

SNS COLLEGE OF TECHNOLOGY

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DEPARTMENT OF BIOMEDICAL ENGINEERING

19BMB302 - BIOMEDICAL SIGNAL PROCESSING

III YEAR/ V SEMESTER

UNIT II FINITE IMPULSE RESPONSE FILTERS

19BMB302 - Biomedical signal processing / Unit-1 / Dr. K. Manoharan, ASP / BME / SNSCT





- Introduction to FIR
- Linear phase FIR filter
- FIR filter design using window method
- Low Pass Filter
- Frequency sampling method
- Realization of FIR filter using direct form 1, Direct form 2
- Realization of FIR filter using Cascade structures
- Realization of FIR filter using parallel structures



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Example 6.21 Using a rectangular window technique design a lowpass filter with passband gain of unity, cutoff frequency of 1000 Hz and working at a sampling frequency of 5 kHz. The length of the impulse response should be 7.

Solution

Given

$$f_c = 1000\,\mathrm{Hz}$$

$$F = 5000\,\mathrm{Hz}$$

The cutoff frequency $\omega_c=2\pi fT$

$$=\frac{2\pi(1000)}{5000}=\frac{2\pi}{5}$$





The desired frequency response of the LPF is shown in Fig. 6.66.

The filter coefficients are given by

$$h_d(n) = \frac{1}{2\pi} \int_{-\frac{2\pi}{5}}^{\frac{2\pi}{5}} e^{j\omega n} d\omega$$

$$= \frac{\sin \frac{2\pi}{5} n}{\pi n} - \infty \le n \le \infty$$





The rectangular window for N=7 is given by

$$w_R(n) = 1$$
 for $-3 \le n \le 3$
= 0 otherwise

For
$$n = 0$$
; $h(0) = \lim_{n \to 0} \frac{\sin \frac{2\pi}{5}n}{\pi n} = \frac{2}{5} = 0.4$

$$n = 1; h(1) = h(-1) = \frac{\sin\frac{2\pi}{5}}{\pi} = 0.3027$$





$$n = 1; h(1) = h(-1) = \frac{\sin\frac{2\pi}{5}}{\pi} = 0.3027$$

$$n = 2; h(2) = h(-2) = \frac{\sin\frac{4\pi}{5}}{2\pi} = 0.0935$$

$$n = 3; h(3) = h(-3) = \frac{\sin\frac{6\pi}{5}}{3\pi} = -0.06236$$

The filter coefficients of realizable filter are

$$h(0) = h(6) = -0.06236; h(1) = h(5) = 0.0935; h(2) = h(4) = 0.3027$$

 $h(3) = 0.4$





Design a filter with following specifications

$$H_d(e^{j\omega}) = e^{-j3\omega} \qquad \frac{-\pi}{4} \le \omega \le \frac{\pi}{4}$$
$$= 0 \qquad \frac{\pi}{4} < |\omega| \le \pi$$

Using a Hamming window with N=7

Solution

Given $H_d(e^{j\omega}) = e^{-j3\omega}$

The frequency response is having a term $e^{-j\omega(N-1)/2}$ which gives h(n) symmetrical about $n=\frac{N-1}{2}=3$, i.e., we get a causal sequence.





$$h_d(n) = \frac{1}{2\pi} \int_{-\frac{\pi}{4}}^{\frac{\pi}{4}} e^{-j3\omega} e^{j\omega n} d\omega$$
$$= \frac{1}{2\pi} \int_{-\frac{\pi}{4}}^{\frac{\pi}{4}} e^{j(n-3)\omega} d\omega$$
$$= \frac{\sin\frac{\pi}{4}(n-3)}{\pi(n-3)}$$

For N = 7 we have

$$h_d(0) = h_d(6) = 0.075$$

 $h_d(1) = h_d(5) = 0.159$
 $h_d(2) = h_d(4) = 0.22$
 $h_d(3) = 0.25$





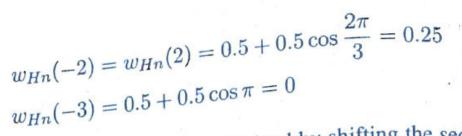
The non-causal window sequence is

$$w_{Hn}(n) = 0.5 + 0.5 \cos \frac{2\pi n}{N-1}$$
 for $-(N-1)/2 \le n \le (N-1)/2$
= 0 otherwise

For
$$N = 7$$

$$w_{Hn}(n) = 0.5 + 0.5 \cos \frac{2\pi n}{N-1}$$
 for $-3 \le n \le 3$
 $= 0$ otherwise
 $w_{Hn}(0) = 0.5 + 0.5 = 1$
 $w_{Hn}(-1) = w_{Hn}(1) = 0.5 + 0.5 \cos \frac{\pi}{3} = 0.75$







The causal window sequence can be obtained by shifting the sequence $w_{H_n(\eta)}$ to right by 3 samples, i.e.,

mples, i.e.,
$$w_{Hn}(0) = w_{Hn}(6) = 0; \ w_{Hn}(1) = w_{Hn}(5) = 0.25$$

$$w_{Hn}(2) = w_{Hn}(4) = 0.75 \& w_{Hn}(3) = 1$$

The filter coefficients using Hanning window are

$$h(n) = h_d(n)w_{Hn}(n) \quad \text{for} \quad 0 \le n \le 6$$

$$h(0) = h(6) = h_d(0)w_{Hn}(0) = (0.075)(0) = 0$$

$$h(1) = h(5) = h_d(1)w_{Hn}(1) = (0.159)(0.25) = 0.03975$$

$$h(2) = h(4) = h_d(2)w_{Hn}(2) = (0.22)(0.75) = 0.165$$

$$h(3) = h_d(3)w_{Hn}(3) = (0.25)(1) = 0.25$$