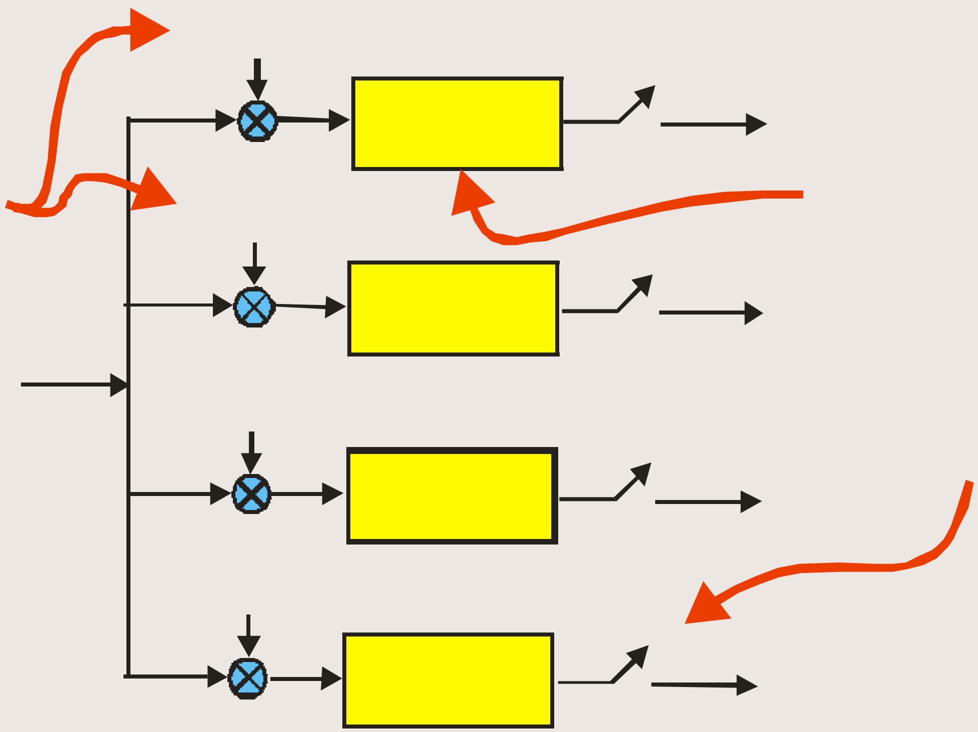
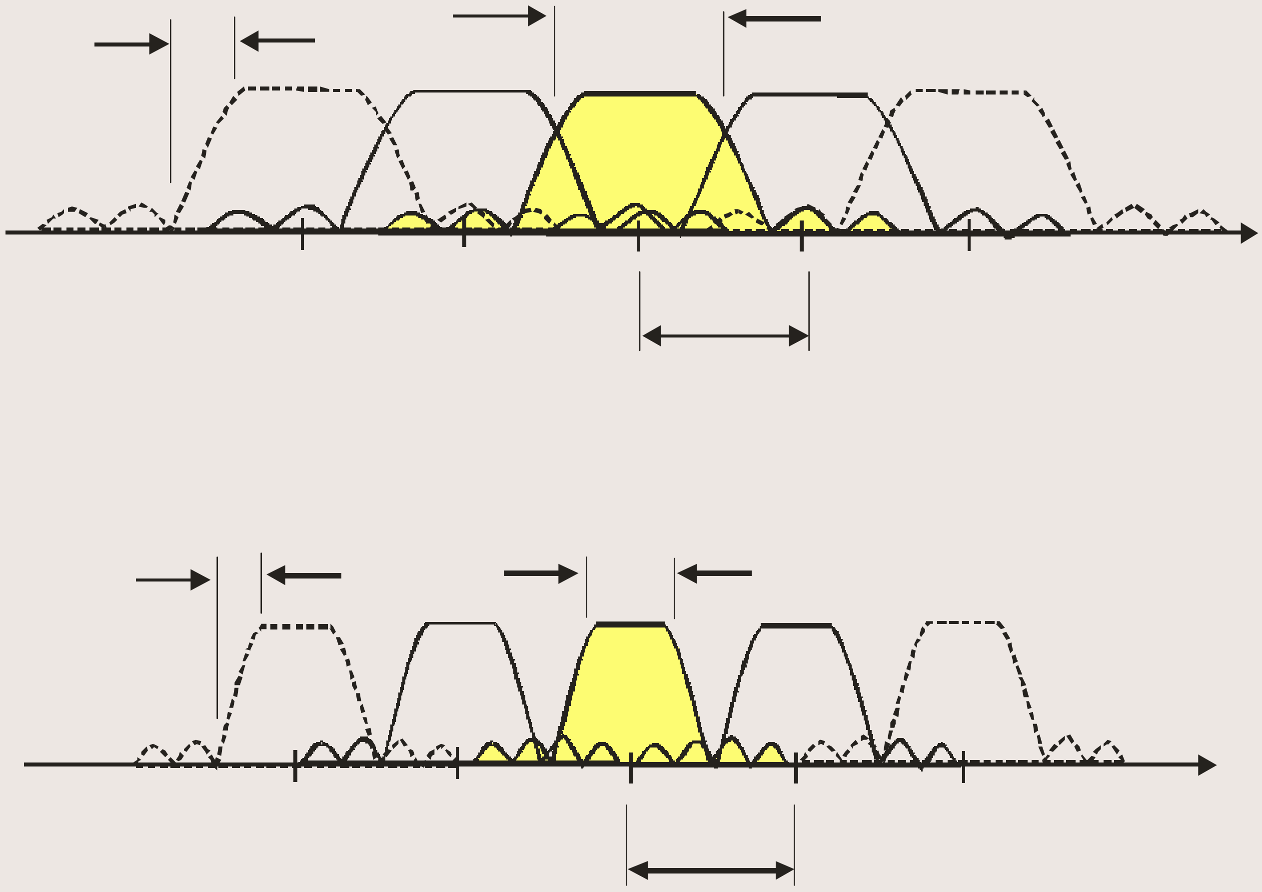
San Diego State University

