MultimediaSignal Processing 1st Module

Fundamentals of Multimedia Signal Processing

19/2/2018

## Ex.1 (Pt.14)

We want to process a signal sampled at 10kHz using a digital band-stop filter able to:

Completely remove the component at 2.5kHz
Preserve with the original amplitude the components at 0kHz and at 5kHz.

In order to design and analyze such a filter,

1. Provide the filter H[*k*] of 4 samples in the frequency domain satisfying the aforementioned constraints [**2pts**]
2. Define the Inverse Discrete Fourier Transform Matrix for the filter and calculate time-domain version h[*n*] of it [**5pts**]
3. Find the attenuation of the filter for a sinusoid at 1.25kHz[**3Pts**].
4. Filter the following signal x[*n*] working in the time domain using the Overlap and Add approach [**4 Pts**].

   x[*n*]={1,-1,-3,-1,1,-1,-3,-1, 1}

## Ex.2 (Pt.9)

A signal is made of two sinusoids at 100kHz and 150kHz.The signal is sampled at 900kHz. Which is the minimum length of a Bartlett window in order to make the two signals completely distinguishable?

| Window Type | Peak Sidelobe Amplitude (Relative, dB) | Approximate Width of Main Lobe | Peak Approximation Error, $20\log(\delta)$ (dB) |
|---|---|---|---|
| Rectangular | -13 | $\frac{4\pi}{M+1}$ | -21 |
| Bartlett | -25 | $\frac{8\pi}{M}$ | -25 |
| Hann | -31 | $\frac{8\pi}{M}$ | -44 |
| Hamming | -41 | $\frac{8\pi}{M}$ | -53 |
| Blackman | -57 | $\frac{12\pi}{M}$ | -74 |

## Ex.3 (Pt. 11 – MATLAB code)

1. [7 pts] Write a MATLAB function

```
[z, p, b, a]=all_pass(z,p,b,a)
```

   that receives as input one among the zeros, the poles, the numerator or the denominator of the difference equations of a filter H(z), and it returns the missing elements to build an all-pass filter.

   ***Hint: look at the following point to see the use of the function***

2. [4 pts ]use the function to compute

```
[z,p,b,a]=all_pass([],[],b,[]);
```

with b=[1,-0.8,0.6] and plot the transfer function in N=512 points.

## Solutions

### Ex.1

H[*k*]={1,0,1,0}

$$W^{-1}=\frac{1}{4}\begin{bmatrix}1 & 1 & 1 & 1\\ 1 & j & -1 & -j\\ 1 & -1 & 1 & -1\\ 1 & -j & -1 & j\end{bmatrix}$$

h[n]=$W^{-1}$H[k]={.5,0,.5,0}

$$H(z)=\frac{1}{2}+\frac{1}{2}z^{-2}\rightarrow H\left(\omega=2\pi\frac{1.25kHz}{10kHz}=\frac{\pi}{4}\right)=\frac{1}{2}+\frac{1}{2}e^{-j\frac{\pi}{2}}=\frac{1}{2}-\frac{1}{2}j$$

$$\left|H\left(\omega=\frac{\pi}{4}\right)\right|=\frac{\sqrt{2}}{2}$$

y[n]=h[n]*x[n]={0.5,-0.5,-1,-1,-1,-1,-1,-1,-1}

### Ex.2

The two signals are represented in the Frequency domain as two impulses at the normalized frequencies

$$\omega_1=\frac{100}{900}2\pi=\frac{2}{9}\pi$$
$$\omega_2=\frac{150}{900}2\pi=\frac{1}{3}\pi$$
$$\Delta\omega=\frac{\pi}{9}$$

The minimum length of the Bartlett window will be:

$$\frac{8\pi}{M}=\frac{\pi}{9}\rightarrow M=72$$

### Ex.3

**File: all_pass.m**

```
function  [z, p, b, a]=all_pass(z,p,b,a)
compute_ab=0;compute_zp=0;
if length(z)>0
p=1./conj(z);compute_ab=1;
elseif length(p)>0
z=1./conj(p);compute_ab=1;
elseif length(b)>0
       a=fliplr(b);compute_zp=1;
elseif length(a)>0
       b=fliplr(a);compute_zp=1;
end
ifcompute_ab==1
```

```
        a=poly(p);b=poly(z);
elseifcompute_zp==1
        p=roots(a); z=roots(b);
end
end
```

**File: script.m**

```
b=[1,-0.8,0.6];
[z,p,b,a]=all_pass([],[],b,[]);

N=512;[H,w]=freqz(b,a,N);

figure;
subplot(2,1,1);plot(w,abs(H));
xlabel('\omega');ylabel('|H(z)|')
title('Magnitude');

subplot(2,1,2);plot(w,angle(H));
xlabel('\omega');ylabel('angle H(z)')
title('Phase');
```