Solved examples on topics presented in Lecture 4

Systems with linear phase: See also the corresponding `Matlab script`

- Decide, which filter saved in files "filter_1.mat" and "filter_2.mat" has linear phase.
- Generate square wave sequence $k = 1 \dots 5$, $n = 0 \dots 999$

$$x[n] = \frac{4}{\pi} \sum_{k} \frac{\sin((2k-1)\,\omega_b n)}{2k-1}, \omega_b = 0.02\pi, \quad (1)$$

  such that all harmonic components are situated in the pass-band of the given filters.
- Obtain the signal $y[n]$ as a response of the selected filter to the signal $x[n]$.
- Compare $x[n]$ a $y[n]$ (plot the into the figure) and confirm that the filtration did not distort the sequence. Compensate the delay which was introduced by the filtering.

System interconnection: Schaum - 2.13/74

Decibel: Let us consider a signal $x[n]$, whose energy is $E_x = 5$. A new signal is $x_2[n]$ is formed by amplification of $x[n]$. What will be the energy of this new signal when the energy

- rises by 20 dB?

$$\begin{aligned} 20 &= 10 \log \frac{E_{x_2}}{E_x} \\ 10^2 &= \frac{E_{x_2}}{E_x} \\ E_{x_2} &= 100 E_x = 500 \end{aligned}$$

- falls by 3 dB? (≈ 2.5)
- falls by 10 dB? (0.5)

Let us consider a harmonic signal $x[n]$ with amplitude A_x equals 5. A new signal is $x_2[n]$ is formed by amplification of $x[n]$. What will be the amplitude of this new signal when the amplitude

- increases by 20 dB

$$\begin{aligned} 20 &= 20 \log \frac{A_{x_2}}{A_x} \\ 10 &= \frac{A_{x_2}}{A_x} \\ A_{x_2} &= 10 A_x = 50 \end{aligned}$$

- decreases by 3 dB? ($\approx \frac{5}{\sqrt{2}}$)
- decreases by 10 dB? ($\approx \frac{5}{\sqrt{10}}$)

Signal-to-Noise-Ratio: See also the corresponding `Matlab script`
Simulated noisy signals are often created in order to test functionality of a speech enhancement algorithm. The noise components added to undistorted speech should have a specific energy, such that the enhancement can be precisely evaluated. Task:

- Create a function to compute SNR, its input should be the speech component and the noise component of a noisy signal.
- Add the noise into the recording of undistorted speech with SNR -10dB, 0dB, 10dB. Listen to the result and check the SNR values using the function you created.

How to change the energy of the noise such that the output SNR exactly matches the requirements? The noise component should be amplified by a suitably selected constant k. Let us assume that we want to create a mixture $x[n] = s[n] + k \cdot v[n]$, where $s[n]$ is the desired speech signal and $v[n]$ is the noise component. Then

$$\begin{aligned}
\text{SNR} &= 10 \log \frac{E_s}{E_{k \cdot n}} \\
\text{SNR} &= 10 \log \frac{\sum s^2[n]}{\sum k^2 v^2[n]} \\
10^{\text{SNR}/10} &= \frac{\sum s^2[n]}{k^2 \sum v^2[n]} \\
k &= 10^{-\text{SNR}/20} \cdot \sqrt{\frac{\sum s^2[n]}{\sum v^2[n]}} = 10^{-\text{SNR}/20} \cdot \sqrt{\frac{E_s}{E_n}}
\end{aligned}$$