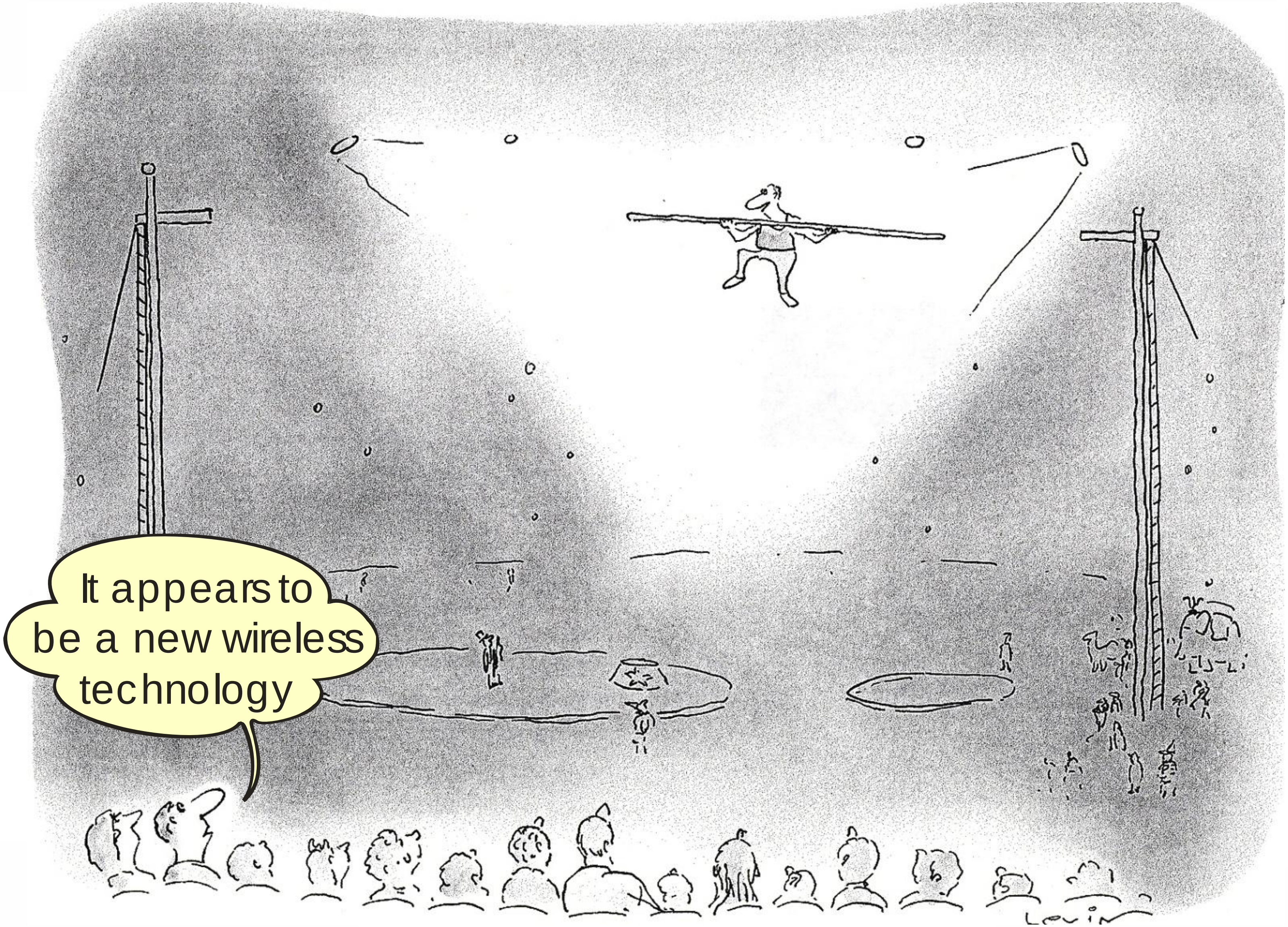
POLYPHASE FILTER BANKS FOR UNEQUAL CHANNEL BANDWIDTHS AND ARBITRARY CENTER FREQUENCIES

