Finite impulse response filtering

FIR windowed-sinc filters

Dr. Ing. Rodrigo Gonzalez

rodralez@frm.utn.edu.ar
rodrigo.gonzalez@ingenieria.uncuyo.edu.ar

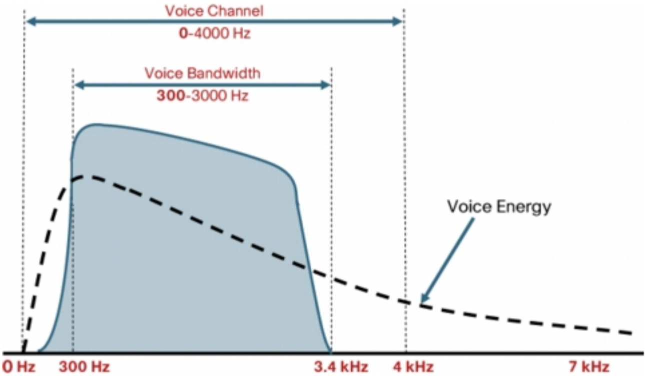
Classification of discrete filters

Table: Classification of discrete filters

	Finite impulse response (FIR)	Infinite impulse response (IIR)
Filtering in time domain	Moving average	Leaky Integrator
Filtering in frequency domain	Windowed-sinc Filters Equiripple Minimax	Bilinear z-transform

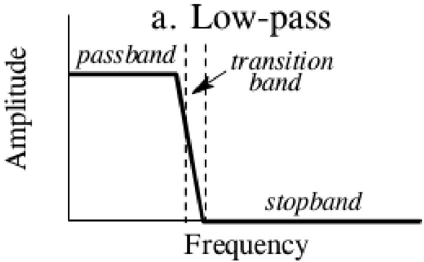
Information in frequency domain

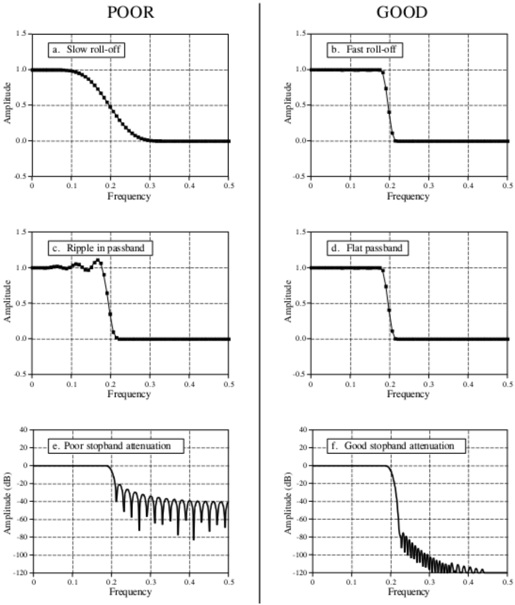
- Information of a signal is contained in frequency response, phase and amplitude.
- **Many samples** in the signal are needed for frequency analysis.
- The **frequency response** shows how information in frequency domain is being changed.
- Examples: telephone voice channel, equalizer...



Frequency domain parameters

- Passband.
- Stopband.
- Cut-off frequency.
- Transition band (fast roll-off).
- Passband ripple.
- Stopband ripple.




POOR
GOOD
a. Slow roll-off
b. Fast roll-off
c. Ripple in passband
d. Flat passband
e. Poor stopband attenuation
f. Good stopband attenuation
Amplitude
Amplitude (dB)
Frequency

Strategy of filtering by windowed-si

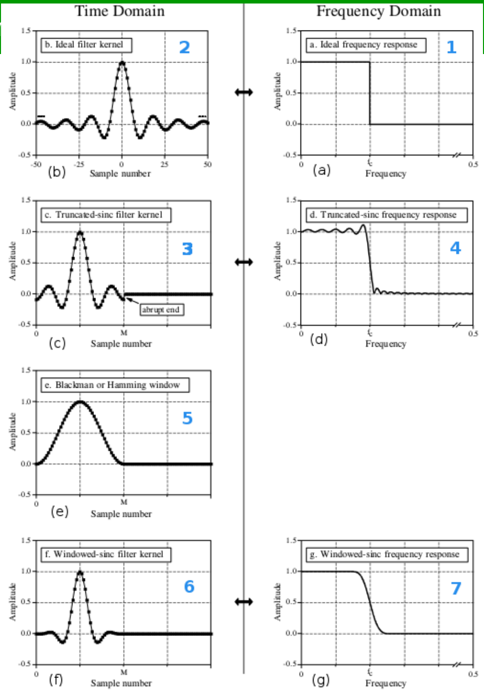
- Taking the Inverse Fourier Transform of an ideal frequency response (1) produces an ideal sinc filter kernel (2, impulse response) with **infinite** length.

$$h_s[n] = \frac{\sin(\pi f[n]/f_s)}{(\pi f[n]/f_s)}$$

- To get around this problem, ideal sinc filter is **truncated** to M+1 points, symmetrically chosen around the main lobe, where M is an even number.
- Truncated-sinc (3) produces the **Gibbs phenomenon** in frequency response (4), no matter how long M is made.
- Multiplying the truncated-sinc (3) by the Blackman window (5) results in a **windowed-sinc filter kernel** (6) with frequency response (7).