Uncoupled Selection of Sampling Rate

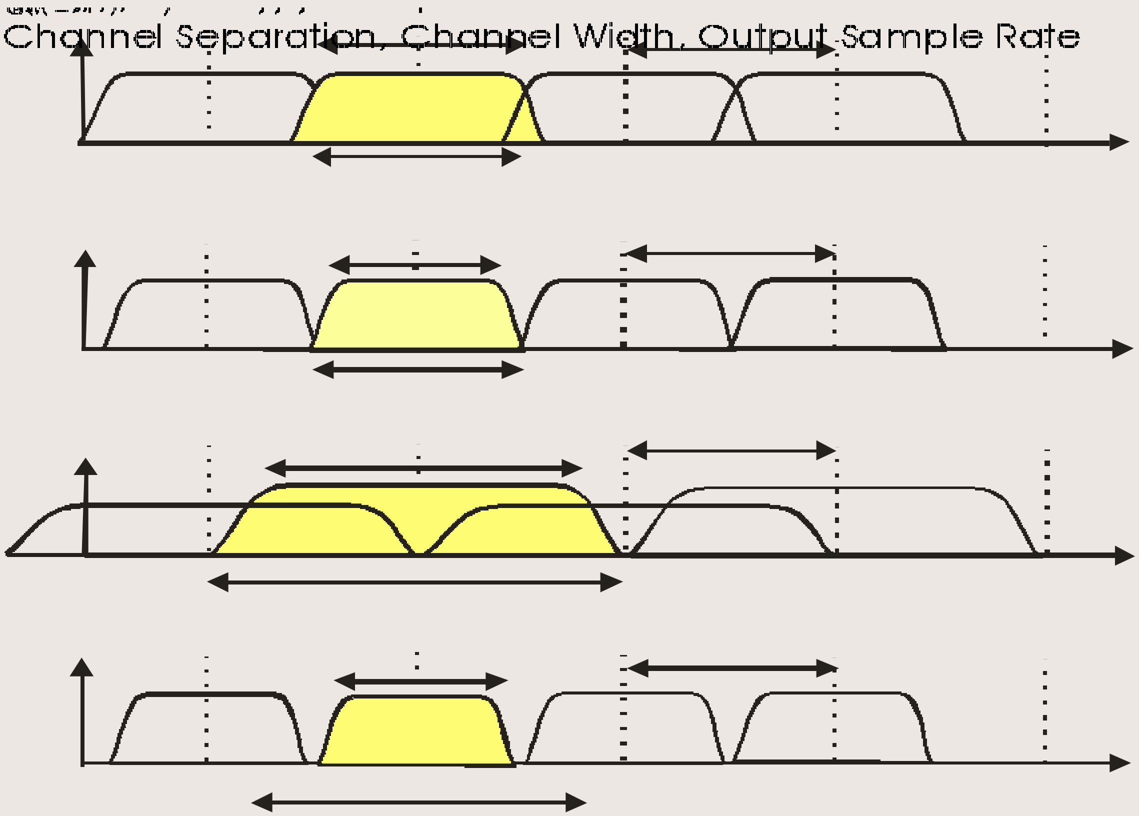


Channel Spectral Characteristics

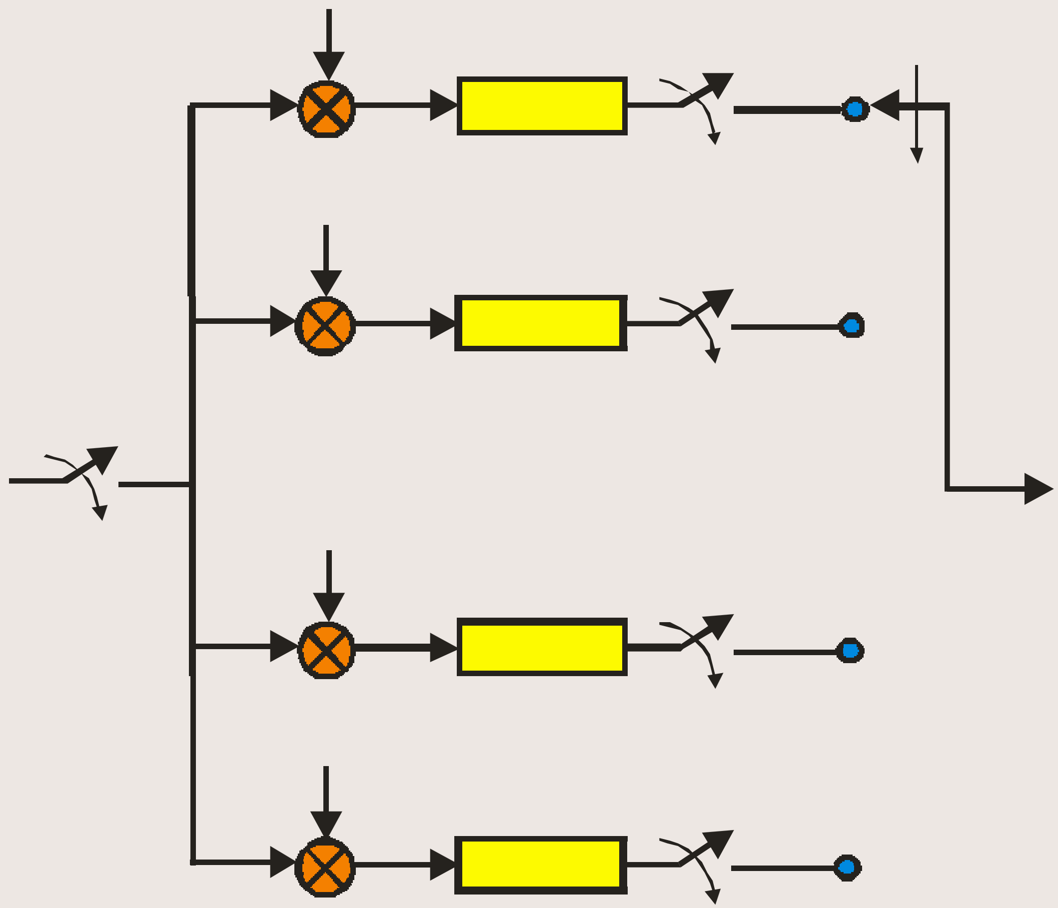
BW



Some Polyphase Filter Options

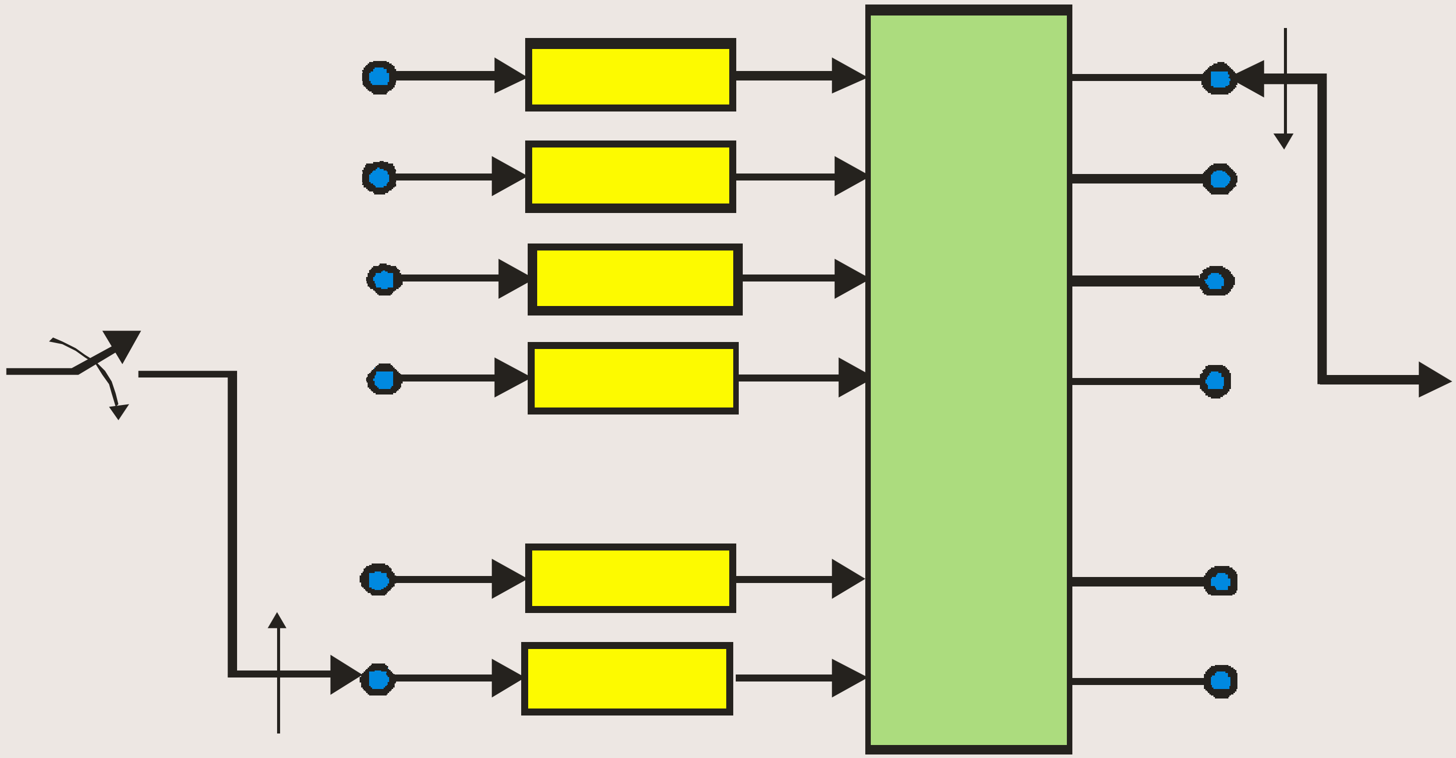


FDM-to TDM Standard Channelizer: Collection of Downconverters

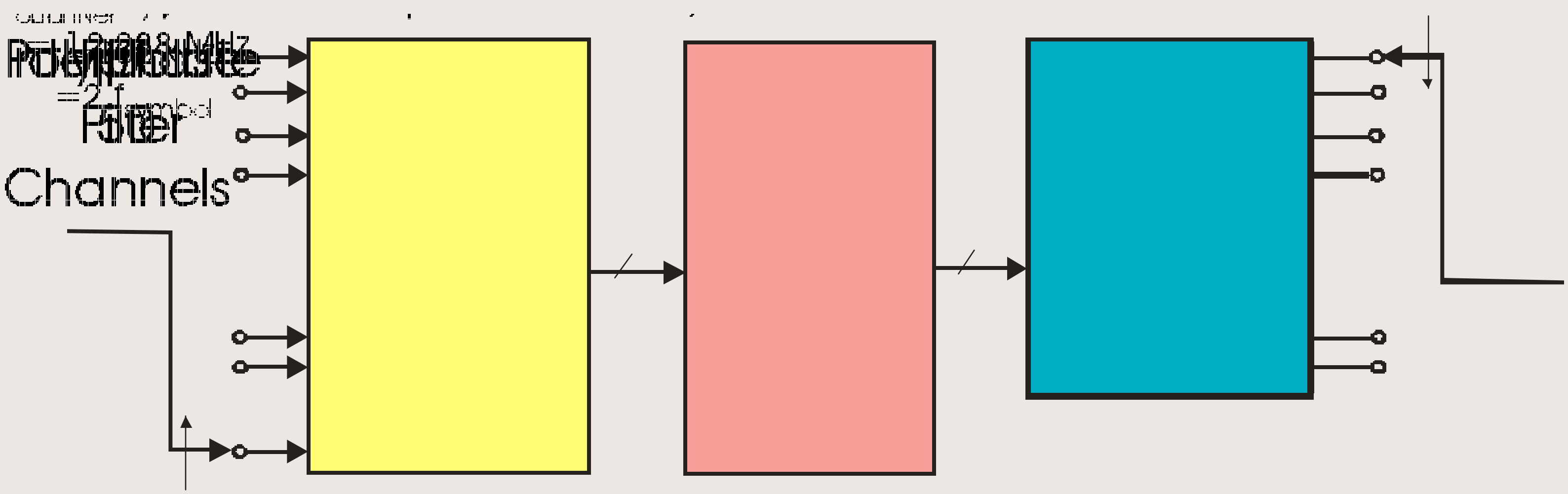


FDM-to TDM Polyphase Channelizer: Input Commutator, M-Path Filter, and FFT

Partition

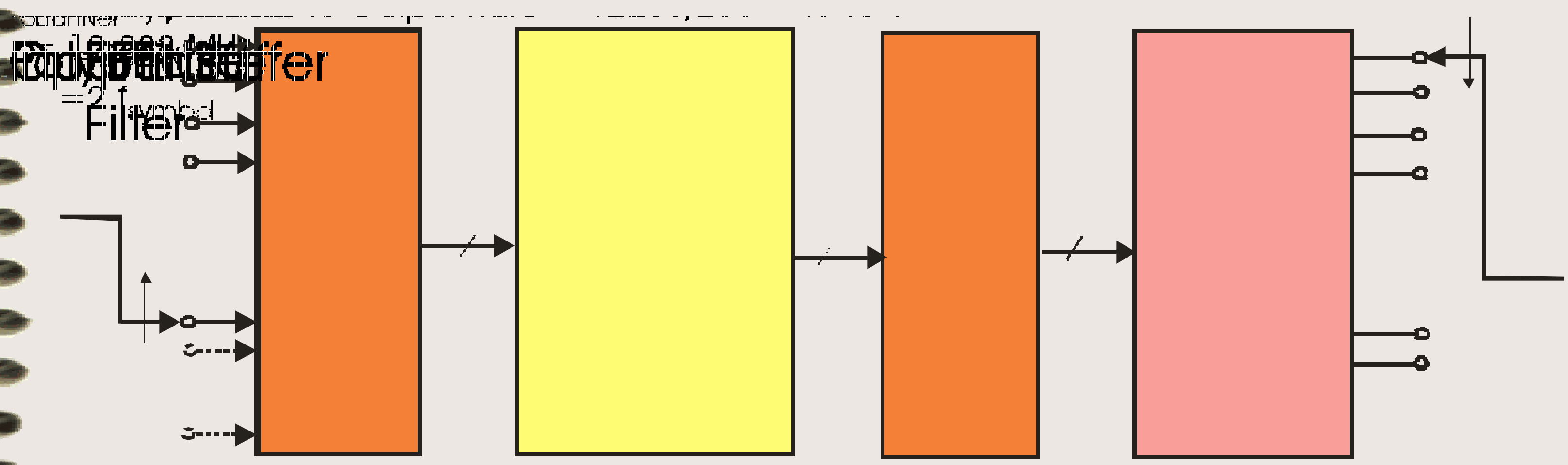


Conventional Channelizer Application Channelize and Downsample to Nyquist Rate, Interpolate to Two Times Symbol Rate

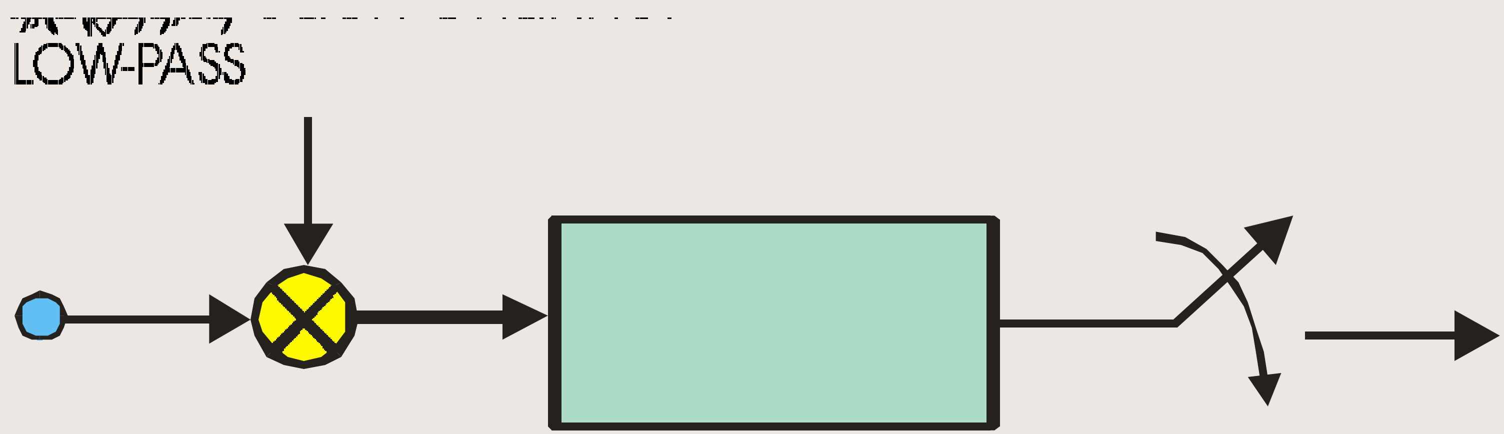


Enhanced Channelizer Solution

Replace Interpolator Function With Buffer Addressing



Standard Downconverter: Heterodyne, Filter, Resample



Equivalency Theorem
Heterodyne and Low Pass Filter Same as Band Pass Filter and Heterodyne

$$y(n,k) = [x(n)e^{-j\theta_k n}] * h(n)$$

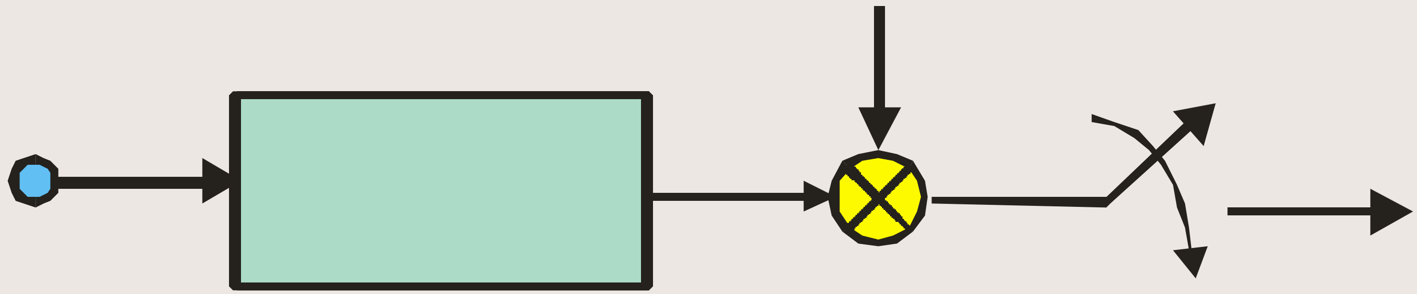
$$= \sum_{r=0}^{N-1} x(n-r)\, e^{-j(n-r)\theta_k}\, h(r)$$

$$= \sum_{r=0}^{N-1} x(n-r)\, e^{-jn\theta_k}\, h(r) e^{jr\theta_k}$$

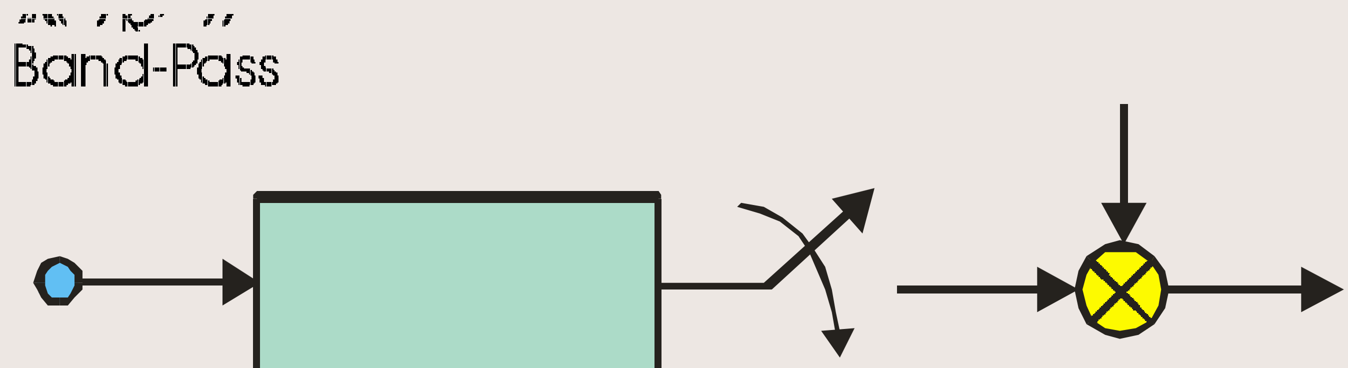
$$= e^{-jn\theta_k} \sum_{r=0}^{N-1} x(n-r)\, h(r) e^{jr\theta_k}$$

Slide Heterodyne Through Filter: Convert Low-Pass to Band-Pass

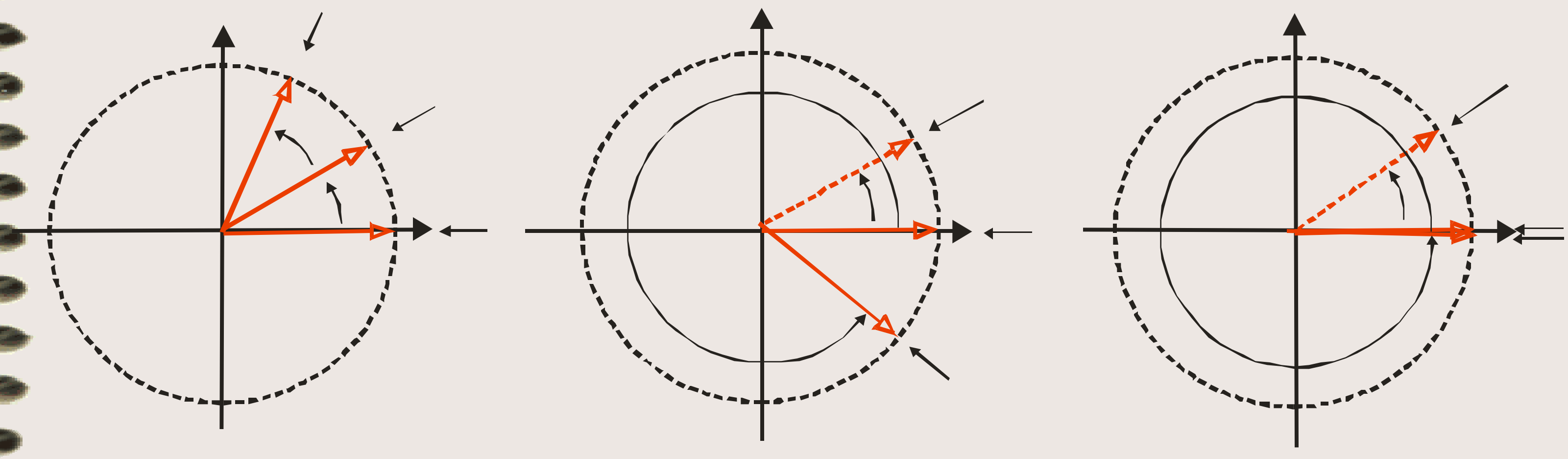
Band-Pass



Slide Heterodyne Through Downsampler: Alias Frequency of Heterodyne

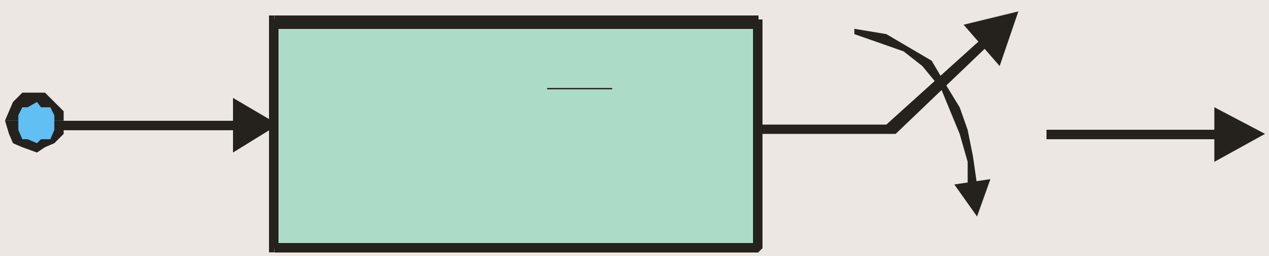


Select Input Center Frequency That Aliases to DC Under Resampling



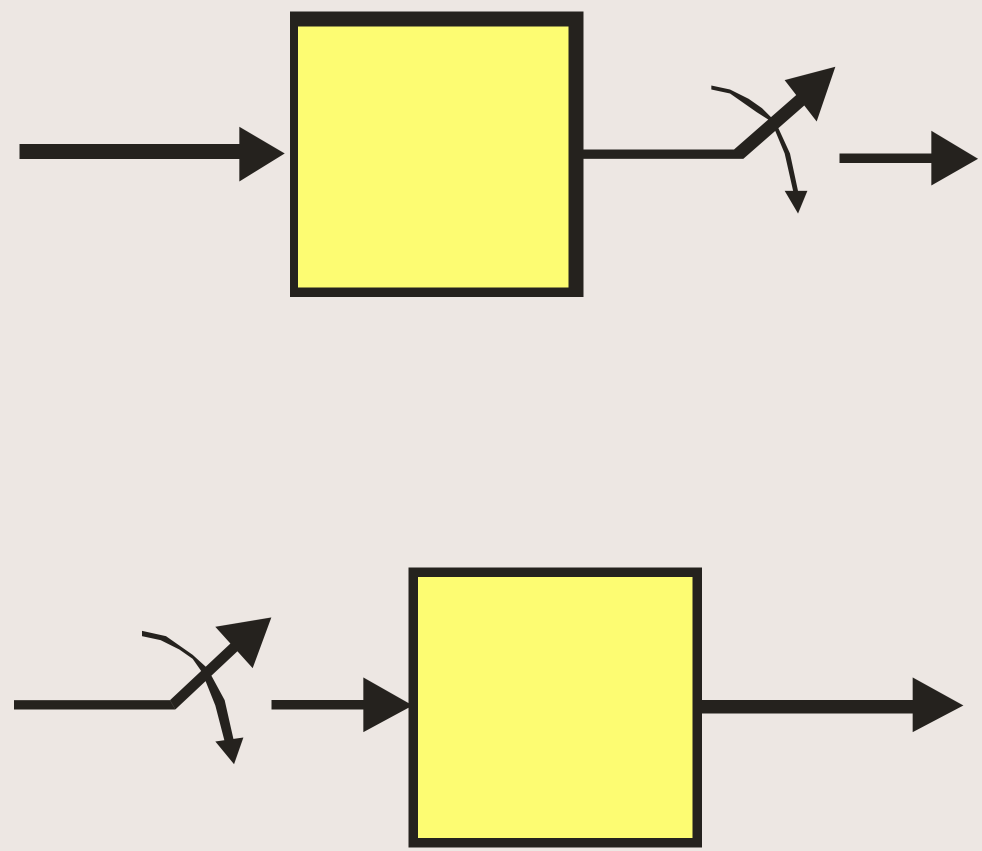
Discard Trivial Heterodyne: Now a Scalar Multiply by Unity