fred harris

30 November – 3 December 2010

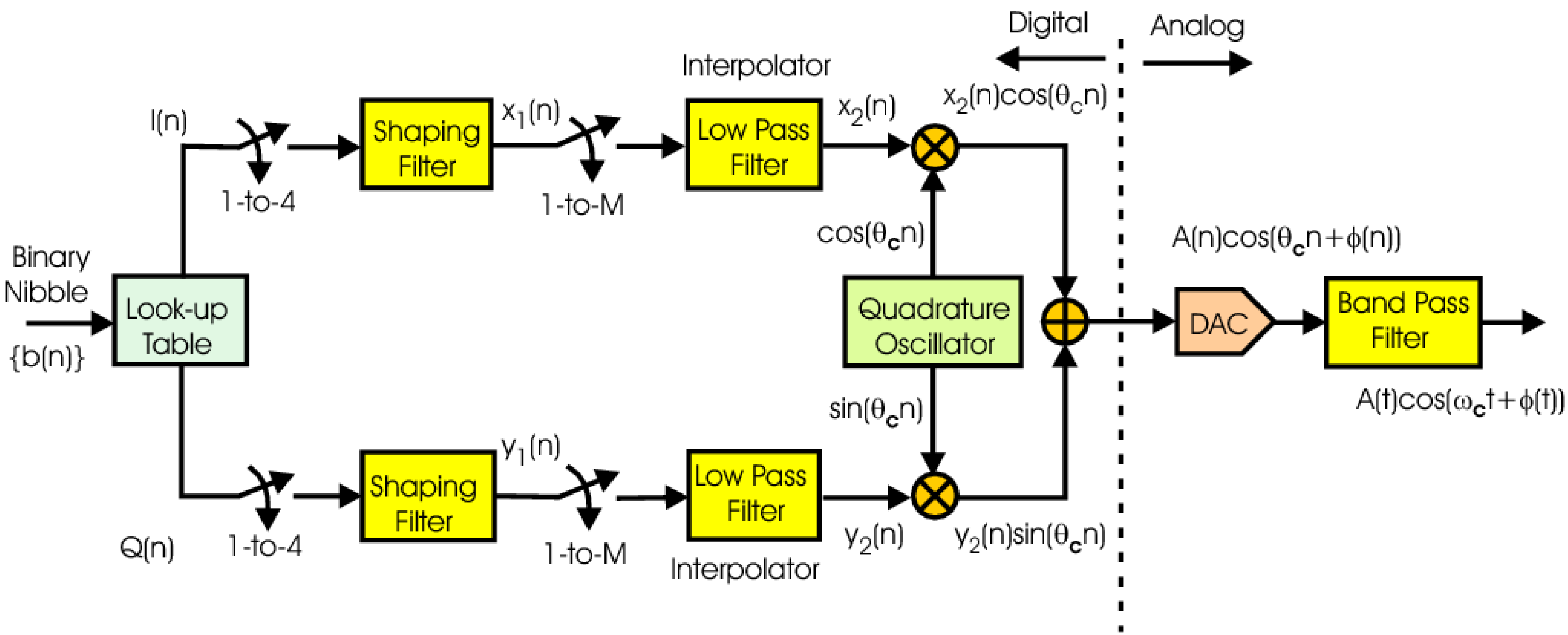
San Diego State University
College of Engineering

