GIERM 22/23. Course: Digital Signal Processing

Lab 2. Digital Filter Design

Objectives: Design of FIR-GLP filters by windowing. Classical windows. Kaiser windows.

Set-up:

Add a new folder *PDS_practica2* in the students' working folder. Set the folder *PDS_practica2* as the *working folder* in MATLAB. The following files must be in the folder:

`parametros21.m`	`parametros22.m`	`parametros23.m`
`practica21.m`	`practica22.m`	`practica23.m`

- The file *parametros2x.m* has the parameters of the simulation number *x*.
- The file *practica2x.m* runs the simulation number *x* and plots the result in a number of figures.

2.1. Analysis of FIR-GLP filters obtained by classical windows

In the working folder we can find the function `impulsopb.m`. Its program code and description in ENGLISH are shown below.

Program code 1. `impulsopb.m`

```
% ----------------------------------------------------------------
% Provides the impulse response
% of a FIR filter by ideal windowing
% ----------------------------------------------------------------
%  h = impulsopb(M,Wc,ventana)
% ----------------------------------------------------------------
%    M          filter order (number of coefficients= M+1)
%    Wc         cut frequency (normalized to pi)
%    ventana    row vector of M+1 points
% ----------------------------------------------------------------

function h=impulsopb(M,Wc,ventana)

n = 0:M;                                % vector representing time samples
n = n+10^(-10);                         % avoids dividing by zero when n=M/2
hr = sin(Wc*pi*(n-M/2))./(pi*(n-M/2));  % ideal response delay
h=hr.*ventana;                          % windowing
```

Question 1. What mathematical expression studied in the course implements `impulsopb.m`?

h[n] =

Using the function `impulsopb.m` **write** a 'script' named `analizaFIR.m` which computes the coefficients of a FIR-GLP filter by windowing and represents its impulse response and its frequency response with **M = 51** and $\boldsymbol{\omega_C=0.4\pi}$ and rectangular window. The program code is:

```
M  = 51;
n=0:M;
Wc = 0.4;
ventana= rectwin(M+1);
h = impulsopb(M,Wc,ventana);

figure(1)
stem(n,h,'filled');
figure(2)
freqz(h,1,4096);
```

Question 2. Check that the impulse response and the frequency response are as expected.

The MATLAB's script with name `practica21.m` computes the coefficients of a low pass filter with rectangular window and parameters given in `parametros21.m` **(M=50,** $\boldsymbol{\omega_C=0.4\pi}$**)** and plots the frequency response in both linear and log scale.

Run `practica21.m.`

Program code 2. `parametros21.m`

```
% -------------------------------------------------------------
% parametros21
% -------------------------------------------------------------

Wc=0.4;
M=50;
ventana  = ones(M+1,1); %rectangular
%ventana = hamming(M+1);
```

Question 3. Using a zoom on the plot check that the maximum ripple in both bands agrees with the theoretical value.

Note: the ripple in the pass band (dB)=20log(1+δ_1); ripple in the reject band (dB)=-20log(δ_2)

Theoretical attenuation in the reject band (dB)	
Attenuation in the reject band according to the plot (dB)	
Theoretical attenuation in the pass band (dB)	
Attenuation in the pass band according to the plot (dB)	

Question 4. Change in `parametros21.m` the value **M = 100**. Run again `practica21.m`. Does the ripple level change?, Does the transition band width change?. Justify your answer according to the theory.

Does the ripple level change? (Yes/No)	
Does the transition band width change ? (Yes/No)	

Justification:

Set again the initial parameters **M=50** and **ω_C=0.4π** and change the window ('ventana') to **Hamming** in `parametros21.m`. Run again `practica21.m`.

Question 5. Using zoom over the plot, verify that the maximum ripple in the attenuation band is that predicted by the theory.

Ripple in the attenuation band according to the theory (dB)	
Ripple in the attenuation band according to the plot (dB)	

Question 6. Has the ripple changed when compared with the rectangular window? Has changed the transition band width?. Justify your answer.

Has the ripple changed? (Yes/No)	
Has changed the transition band width? (Yes/No)	

Justification:

2.2. Design of FIR-GLP filters using classical windows

In the MATLAB's script `practica22.m.` a FIR-GLP low pass filter is designed using classical windows and frequency response is represented. In the file `parametros22.m` the design parameters are set. Especifically, the following filters are designed **ω_P=0.4π, ω_S=0.5π** and **A=20, 40, 50** and **70**.

Run `practica22.m.`

Program code 3. `parametros22.m`

```
% ------------------------------------------------------------
% parametros22
% ------------------------------------------------------------

Wp = 0.4;
Ws = 0.5;
A=[20 40 50 70];
```

Question 7. Annotate the value of **M** obtained in each case. What is the effect on **M** of a change of $\boldsymbol{\omega_P}$ to $\mathbf{0.45\pi}$?. Justify your answer. Check it after running `practica22.m` with the new value of $\boldsymbol{\omega_P}$.

Effect on M (Increase/Decrease)	

Justification:

2.3. Design of FIR-GLP filters by the Kaiser method

The MATLAB's script `practica23.m` designs a FIR-GLP low pass filter using the Kaiser window and represents the frequency response. In the file `parametros23.m` the design parameters are set. Especifically, the following filters are designed: $\boldsymbol{\omega_P=0.4\pi}$, $\boldsymbol{\omega_S=0.5\pi}$ and **A=20, 40, 50** and **70**.

Run `practica23.m.`

Program code 4. `parametros23.m`

```
% ------------------------------------------------------------
% parametros23
% ------------------------------------------------------------

Wp = 0.4;
Ws = 0.5;
A=[20 40 50 70];
```

Question 8. Check that the attenuation in the reject band are those predicted by the Kaiser formulae. Annotate below and also check that **M** and **beta** are consistent with those obtained by the Kaiser formulae.

A	20	40	50	70
M				
beta				