Band-Pass



Noble Identity

Interchange Order of Filter and Resample



M-Path Partition of FIR Filter

$$H(Z) = \sum_{n=0}^{N-1} h(n)\, Z^{-n}$$

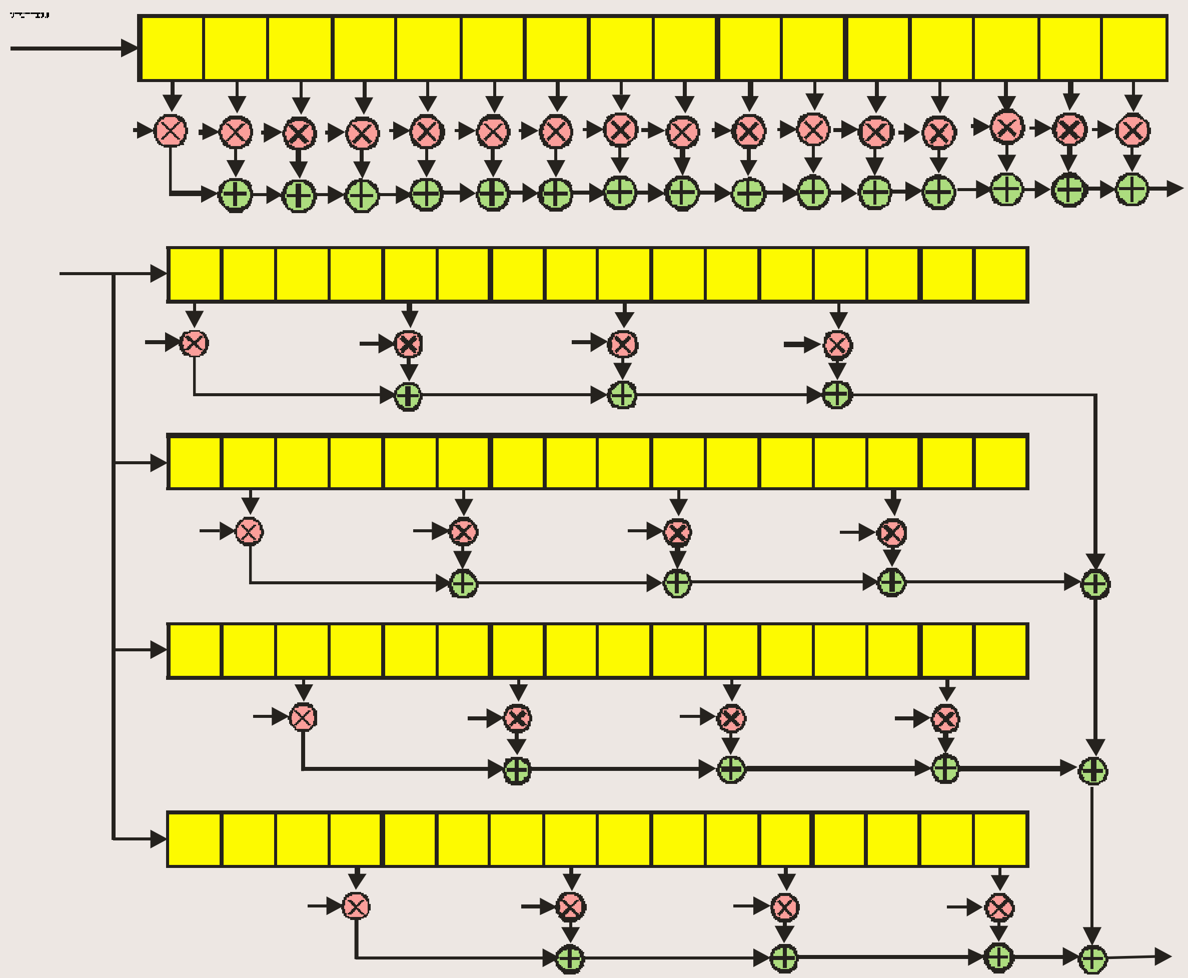
$$= h(0) + h(1)\,Z^{-1} + h(2)\,Z^{-2} + h(3)\,Z^{-3} + \cdots + h(N-1)\,Z^{-(N-1)}$$

$$\begin{array}{lllll}
H(Z) = \quad h(0) & + \quad h(M+0)\,Z^{-M} & + h(2M+0)Z^{-(2M+0)} & + \cdots \\
h(1)Z^{-1} & + \quad h(M+1)Z^{-(M+1)} & + h(2M+1)Z^{-(2M+1)} & + \cdots \\
h(2)Z^{-2} & + \quad h(M+2)Z^{-(M+2)} & + h(2M+2)Z^{-(2M+2)} & + \cdots \\
h(3)Z^{-3} & + \quad h(M+3)Z^{-(M+3)} & + h(2M+3)Z^{-(2M+3)} & + \cdots \\
\vdots & \vdots \quad\quad \vdots & \vdots \quad\quad \vdots & \vdots \\
h(M-1)Z^{-(M-1)} & + h(2M-1)Z^{-(2M-1)} & + h(3M-1)Z^{-(3M-1)} & + \cdots
\end{array}$$

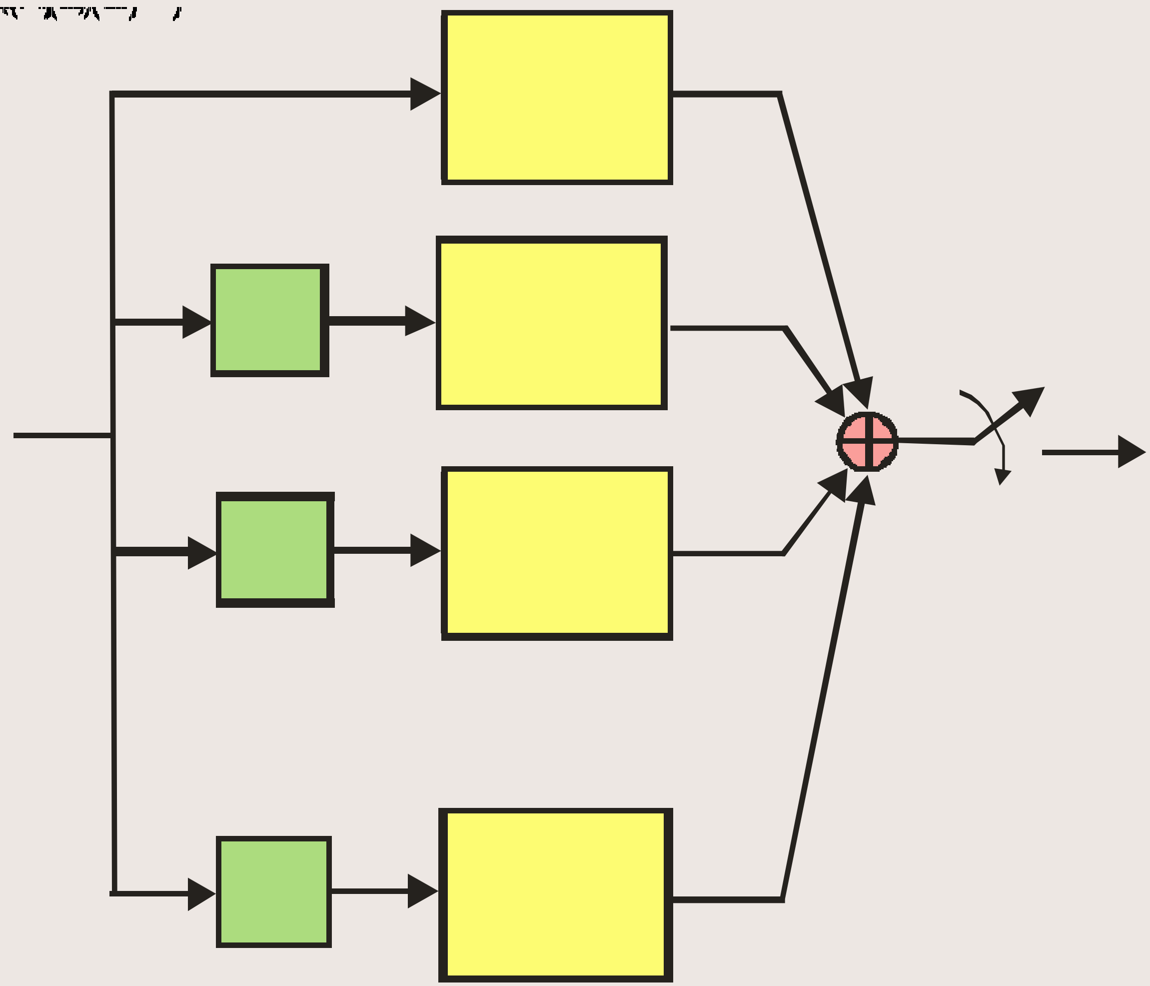
$$H(Z) = H_0(Z^M) + Z^{-1}H_1(Z^M) + Z^{-2}H_2(Z^M) + \cdots\cdots + Z^{-(M-1)}H_{(M-1)}(Z^M)$$

$$H(Z) = \sum_{r=0}^{M-1} Z^{-r} H_r(Z^M) \quad = \quad \sum_{r=0}^{M-1} Z^{-r} \sum_{n=0}^{(N/M)-1} h(r+nM) Z^{-M\,n}$$

