Signals and Systems
Lab Experience Session 1

Exercise 1

Consider the signal $x[n] = a^{|n|}$ with n integer from $-\infty$ to ∞ and:

a) $|a| < 1$

b) $|a| \geq 1$

For both cases:

- Plot the signal assuming a and finite extension of your choice (you can use the `stem` function to plot the signal);
- Determine energy and average power and compare the results to the theory;
- Analyze the evolution of energy and average power for increasing extension size.

Required outputs:

- Plot of the signal;
- Report the values of energy and/or average power both from theory and numerical estimation;
- What is the minimum extension size needed to estimate the energy/average power with a relative error lower than 0.001%?

Exercise 2

Repeat exercise 1 considering the signals $x[n] = exp(j4\pi n/N)$ and $y[n] = exp(j8\pi n/N)$ for n in [0,N-1], N=8. Verify if x[n] and y[n] are orthogonal in [0,N-1].

Required outputs:

- Plot of the signals;
- Report the values of energy and/or average power both from both theory and numerical estimation;
- Show if the two signals are orthogonal in $[0, N-1]$.

Exercise 3

Given the signal $x[n] = 3\delta[n] + 2\delta[n-1] - \delta[n-2] + 4\delta[n-3]$, determine its extension and consequently the value of N.
Considering the following basis:

a) The canonical basis $\mathbf{U}_\delta$

b) The Fourier basis $\mathbf{U_F}$

c) An orthonormal basis invented by you

with size $N \times N$, compute the coefficients obtained by projecting $x[n]$ on the new basis. This corresponds to computation of the vector $\mathbf{c} = \mathbf{U}^\dagger \mathbf{x}$. Then write the signal using the new basis.
Suggestion: to generate $\mathbf{U}_\delta$ and $\mathbf{U_F}$, write a general function that works for any N.

Required output:

- Figure representing the computed vector, i.e. the signal projected on the new basis;
- The expression of the signal using the new basis.

Exercise 4

Write a function that generates the Walsh basis $\mathbf{U_W}$ in case of N=128.
Given the sequence $x[n] = r_{88}[n-5]$ defined in [0,N-1] with $N = 128$, compute the vector of coefficients $\mathbf{c}$ considering:

a) The canonical basis $\mathbf{U}_\delta$

b) The Fourier basis $\mathbf{U_F}$

c) The Walsh basis $\mathbf{U_W}$

In addition, verify the Parseval equality.

Required output:

- Figure of the original signal;
- Figure of the computed vector, i.e. the signal projected on the new basis;
- Output if the Parseval equality is verified or not.