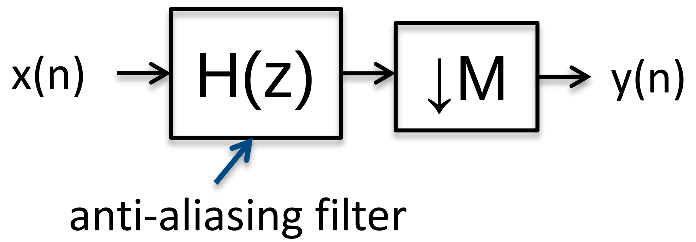
Module 7

Upsampling and Downsampling, Part II

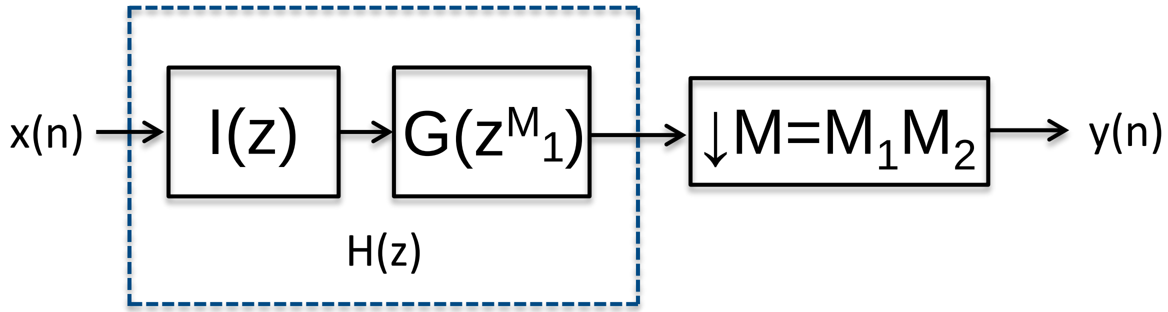
Overview

- Multistage downsampling concept
- Interpolated FIR (IFIR)
- IFIR design example
- Other stretch factors
- Multistage decimator design
- Multistage design example

Multistage Decimator Design

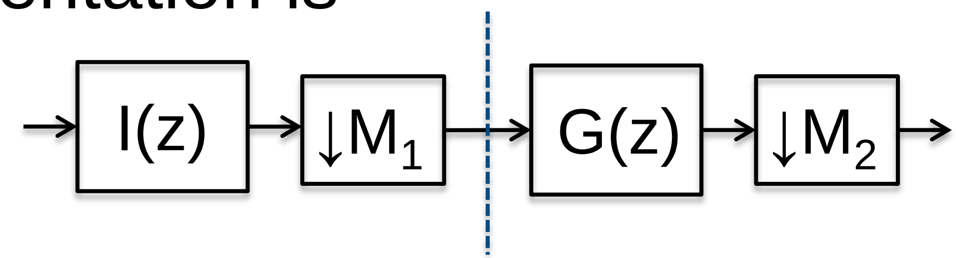


H(z) can be designed using the IFIR technique with stretch factor M_1 ($M=M_1 x M_2$)



Multistage Decimator Design

- Using the noble identity, the two stage implementation is



- If each stage is implemented with a polyphase structure, the total *computation rate* is

$$\frac{N_G}{M_1 M_2}+\frac{N_I}{M_1}=\frac{D(\delta_1/2,\delta_2)}{M_1^2 M_2(\omega_s-\omega_p)}+\frac{D(\delta_1/2,\delta_2)}{2\pi-M_1(\omega_s+\omega_p)}$$

Multistage Decimator Design

- As M_1 increases the 1st term (N_G) decreases while the 2nd term (N_I) increases. There is a value of M_1 that minimizes the overall computational rate.
- Development presented for two stages, but the concept can be extended to multiple stages.

Design Example

- Design a 2-stage decimator with M=50 and the following filter specifications:
  - $\omega_p = 7/8\ \pi/50$, $\omega_s = \pi/50$
  - $\delta_1 = 0.01$, $\delta_2 = 0.001$
- Direct implementation using the Parks-McClellan algorithm requires a filter order of N=2033 and a computational rate of N/M=40.7.