SDR`10
Wireless Innovation Conference and Product Exposition

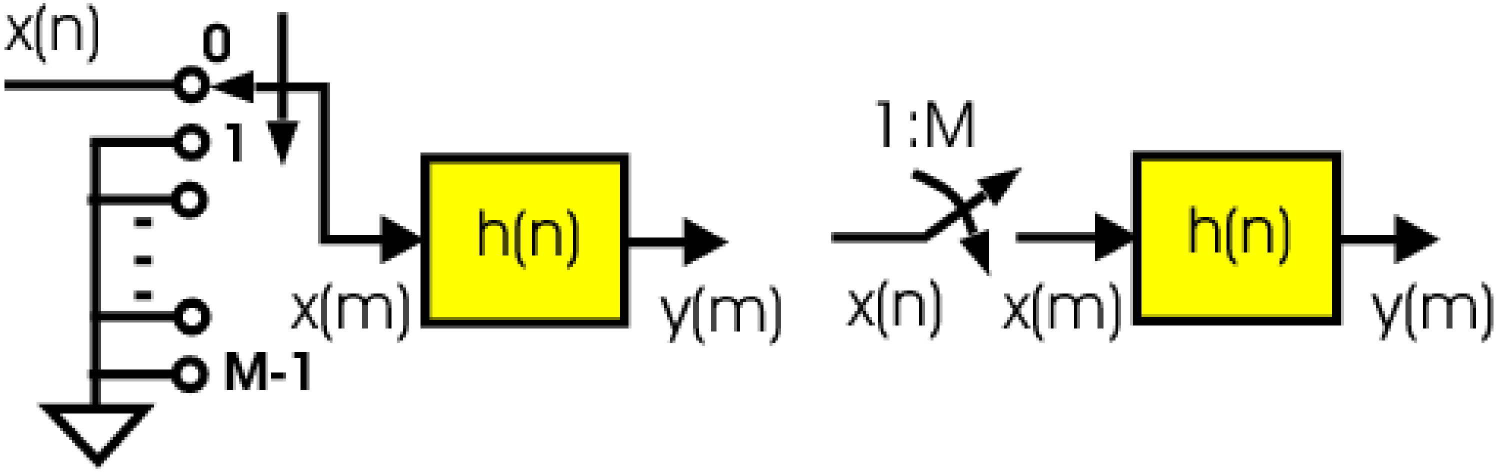

It appears to be a new wireless technology
Levin

Traditional Digital Up-Converter

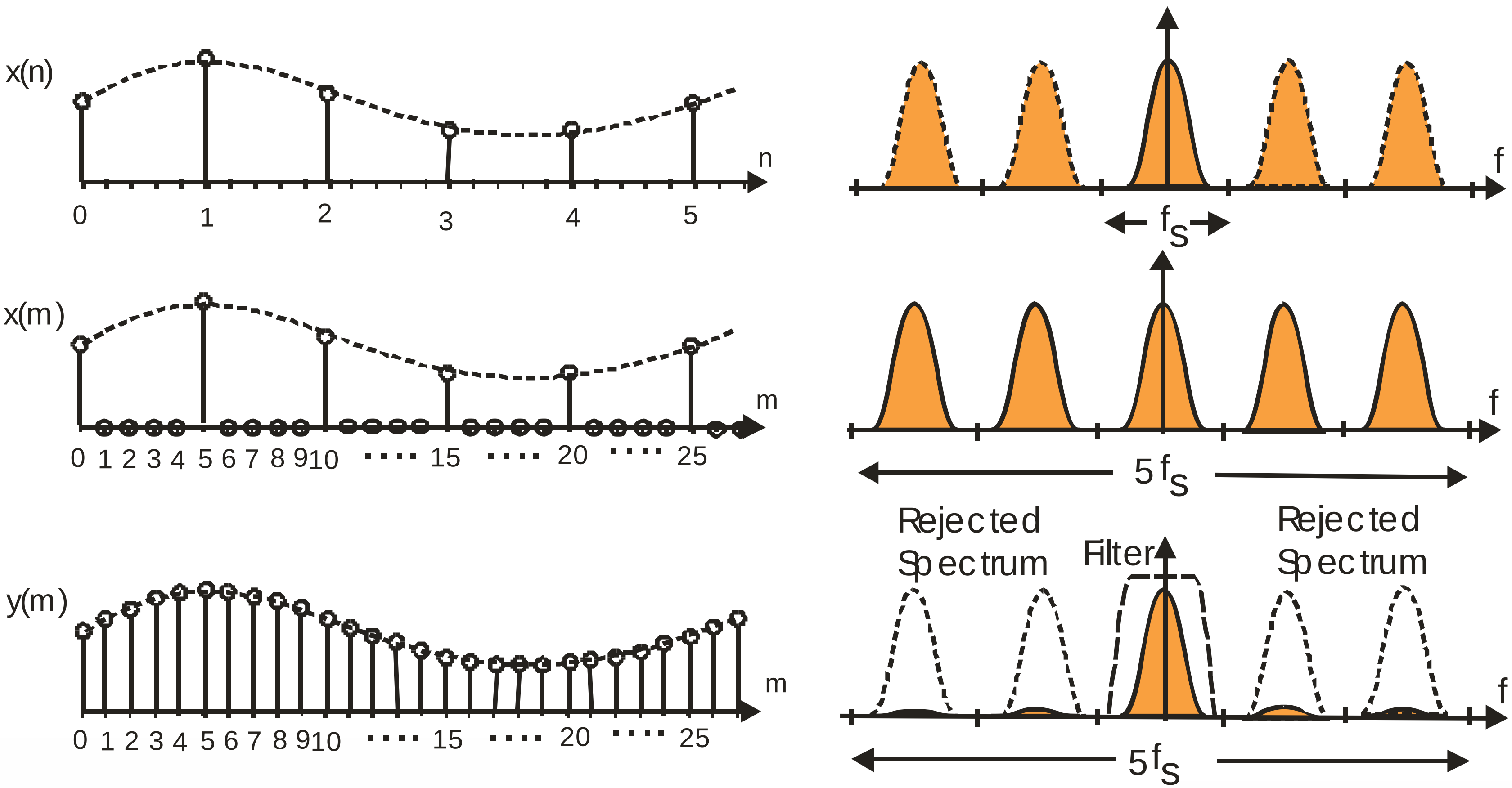