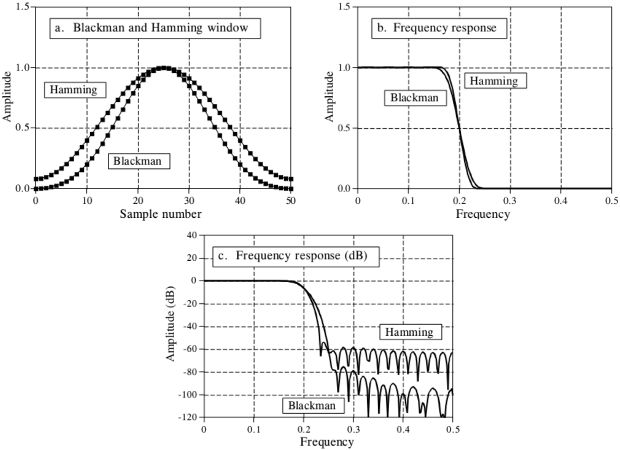
$$h_w[n] = h_s[n] \cdot w[n]$$

$$y[n] = h_w[n] * x[n]$$

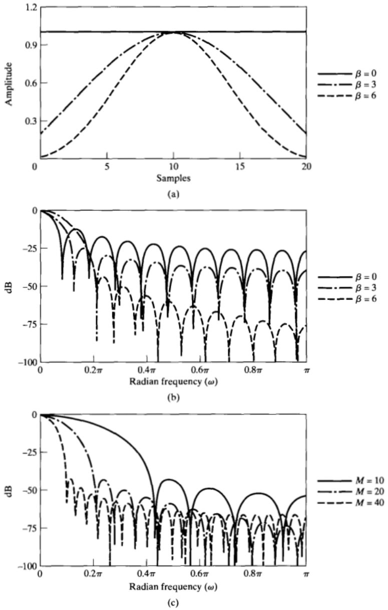


Differences between Blackman and Hamming

- The two windows have M = 50 (51 points)
- Which of these two windows should you use? It's a trade-off between parameters.
- The Hamming window has about a 20% faster roll-off than the Blackman.
- However, the Blackman has a better stopband attenuation, -74dB (-0.02%) vs. -53dB (-0.2%).
- The Blackman has a passband ripple of only about 0.02%, while the Hamming is typically 0.2%.
- In general, the Blackman should be your first choice; a slow roll-off is easier to handle than poor stopband attenuation.

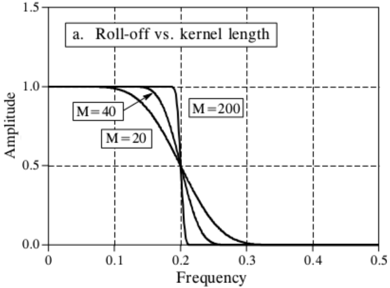


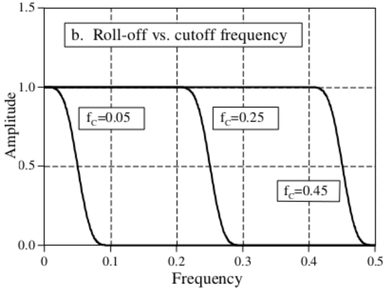
- The Kaiser window has two parameters:
  - Lenght, M+1.
  - Shape parameter, β.
- Trade-off between side-lobe amplitude and main-lobe width.



- To design a windowed-sinc, two parameters must be selected: the cutoff frequency, f_c , and the length of the filter kernel, M.
- M sets the roll-off according to the approximation, where BW_{TB} is the width of the transition band,

$$M \approx \frac{4}{BW_{TB}}$$





$$H(z) = b_0 + b_1 z^{-1} + ... + b_{M-1} z^{M-1}$$

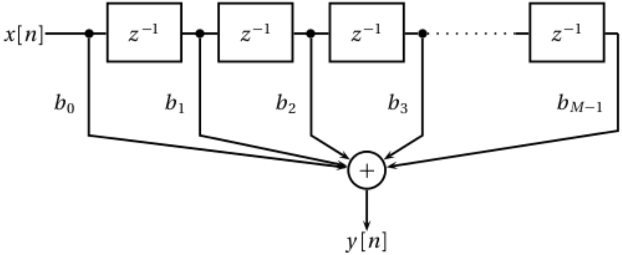


Figure 7.22 Direct FIR implementation.

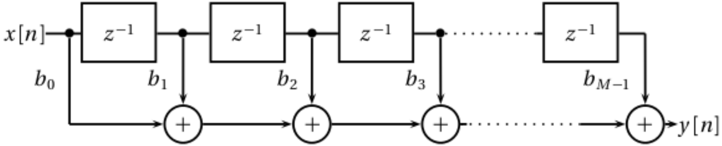


Figure 7.23 Transversal FIR implementation.

Bibliography

1 Steven W. Smith, The Scientist and Engineer's Guide to Digital Signal Processing. Chapter 16. www.dspguide.com.