Design Example

- Overall computation rate for a 2-stage decimator:

$$\frac{N_G}{M_1 M_2}+\frac{N_I}{M_1}=\frac{D(\delta_1/2,\delta_2)}{M_1^2 M_2(\omega_s-\omega_p)}+\frac{D(\delta_1/2,\delta_2)}{2\pi-M_1(\omega_s+\omega_p)}$$

M_1	M_2	Computation Rate
2	25	24.8
5	10	11.8
10	5	7.8
25	2	6.9

M_1=25, M_2=2 minimizes the computation rate

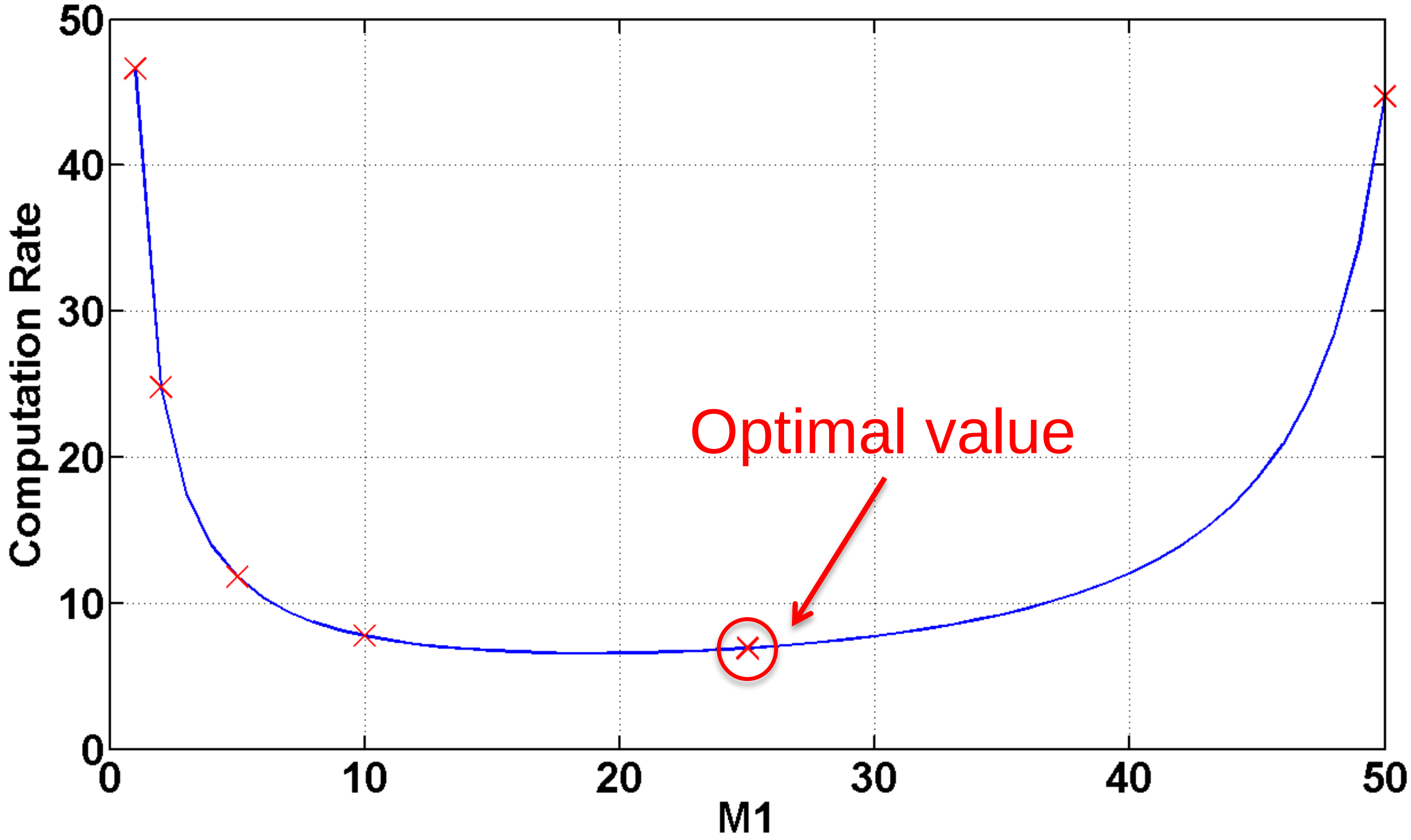
Design Example

- Filter parameters for $G(z)$ and $I(z)$ are ($M_1=25, M_2=2$):
  - o $G(z)$
    - o $M_1\omega_p = 7\pi/16$, $M_1\omega_s = \pi/2$
    - o $\delta_1/2=0.005$, $\delta_2=0.001$