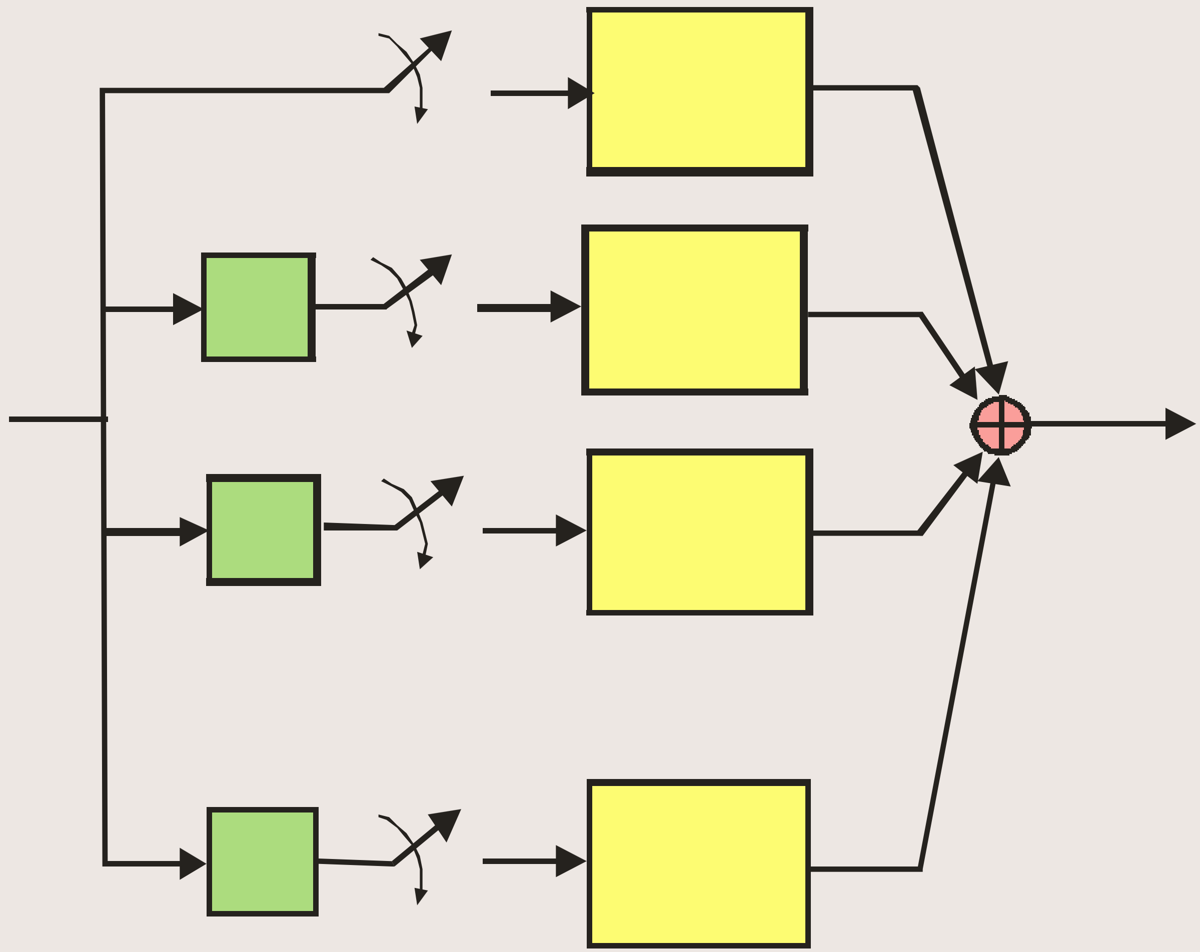
Example of Polyphase (M-Path) Partition



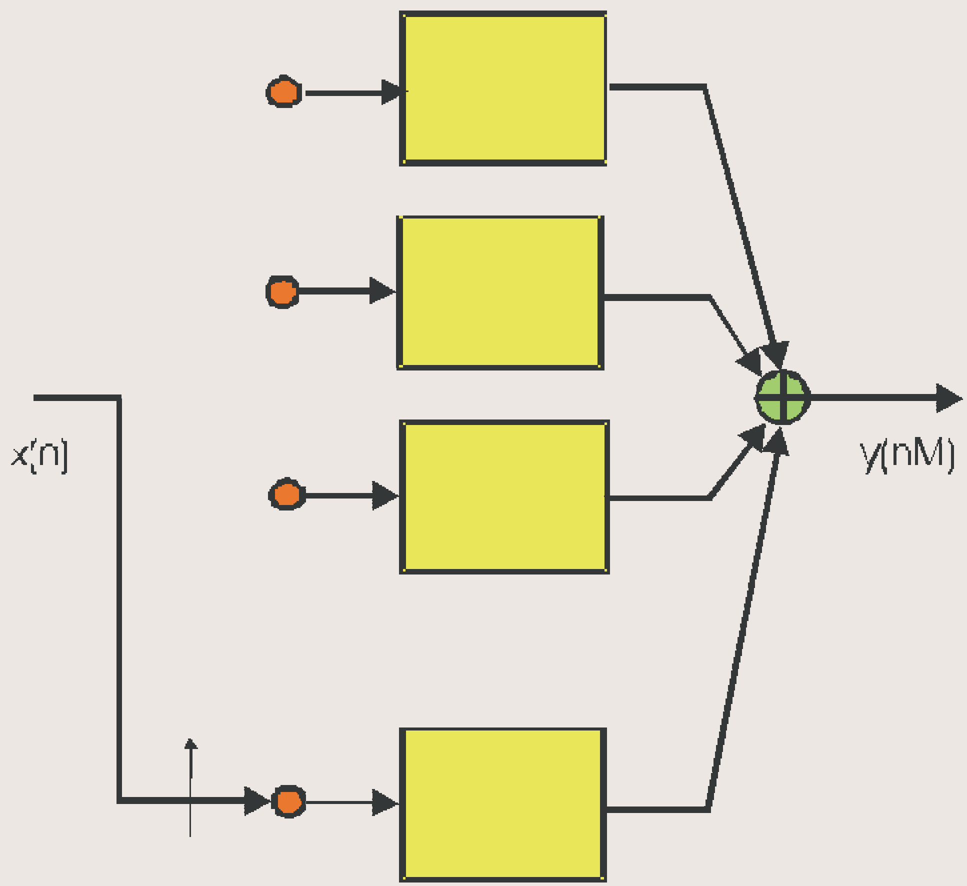
Block Diagram of M-Path Filter



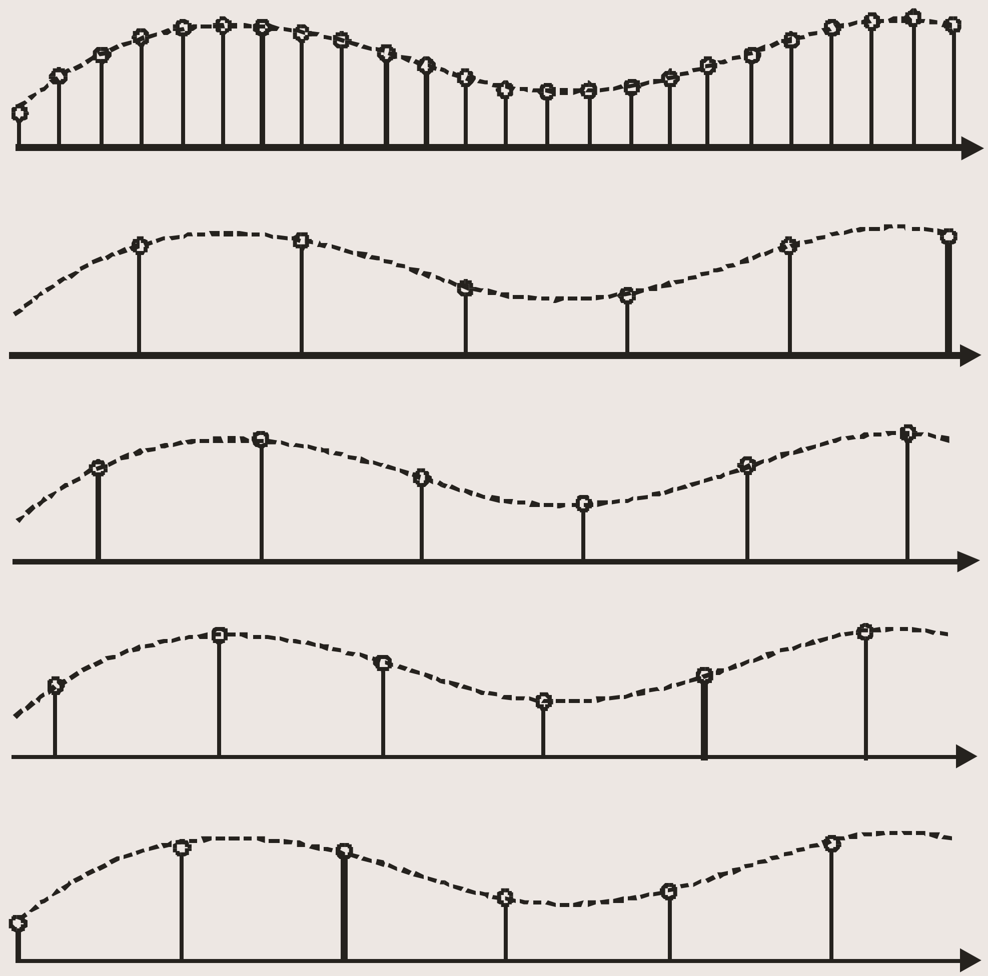
Pull Resamplers Through Filters in Each path



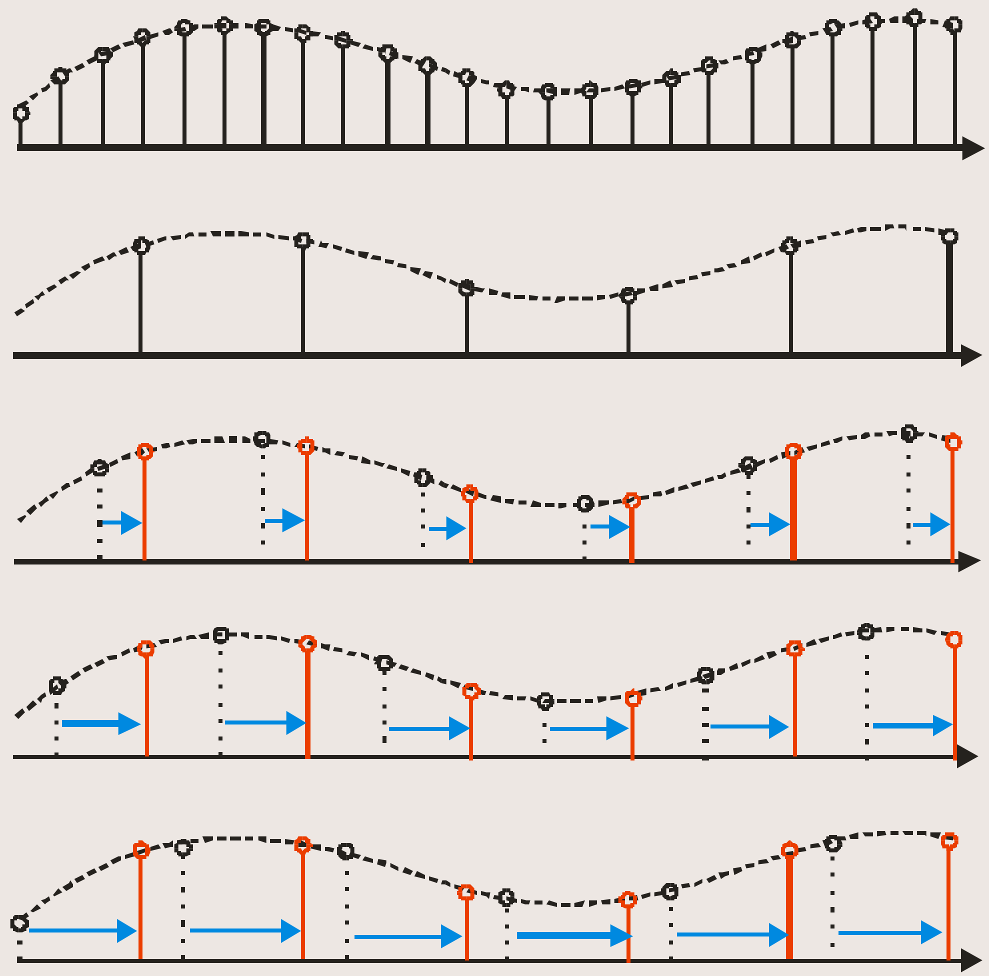
Delays and Synchronous Rersamplers are Equivalent to Input Commutator



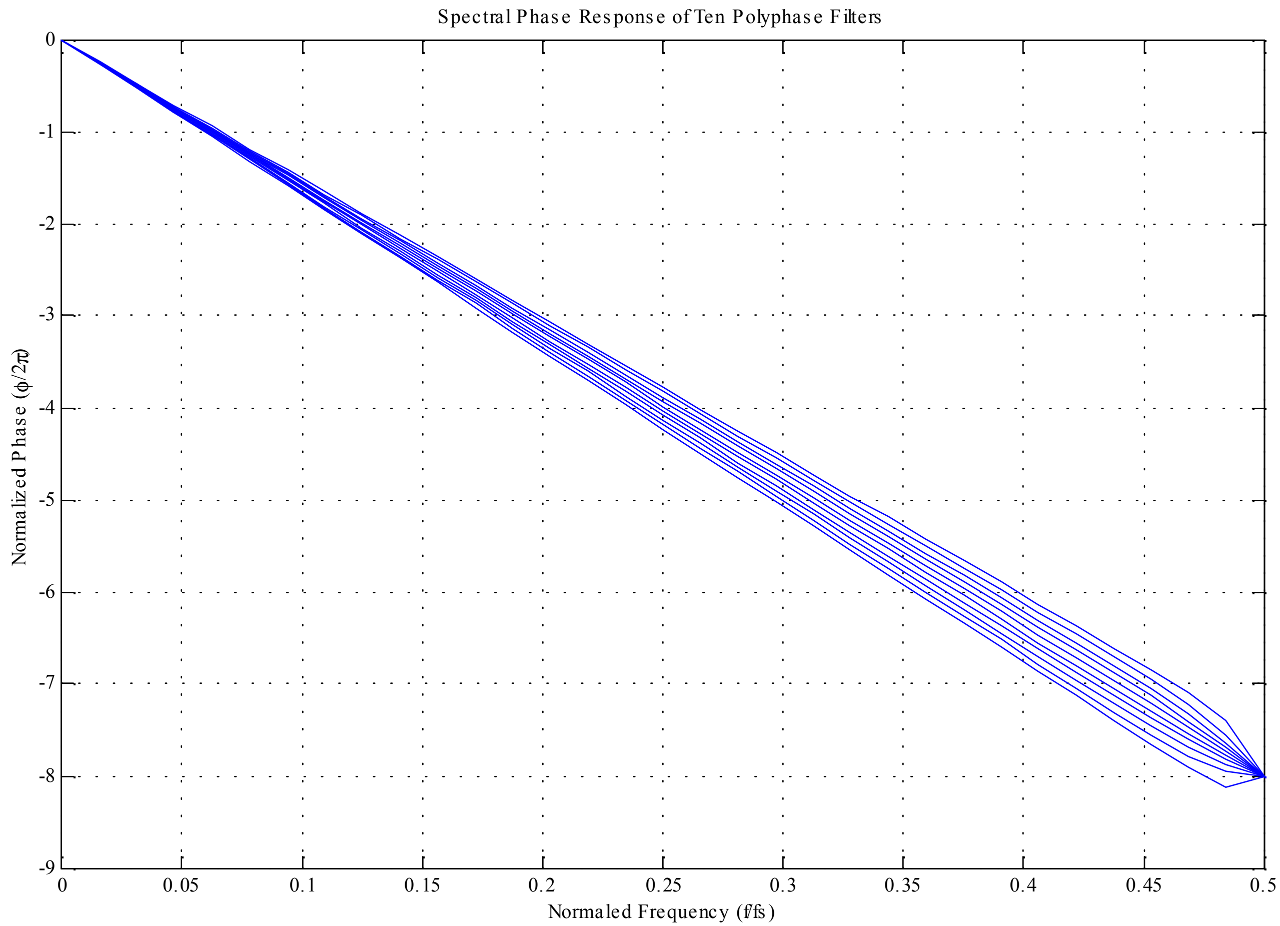
Input Series in Each Path of M-Path Filter have Offset Time Origins



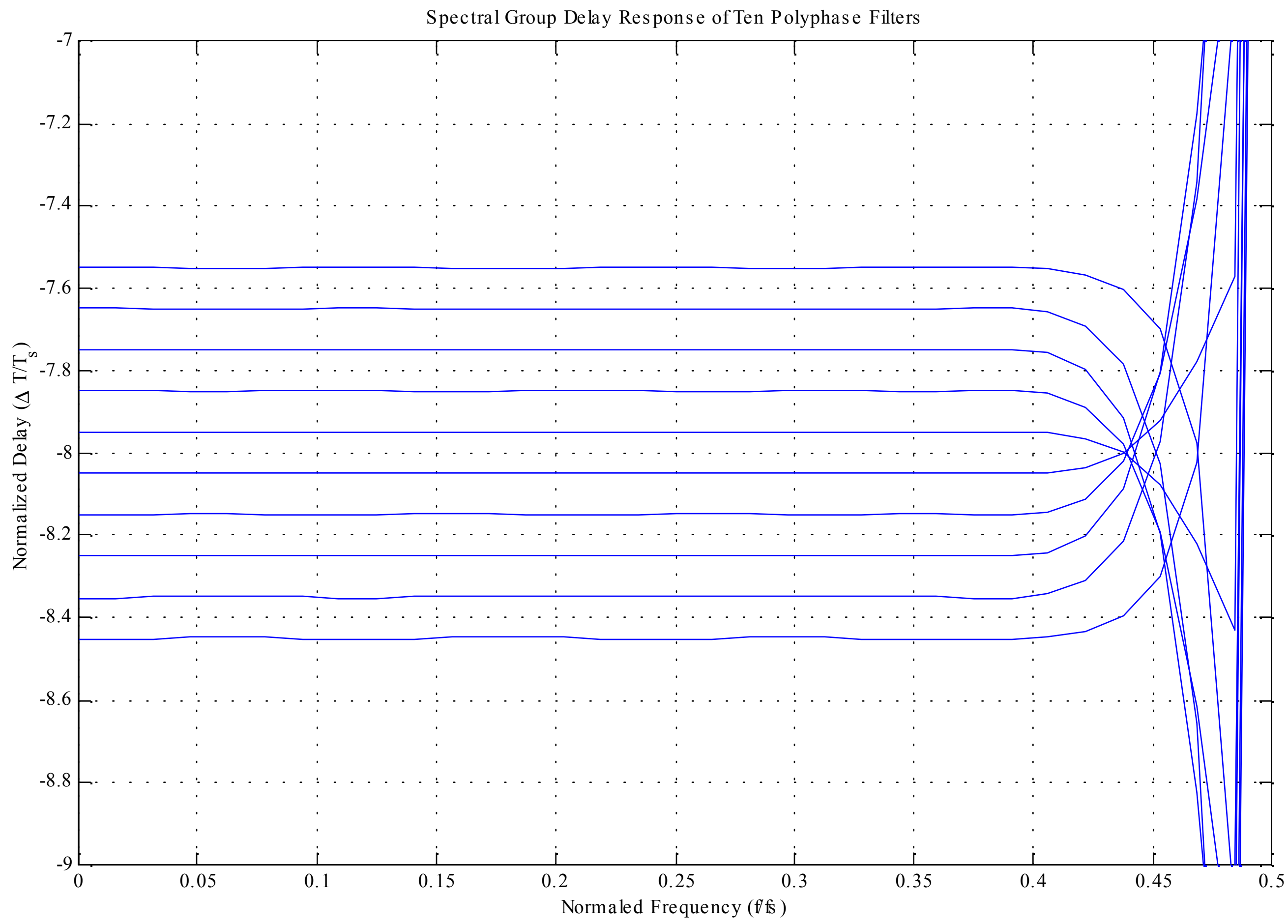
Path Filters are Interpolators: Computing Output Samples with Common Time Origin



