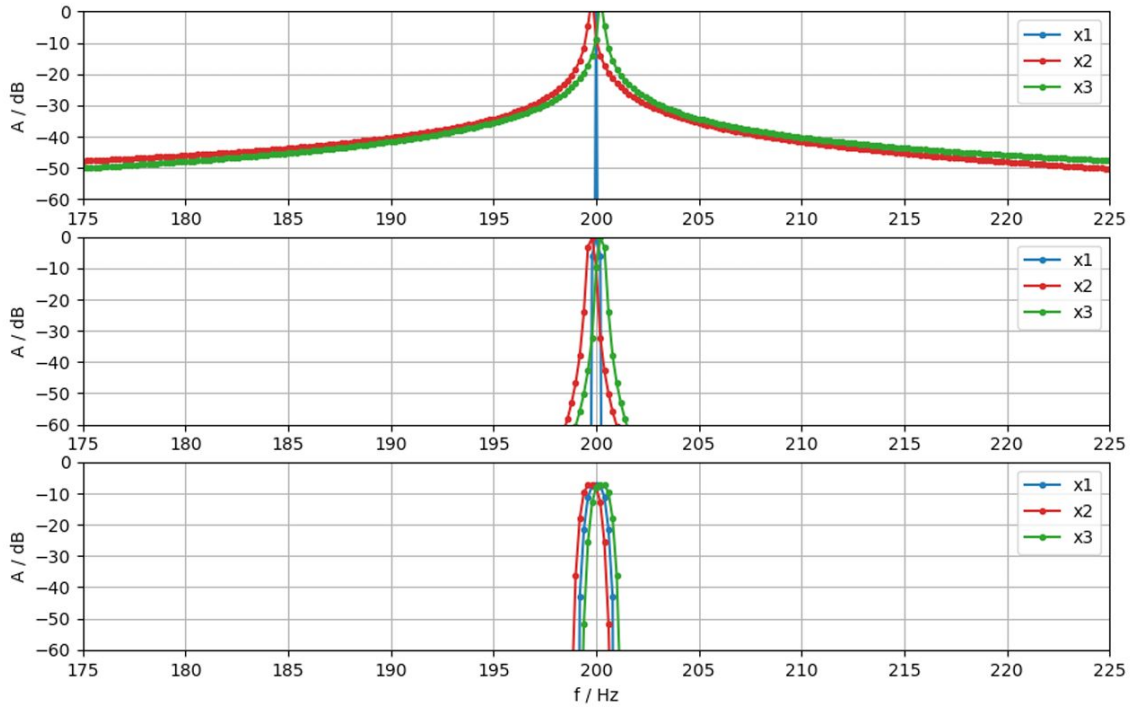

Fig. 1: DFT spectra using FFT algorithm

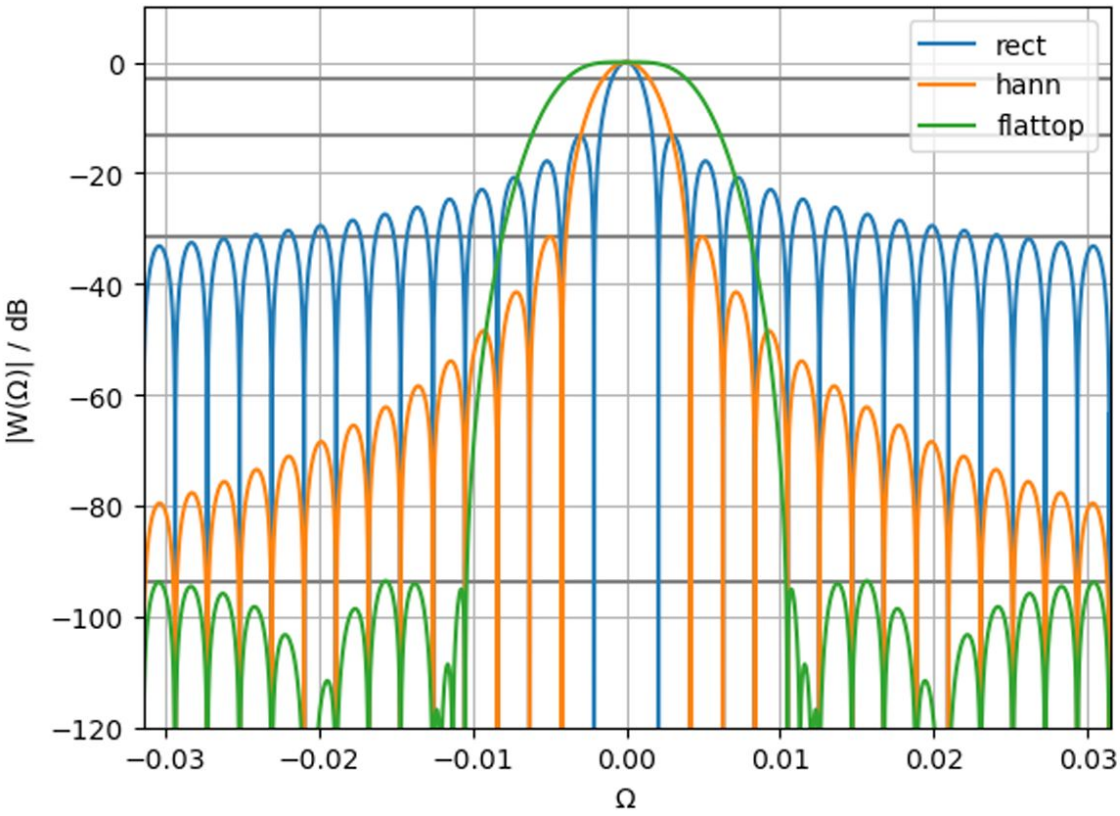

Fig. 2: Window DTFT spectra normalized to their mainlobe maximum

5. Conclusions:

It can be concluded that different windows give very different results and choosing the right window depends on the specific situation. For all windows *x1* is the best case scenario while *x2 and x3* are the worst case scenarios, differing only in their relative positions. The differences between those functions are due to different levels of the leakage effect.