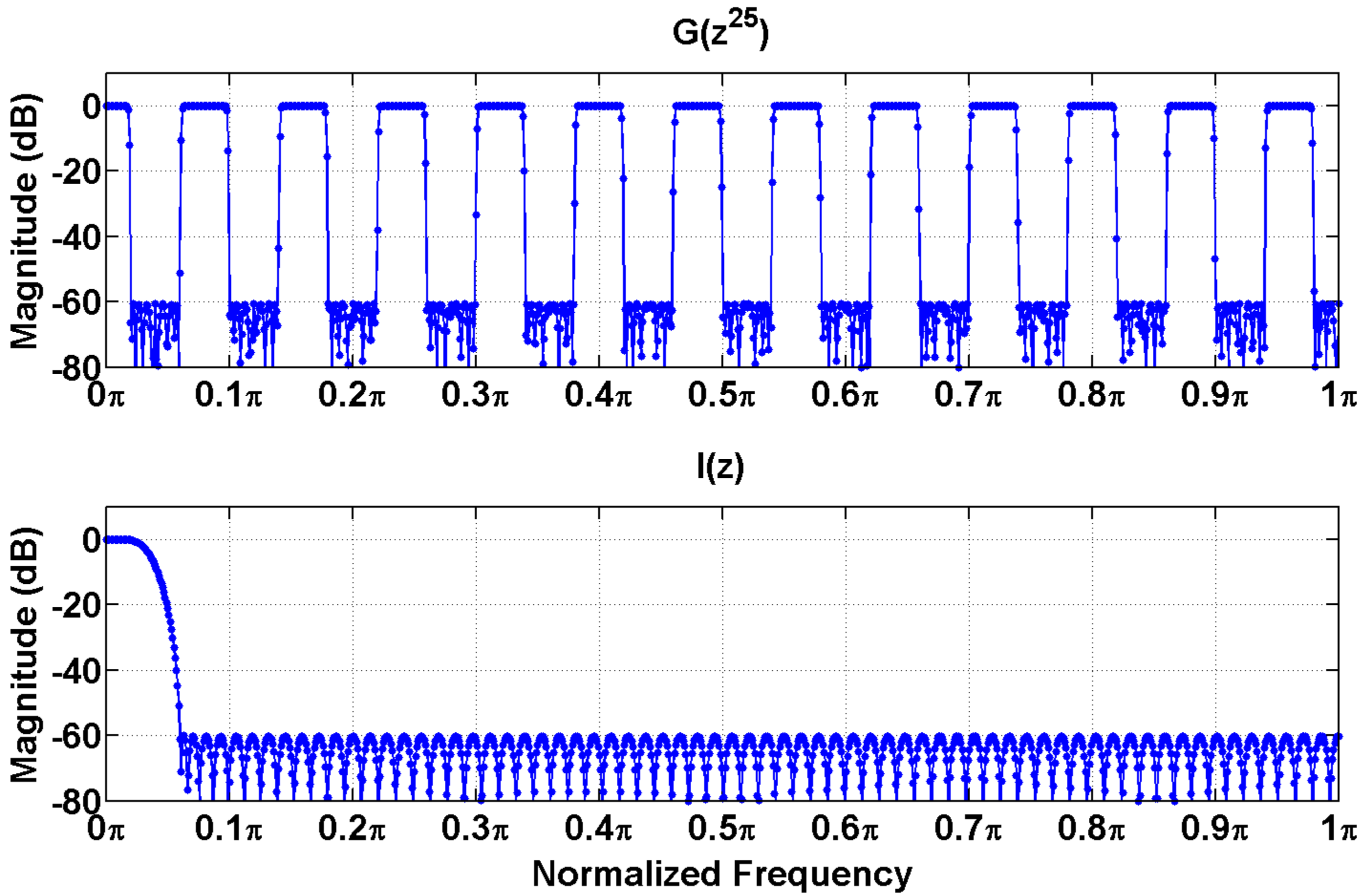
    $\Rightarrow$ $N_G=90$
  - o $I(z)$
    - o $\omega_p = 7/8\ \pi/50$, $2\pi/M_1 - \omega_s = 3\pi/50$
    - o $\delta_1/2=0.005$, $\delta_2=0.001$

    $\Rightarrow$ $N_I=142$

Design Example



Design Example



Design Example