Phase Response of Paths in Ten Stage Polyphase Filter



Group Delay of Paths in Ten-Stage Polyphase Filter



Modulation Property for Z-Transform

if

$$H(Z) = h(0) + h(1)Z^{-1} + h(2)Z^{-2} + \cdots + n(N-1)Z^{-(N-1)}$$

$$= \sum_{n=0}^{N-1} h(n)Z^{-n}$$

and

$$G(Z) = h(0) + h(1)e^{j\theta}Z^{-1} + h(2)e^{j2\theta}Z^{-2} + \cdots + h(N-1)e^{j(N-1)\theta}Z^{-(N-1)}$$

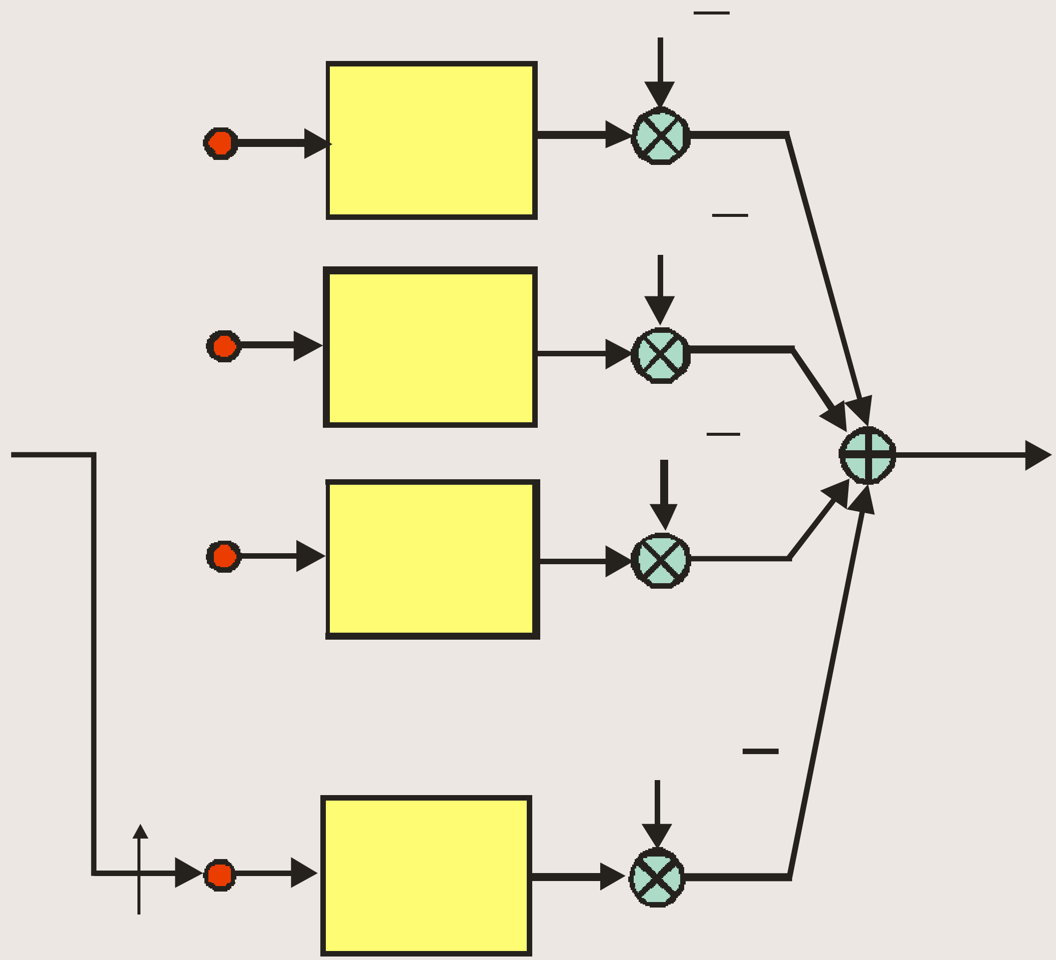
$$= h(0) + h(1)[e^{-j\theta}Z]^{-1} + h(2)[e^{-j2\theta}Z]^{-2} + \cdots + h(N-1)[e^{-j(N-1)\theta}Z]^{-(N-1)}$$

$$= \sum_{n=0}^{N-1} h(n)[e^{-j\theta}Z]^{-n}$$

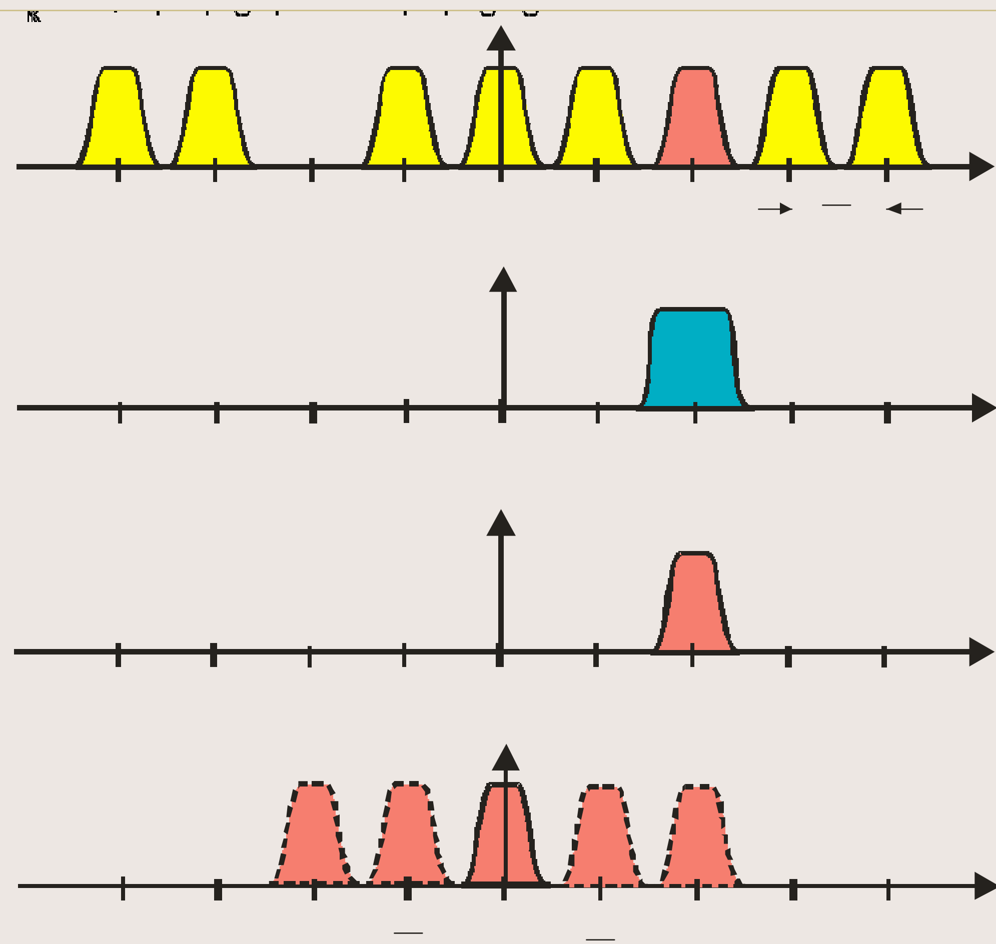
then

$$\mathrm{G(Z)} = \mathrm{H(Z)}\Big|_{\mathrm{Z=e^{-j\theta}}Z} = H(e^{-j\theta}Z)$$

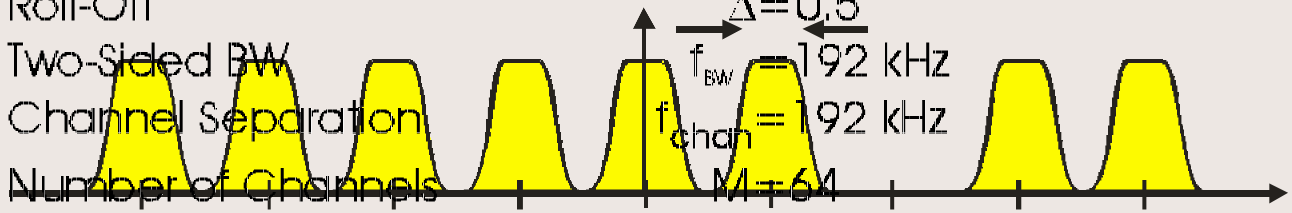
Polyphase Partition of Band-Pass Filter



Spectral Response of Signal in Resampled Pass Band Filter

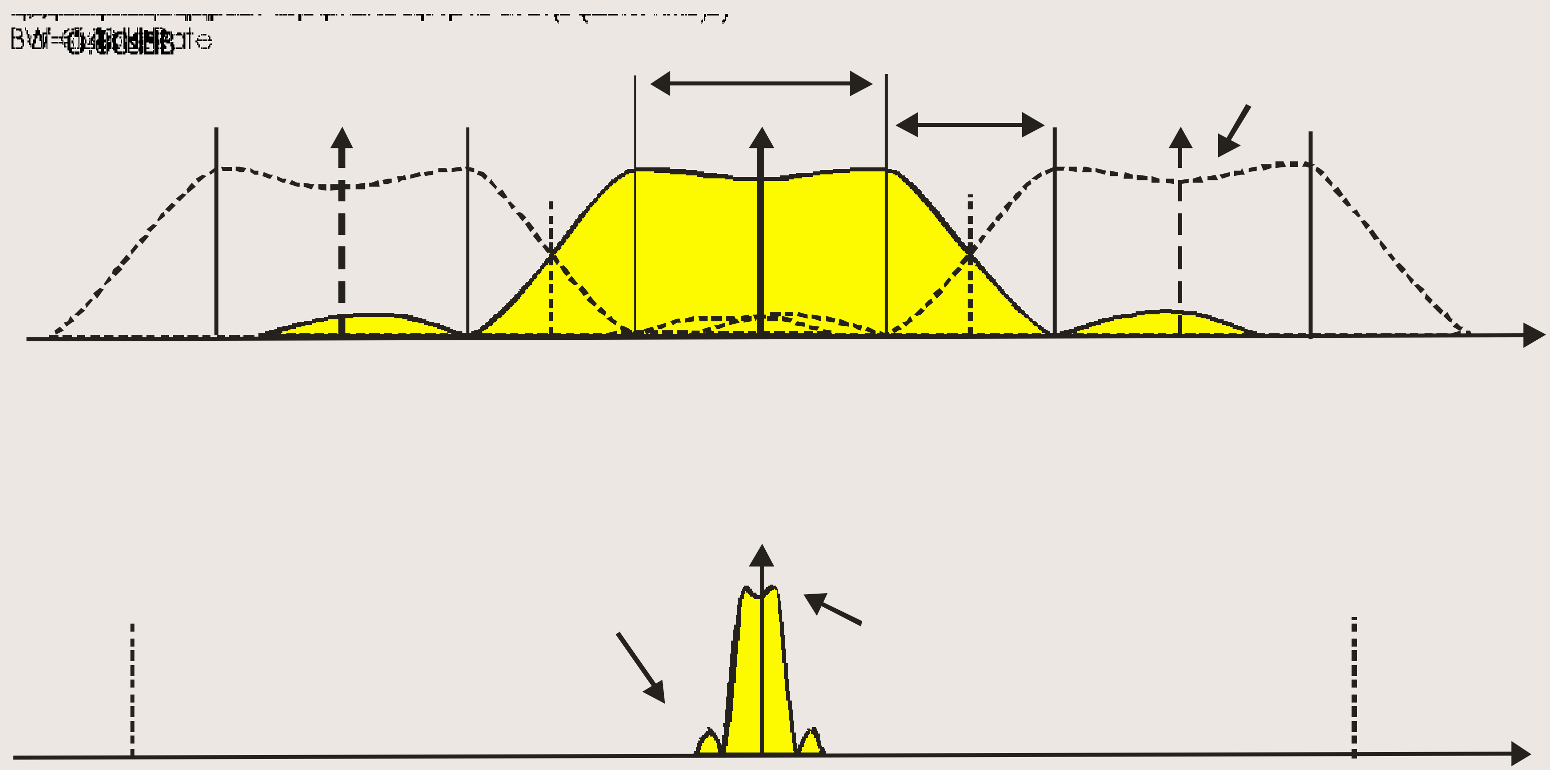


Performance Specifications for 50-Channel Polyphase Channelizer

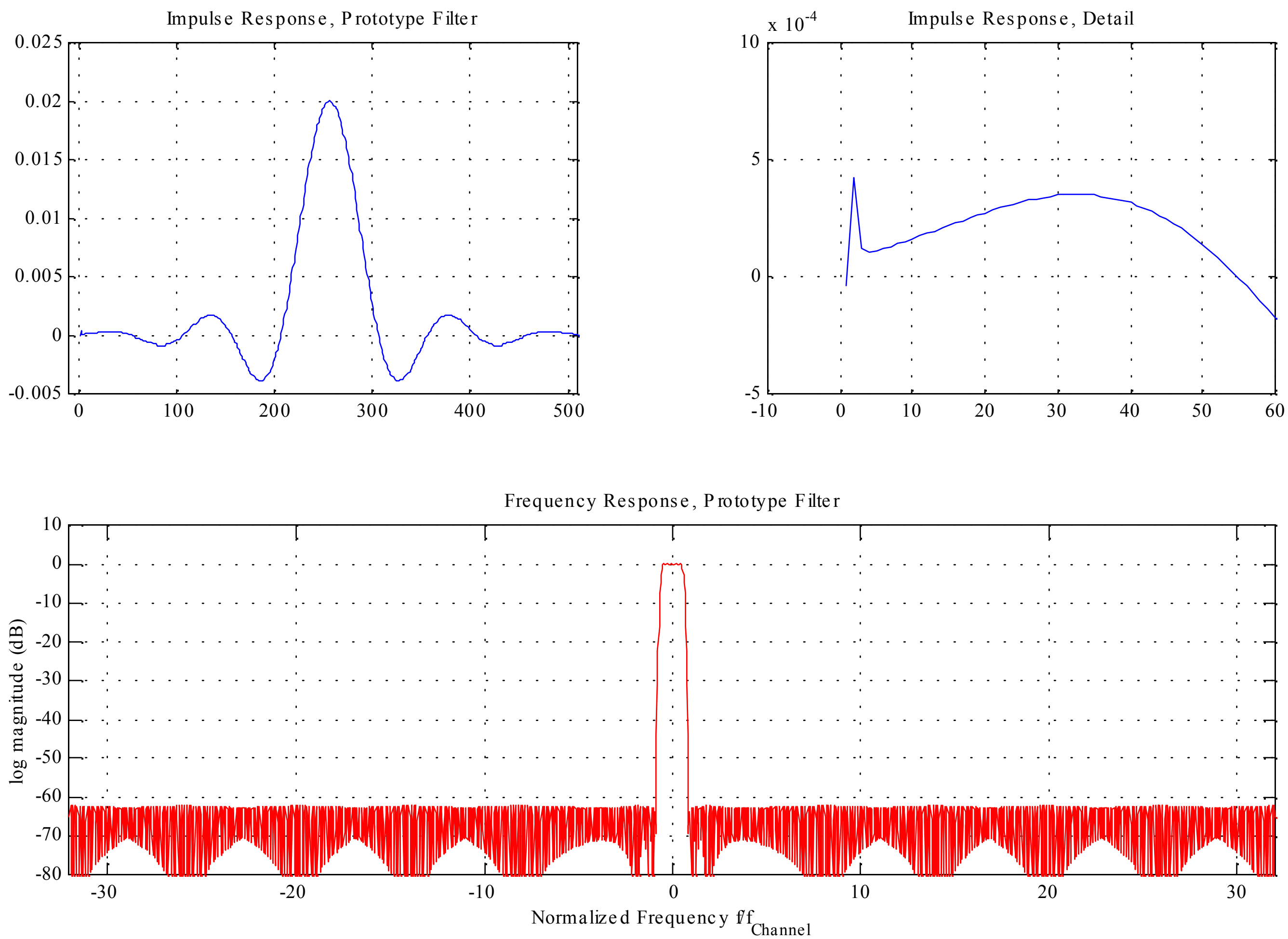


Roll-Off		$\Delta = 0.5$
Two-Sided BW	f_{BW}	$= 192$ kHz
Channel Separation	f_{chan}	$= 192$ kHz
Number of Channels		$M = 64$
Number of Useful Channels		$N = 50$
Input Sample Rate 64*192	$f_{s\text{-}input}$	$= 12.288$ MHz
Output Rate 2*128	$f_{s\text{-}output}$	$= 256$ kHz

