Digital Filter Design

(Subject Code - EET 3134)

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Equiripple Linear Phase FIR Filter

or

Optimal FIR Filters

Fundamental Difference

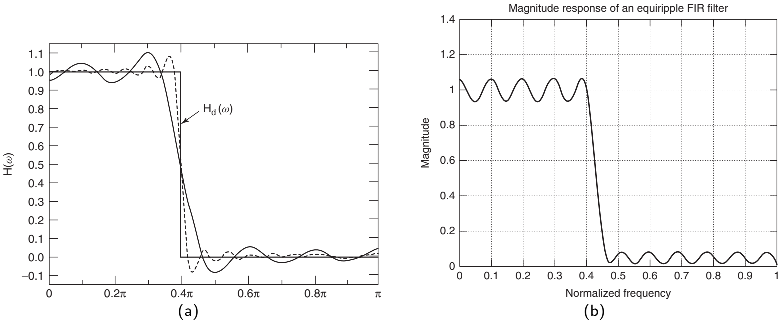

Figure: (b) Equiripple or Chebyshev response

- This method minimizes the maximum error in the passband and stopband, so called "minimax design" or the "Equiripple design"

Optimal FIR Filter Design

- Allow an unconstrained optimization of the filter coefficients to minimize a cost function. The cost function generally defined as:

$$J(\omega) = W(\omega)\left[H_d(\omega) - H(\omega)\right]$$

- $H_d(\omega)$ is the desired frequency response normally specified over subinterval of $0 \leq \omega \leq \pi$.
- $W(\omega)$ is a weighting function chosen by the designer to emphasize relative magnitude of the error over different subintervals.
- One approach is to determine the $h(n)$ such that the maximum weighted value of $J(\omega)$ is minimized.

Optimal FIR Filter Design

- It has been shown that when this minimum value is achieved, the frequency response exhibits an equiripple behaviour.

$$\min_{\{h_n\}} \left\{ \max_{\{\omega\}} \quad |W(\omega) [H_d(\omega) - H(\omega)]| \right\} \qquad (1)$$

  where $\{\omega\}$ is used to denote the union of the disjoint frequency band in $0 \leq \omega \leq \pi$.

- Parks & McClellen solved this minimizing the maximum absolute value of the error function $J(\omega)$ using the theory of Chebyshev approximation & developed an algorithm to implement it by using scheme called Remez exchange algorithm.

Optimal FIR Filter Design in MATLAB

- For the optimum design filter method it is necessary to first estimate the number of coefficients required.
- The empirical formula to calculate number of coefficients

$$\widehat{N} = \frac{2}{3}\frac{1}{\Delta F}\log_{10}\left[\frac{1}{10\delta_p\delta_s}\right] \tag{2}$$

- The values of the coefficients are then determined using suitable DSP simulation package (e.g. REMEZ in matlab). Using these coefficient values, the frequency response is compared with that required; if it is outside the original specification then the value of N is increased, and the design process repeated.
- The advantage of this technique over the window-based method is that a smaller value can be specified for δ_s than for δ_p, and this can lead to a significant saving in the number of coefficients required.

Digital Filter Design Lab

Lab Session 02

Assignment 1

- Design a low-pass filter using FIR windowing technique that satisfies the specification of $\omega_p = 0.4\pi$ and $\omega_s = 0.6\pi$ and exhibits a minimum attenuation greater than 50dB in the stop-band.

Lab Session 02

Assignment 1

- Design a low-pass filter using FIR windowing technique that satisfies the specification of $\omega_p = 0.4\pi$ and $\omega_s = 0.6\pi$ and exhibits a minimum attenuation greater than 50dB in the stop-band.

Assignment 2

- A FIR low-pass filter is required to have the following specifications:
  - Pass-band edge frequency $f_p = 2kHz$
  - Transition band $\Delta f = 200Hz$
  - Pass-band ripple $A_p = 0.1dB$
  - Minimum stop-band attenuation $A_s = 50dB$
  - Sampling frequency of $f_s = 10kHz$

  Using the window method, determine an appropriate window function and calculate the required number of filter coefficients to design this filter. Furthermore, ascertain the corresponding filter coefficient values $h[n]$ for $-10 \leq n \leq 10$.

Lab Session 02

Assignment 3

- Design an FIR filter using windowing method that need to adhere to the following specifications.
  - Passband 8-12 kHz
  - Stopband ripple 0.001
  - Peak passband ripple 0.01
  - Sampling frequency 44.14 kHz
  - Transition width 3 kHz

Lab Session 02

Assignment 3

- Design an FIR filter using windowing method that need to adhere to the following specifications.
  - Passband 8-12 kHz
  - Stopband ripple 0.001
  - Peak passband ripple 0.01
  - Sampling frequency 44.14 kHz
  - Transition width 3 kHz

Assignment 4

- Design an optimal FIR filter for the same specifications of Assignment 3 and compare the performances of both.

Thank You

Queries?