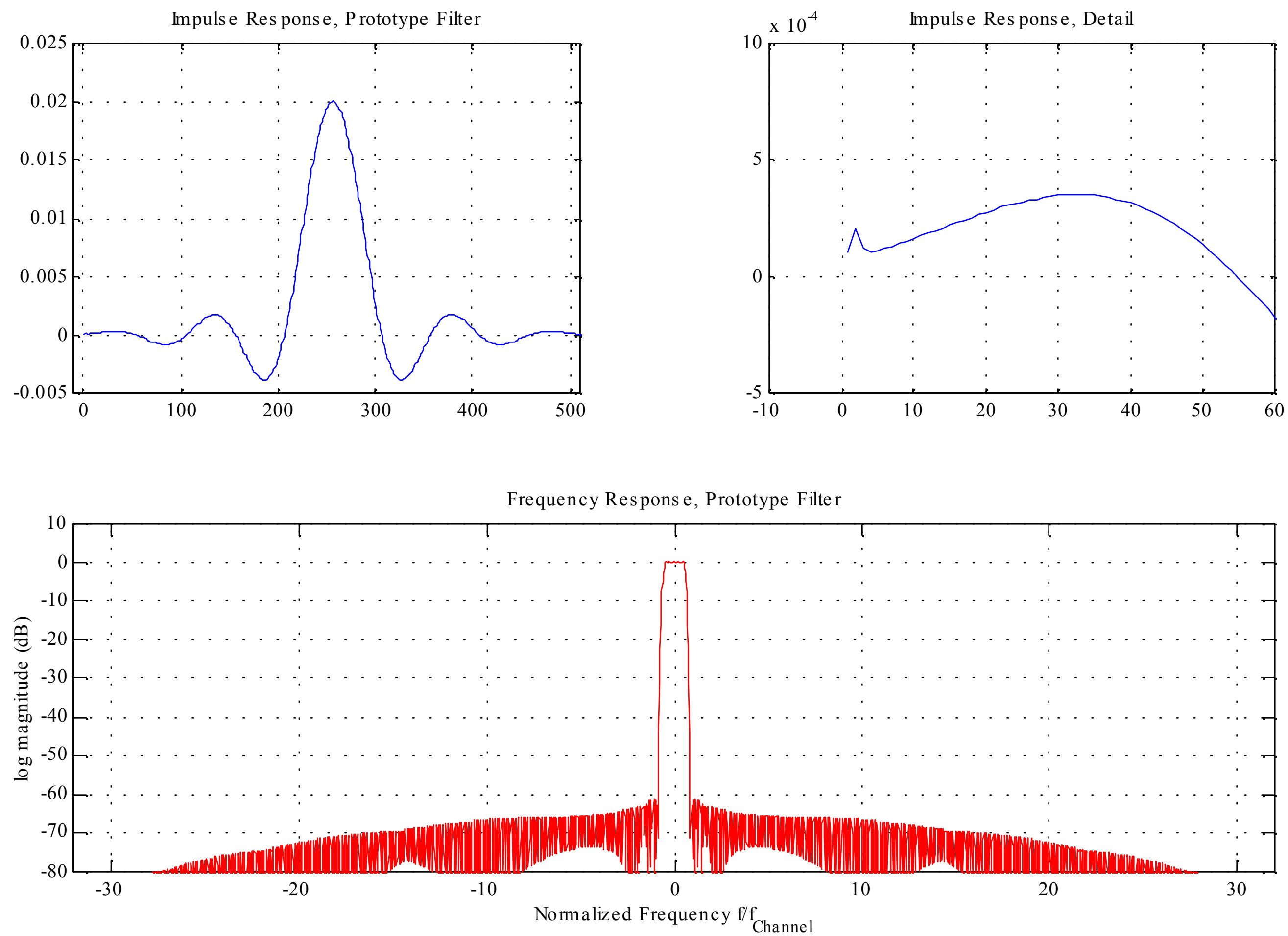
Required Spectral Response of Channel Filter at Output and at Input Rates



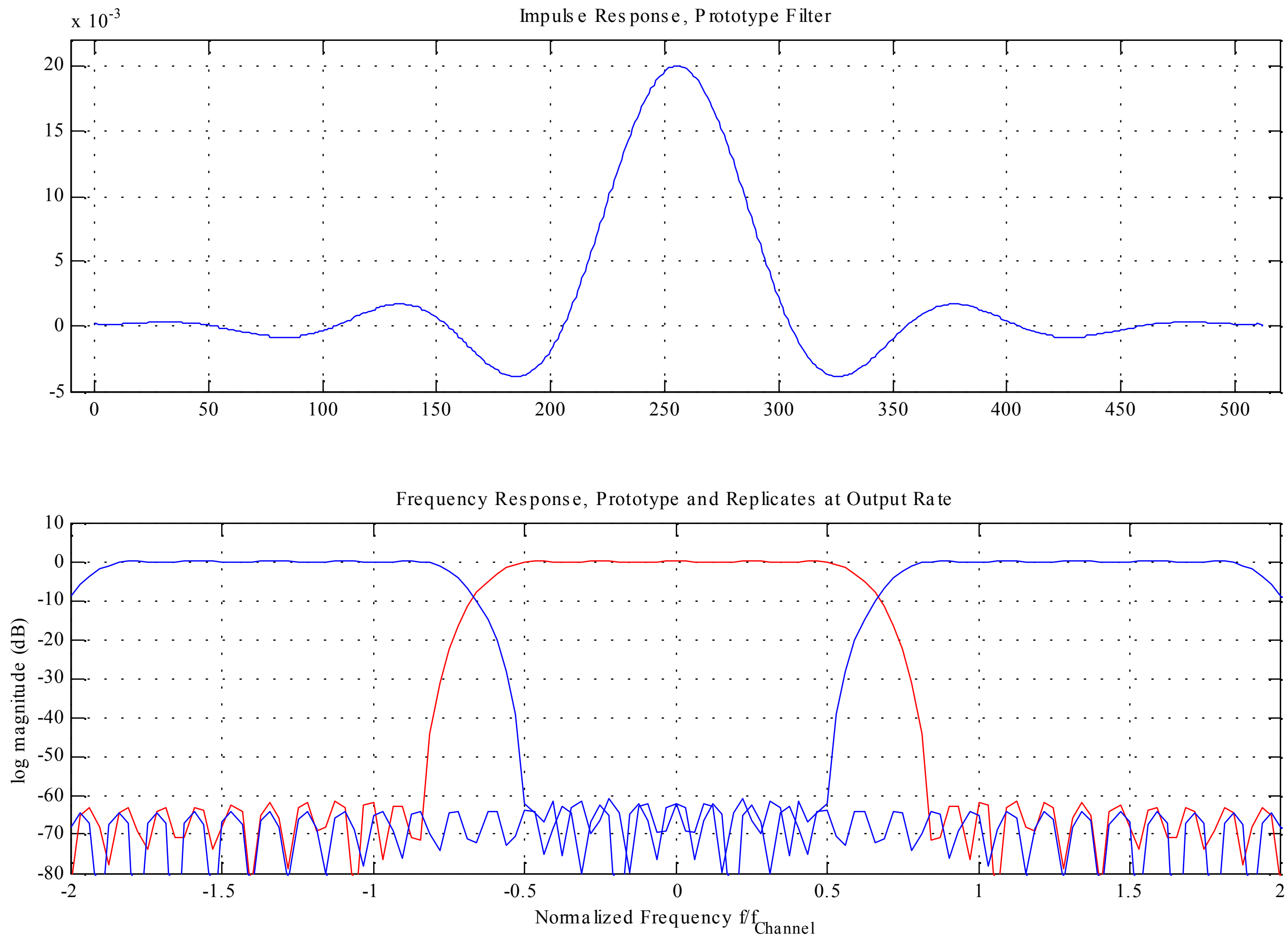
Time and Frequency Response of Remez Filter Design



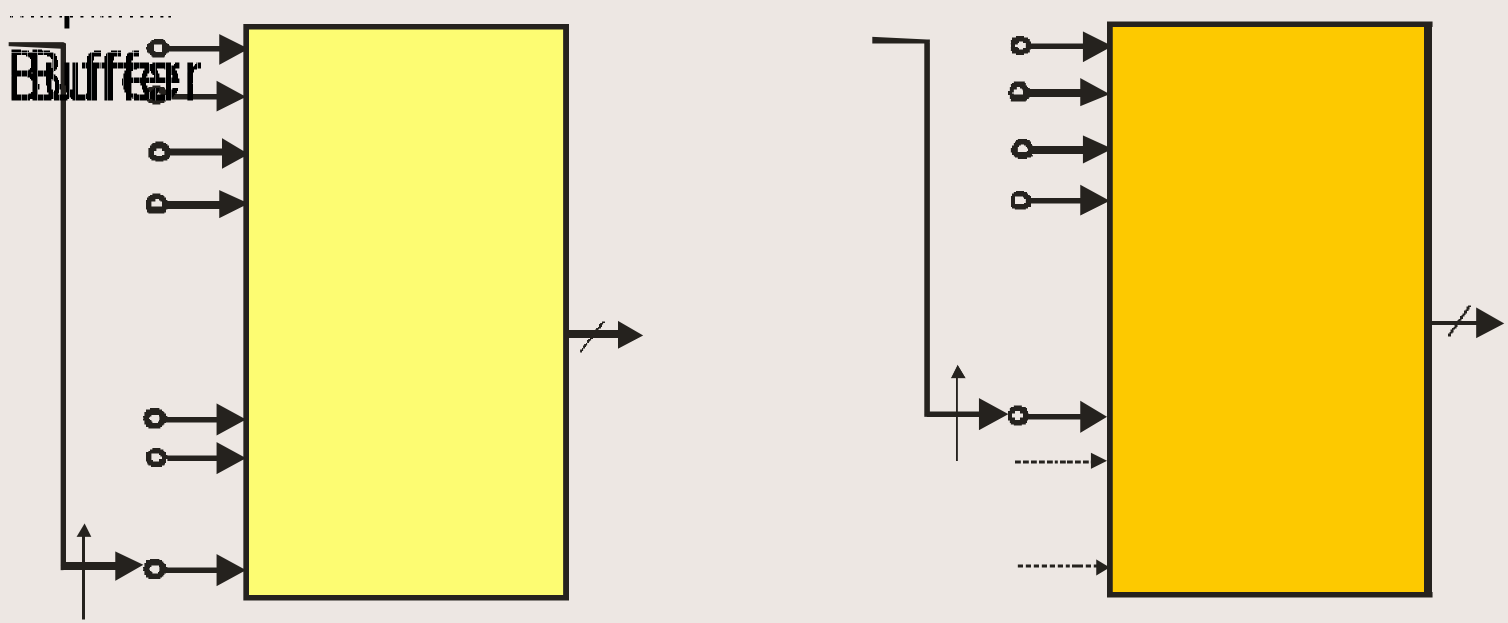
Time and Frequency response of Remez Filter Design with Modified End Points



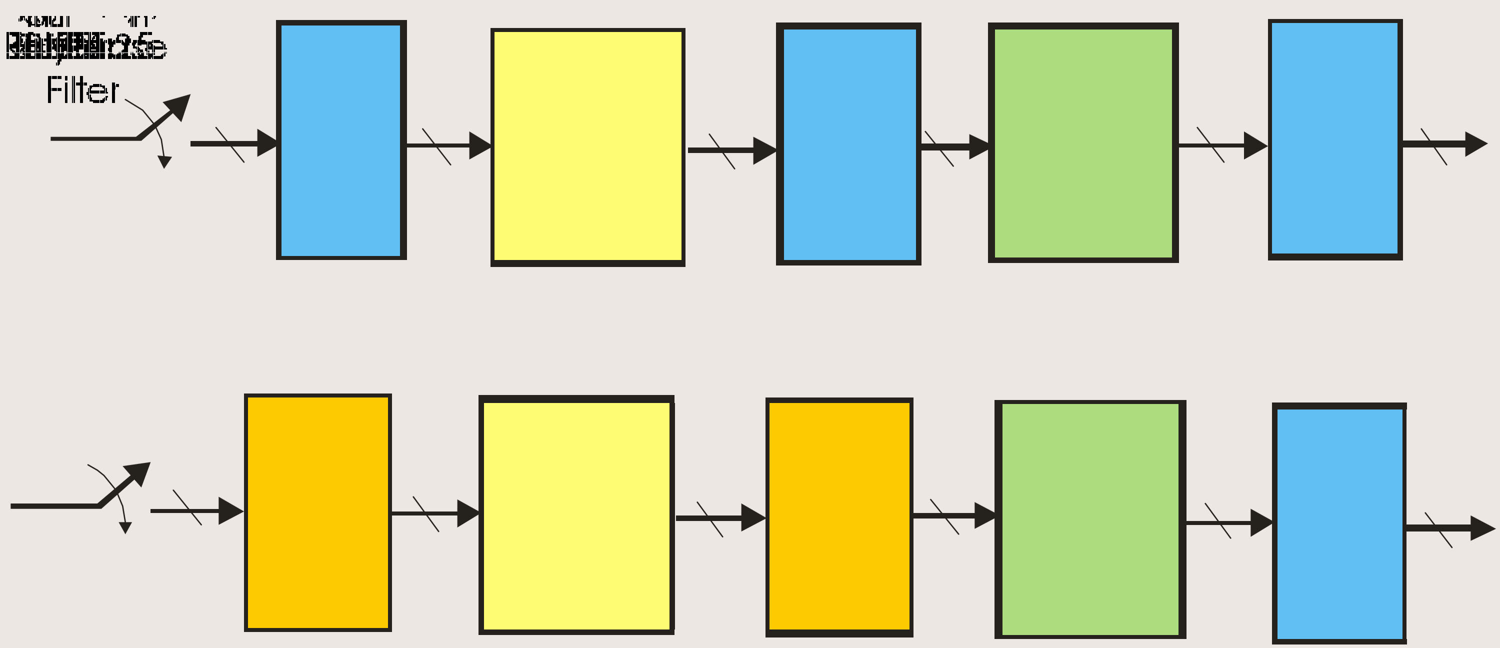
Time and Frequency Response of Prototype Filter at Output Sample Rate



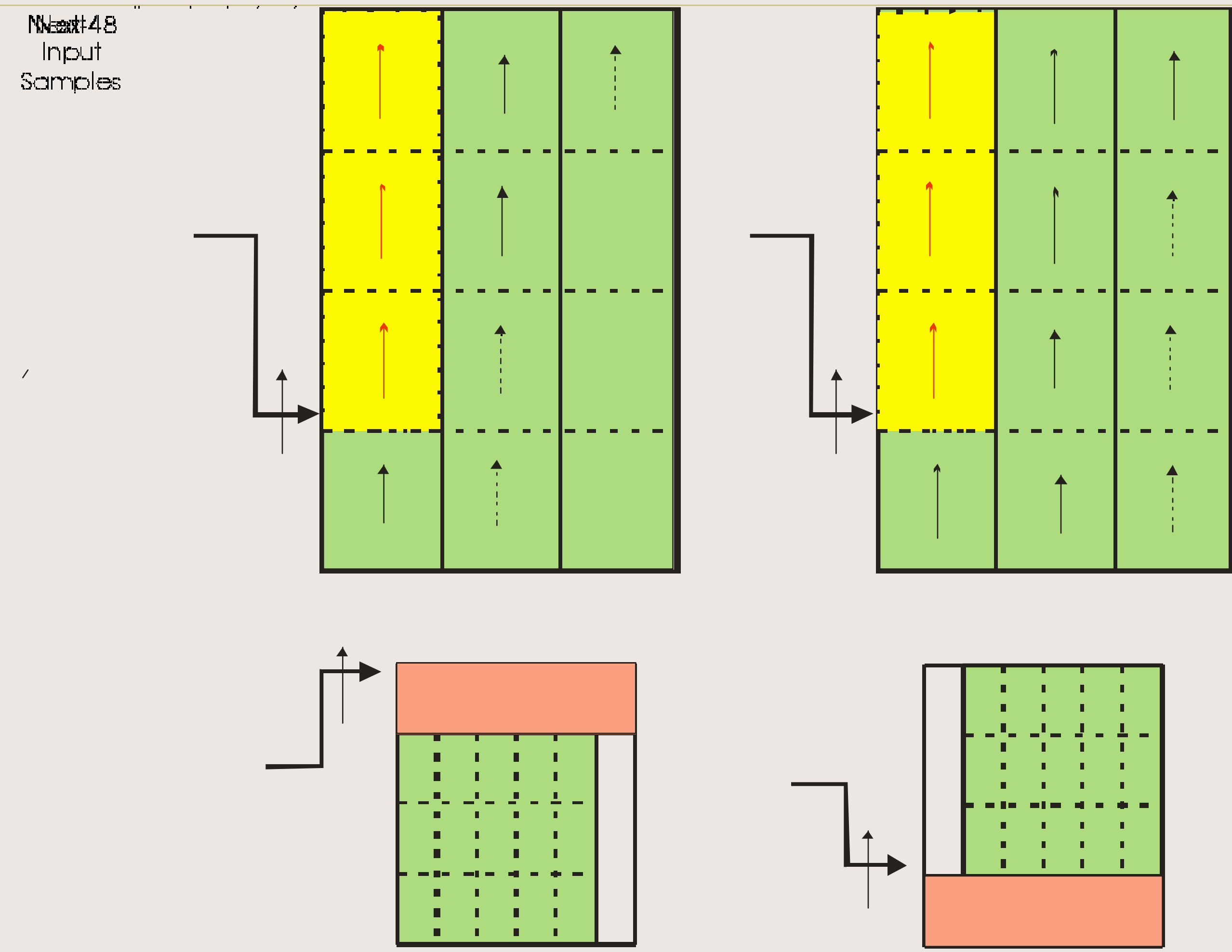
Commutators for Standard Input Buffer and for Circular Input Buffer



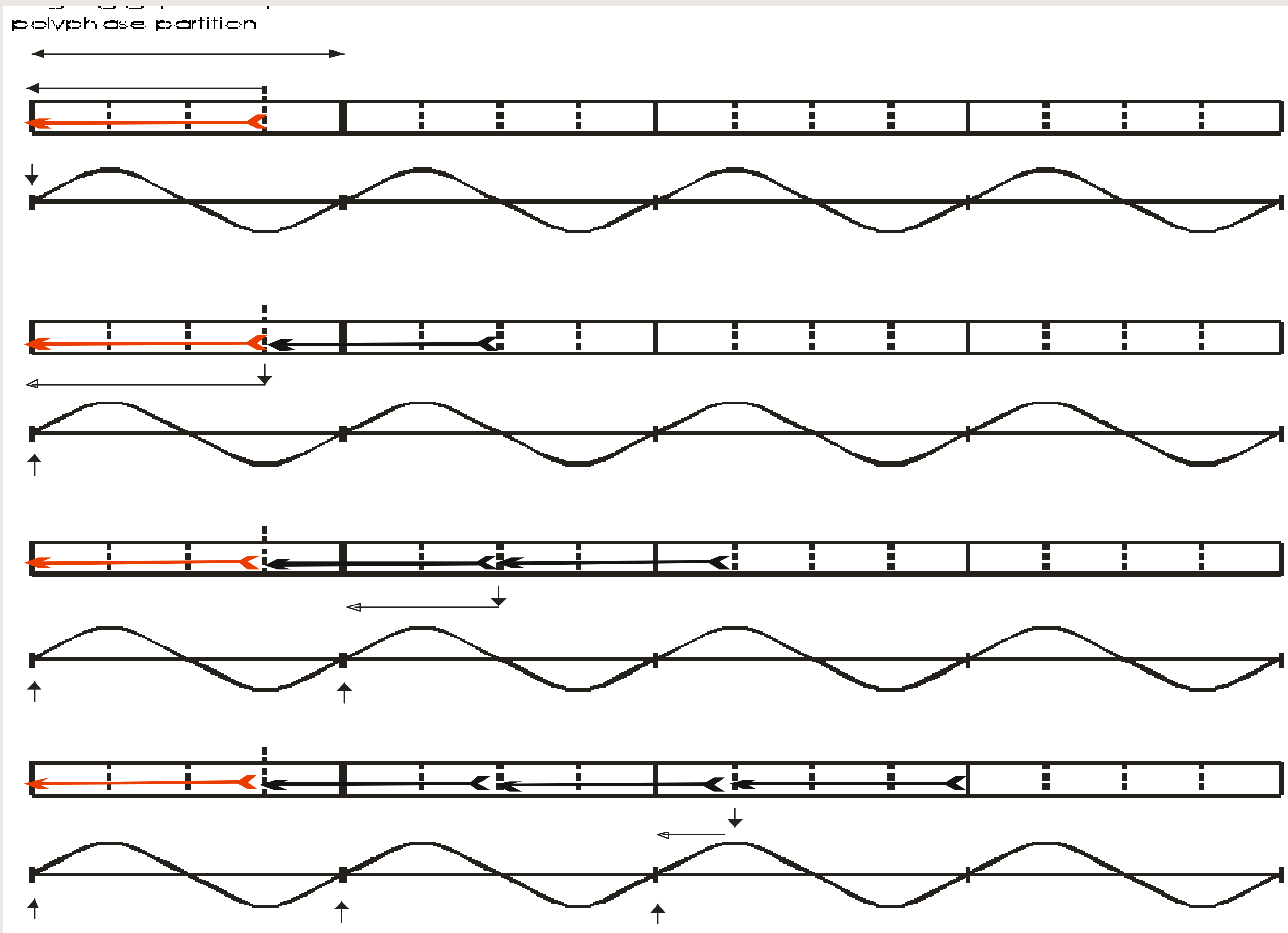
Standard Polyphase Channelizer and Modified Channelizer with Circular Buffers



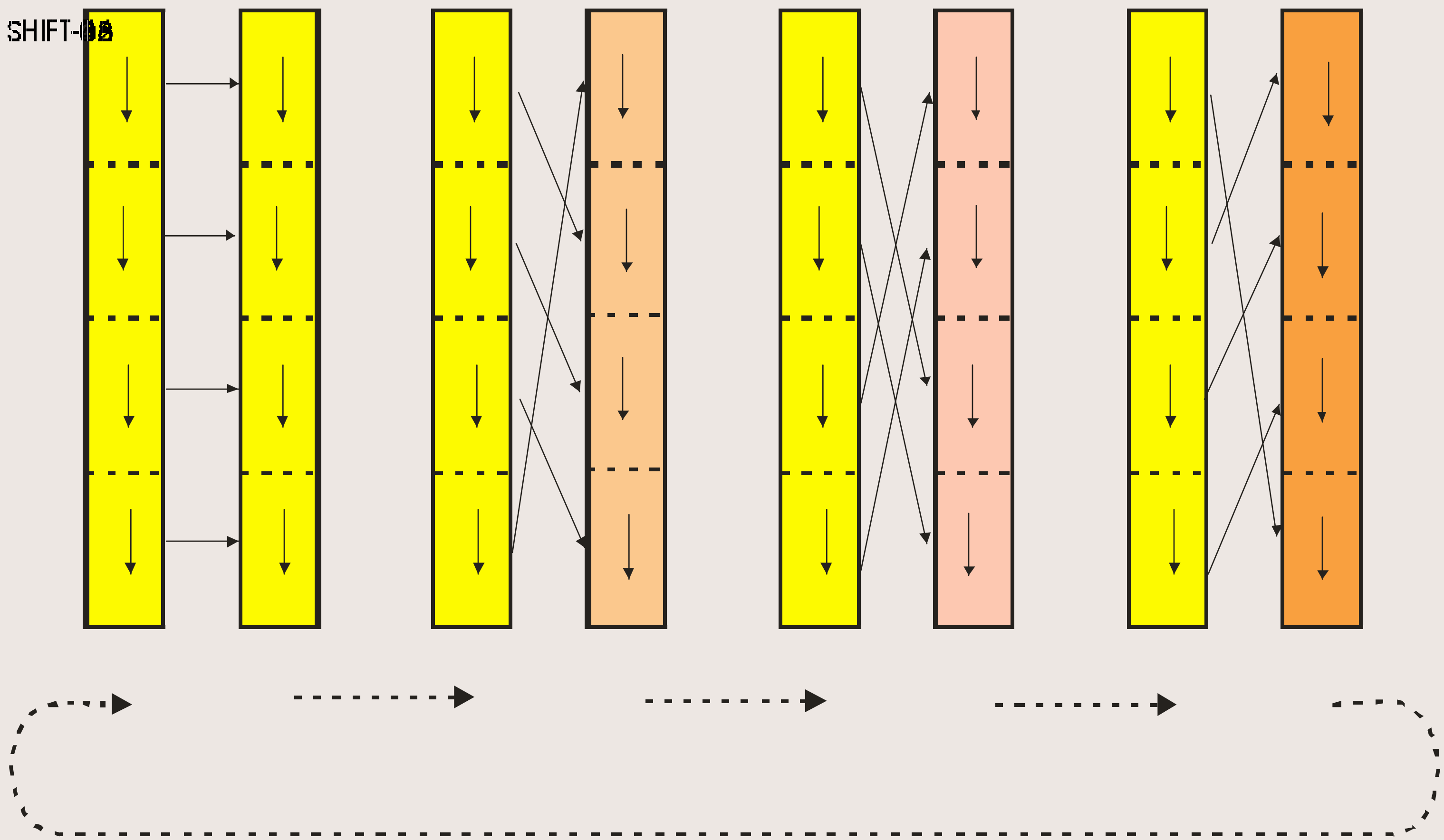
Content of 64-Point Circular Input Buffer for Two Successive 48 Point Input Blocks



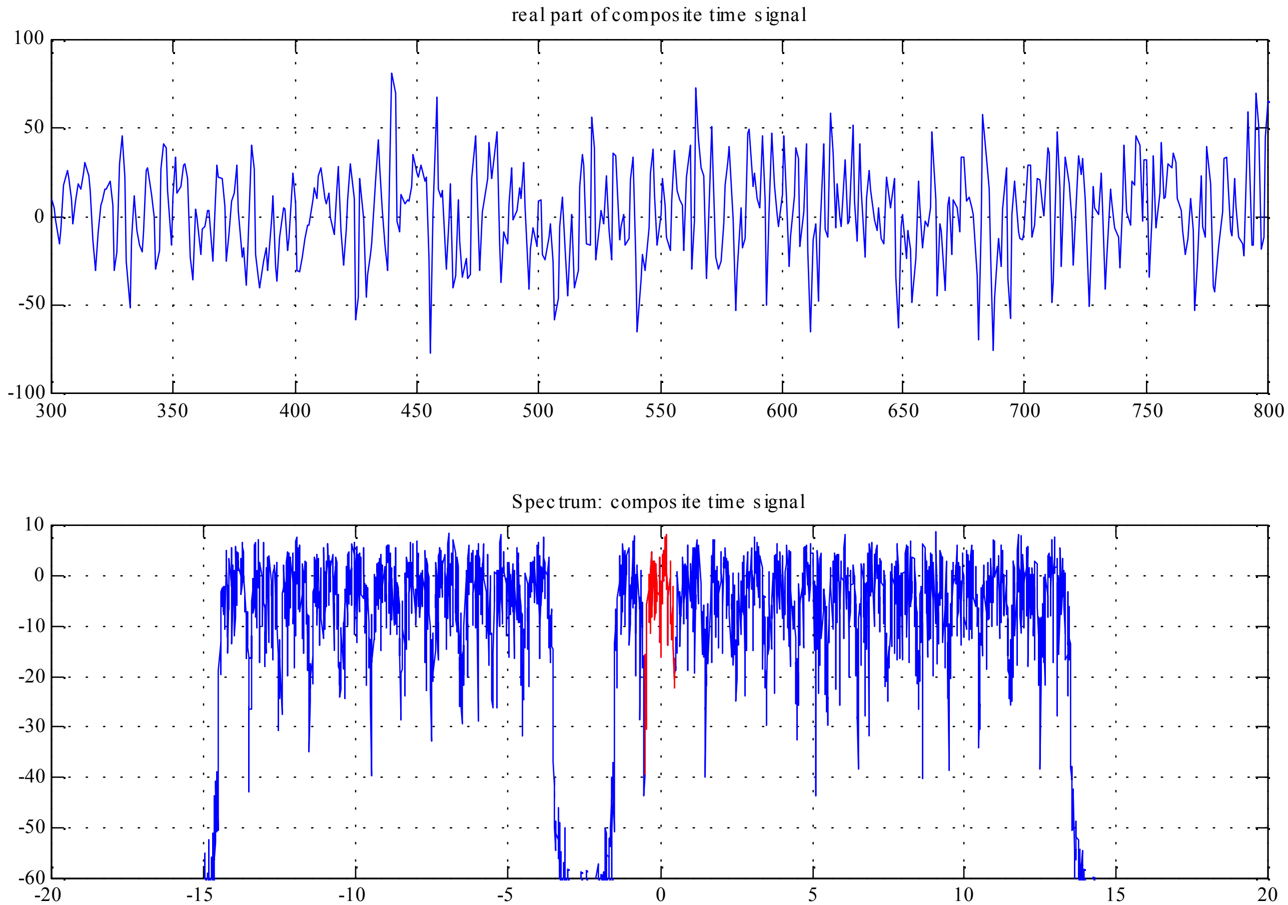
Shifting Time Origin for Input Data of Polyphase Filter and of Resetting FFT



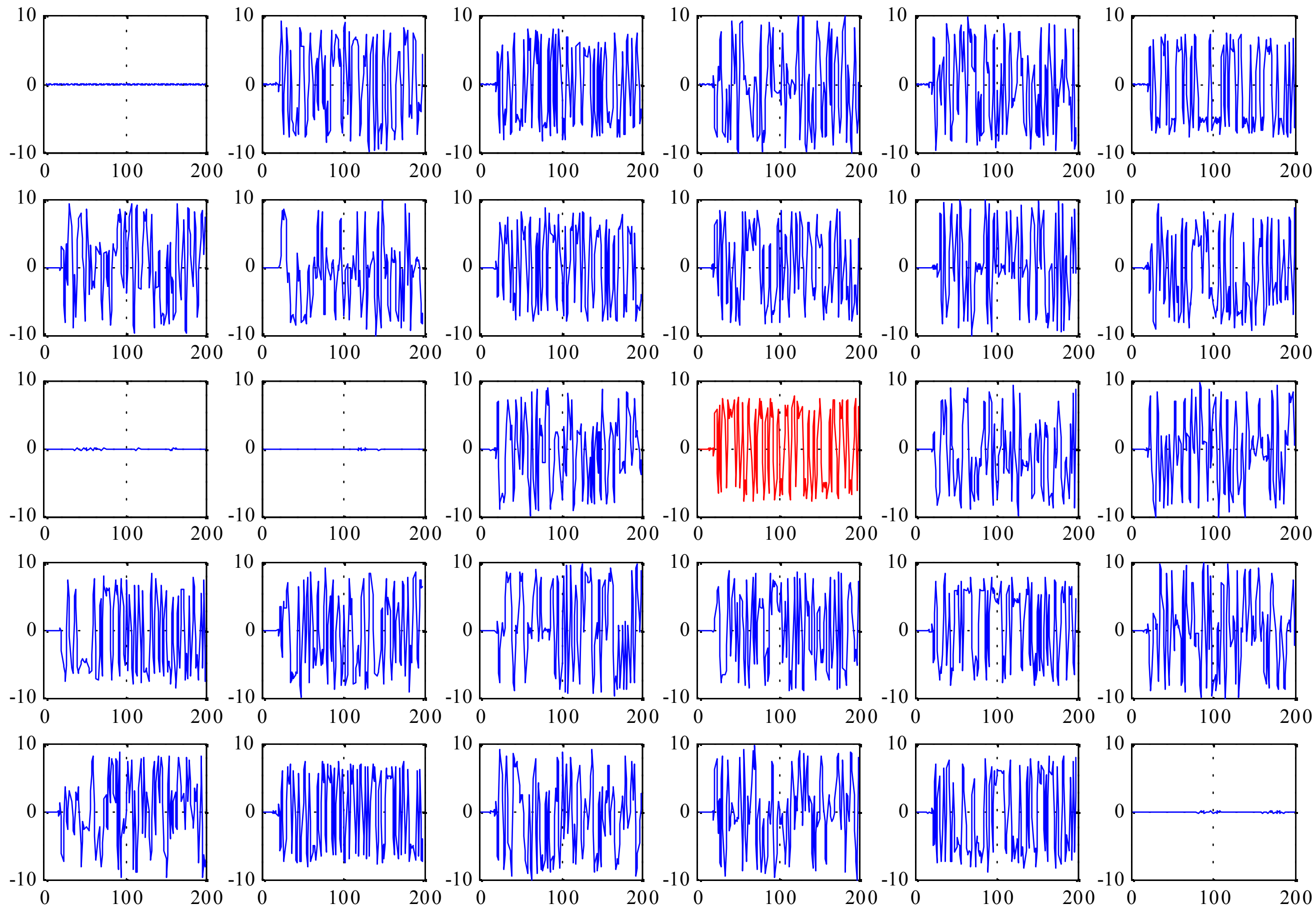
Contents of Transfer Circular Buffer Aligning Origins for Successive Input Blocks



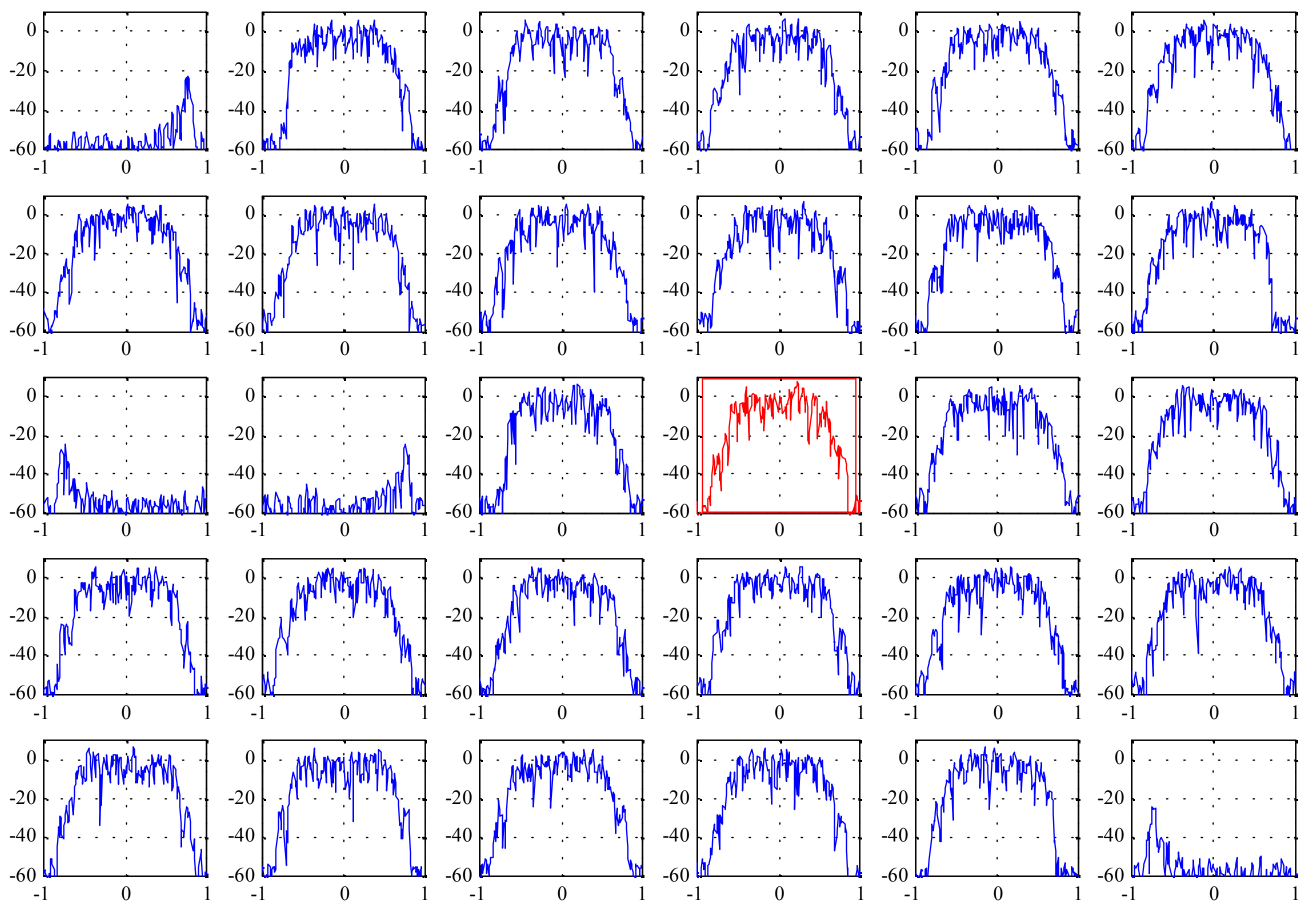
Input Time and Spectrum to 30 Channel, 40 Point FFT Channelizer



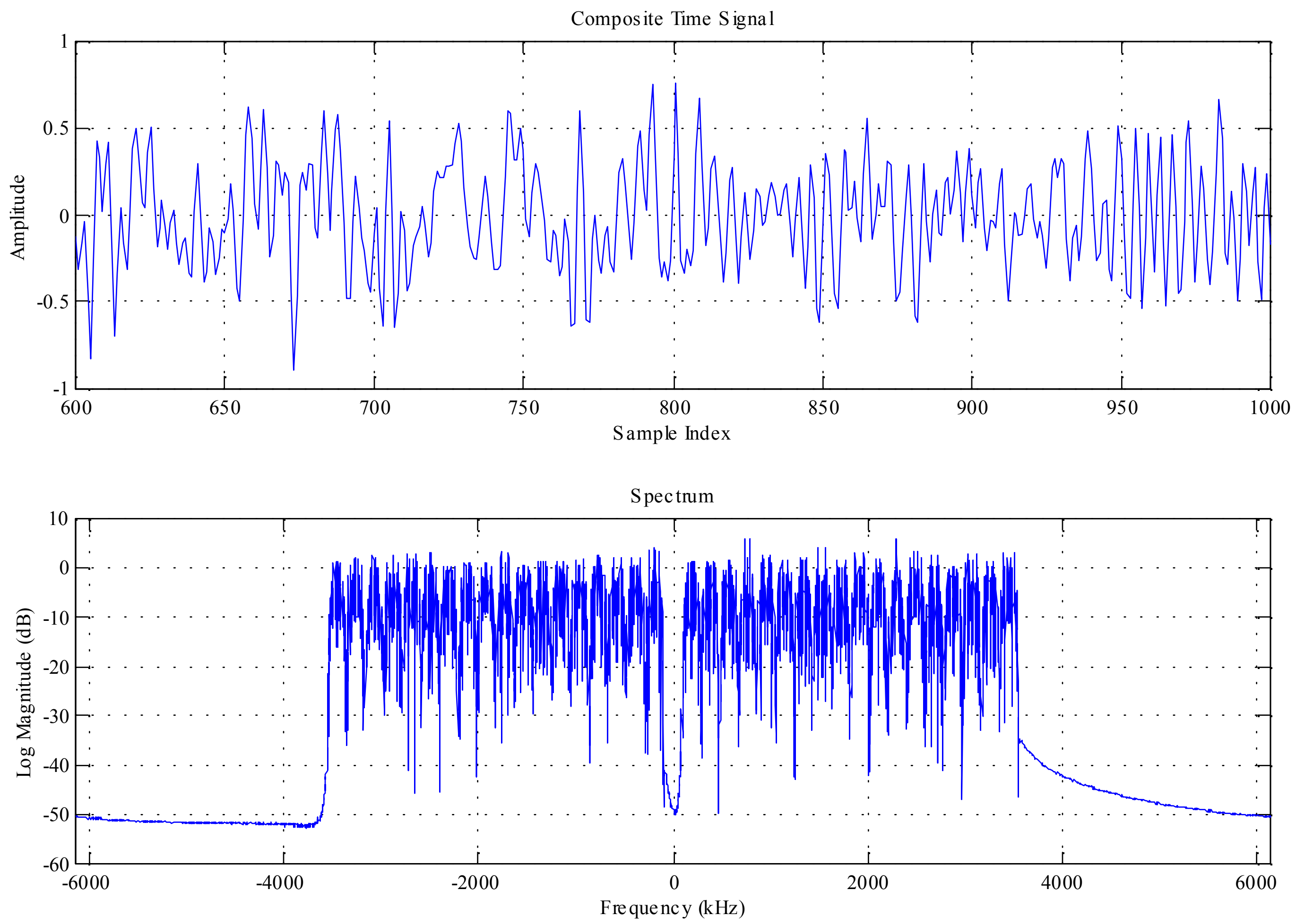
Time Series from 30 Channel Channelizer



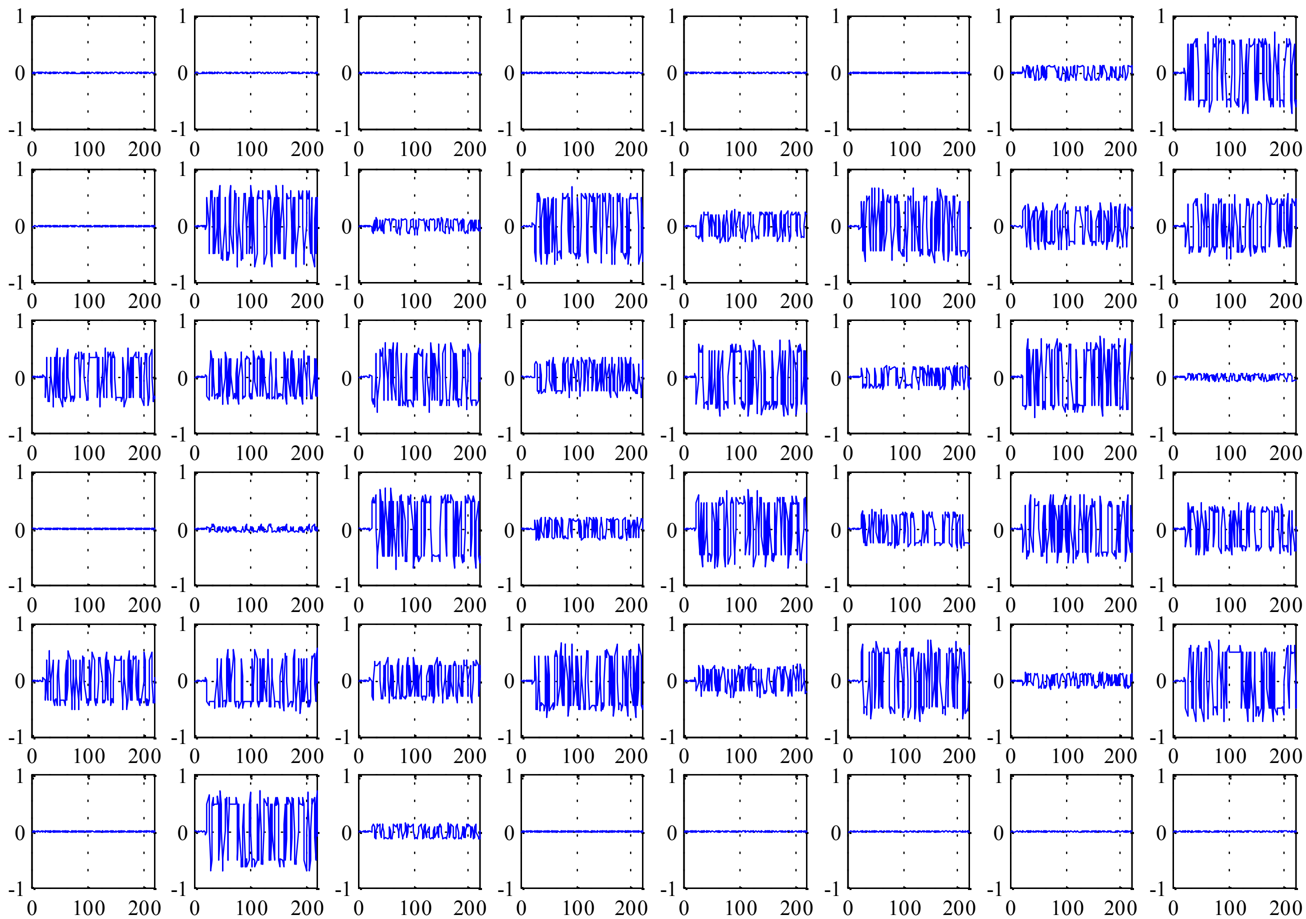
Spectra for 30 Channel Channelizer



Input Time and Spectrum to 50 Channel, 64 Point FFT Channelizer



Time Series from 50 Channel Matched Filter Channelizer



Spectra from 50 Channel Matched Filter Channelizer