Up Sample, Filter, Heterodyne



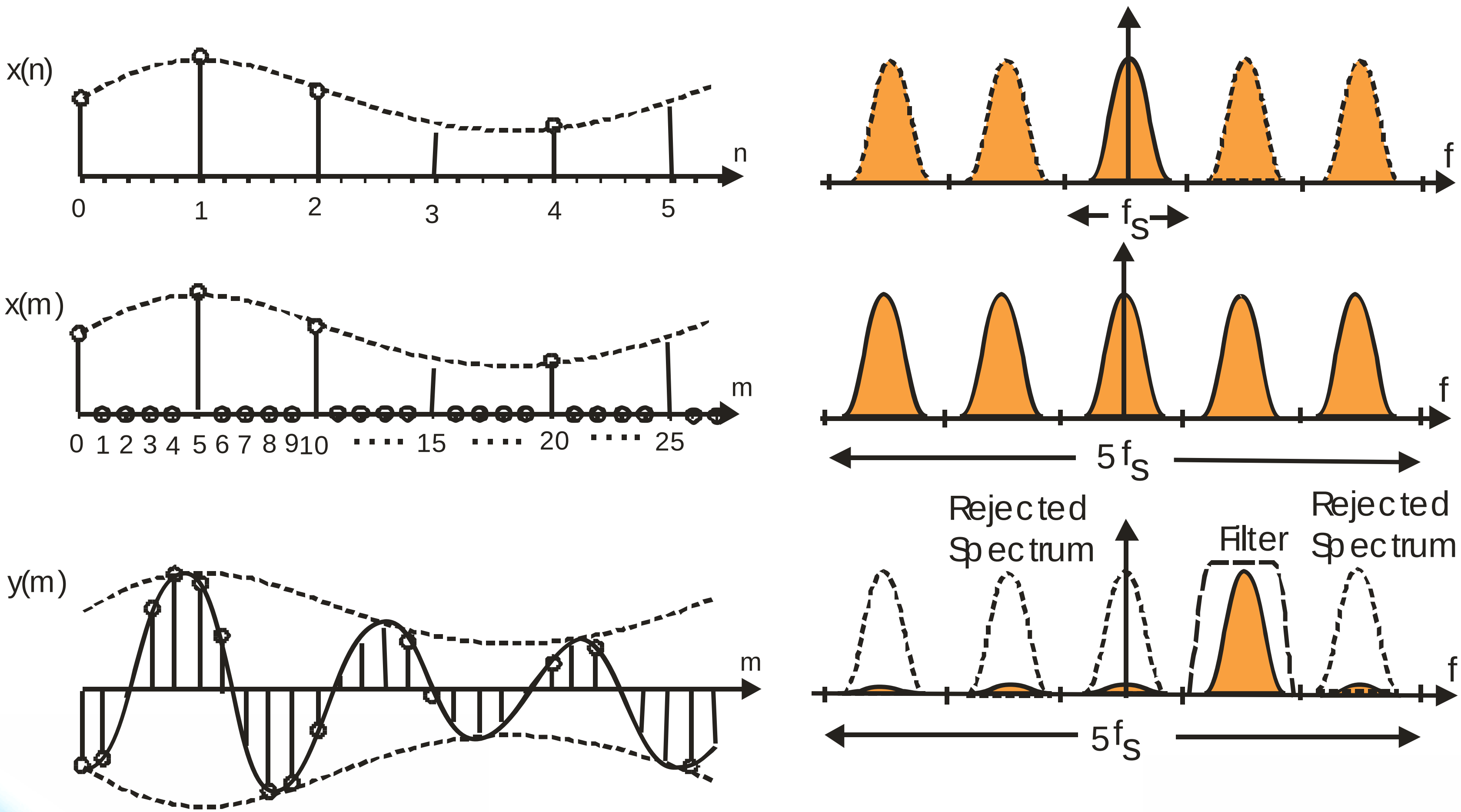
Up-sampling by Zero Packing and Filtering



Spectra Of Input, of Zero-Packed, and of Low-Pass Filtered Zero-Packed Signal

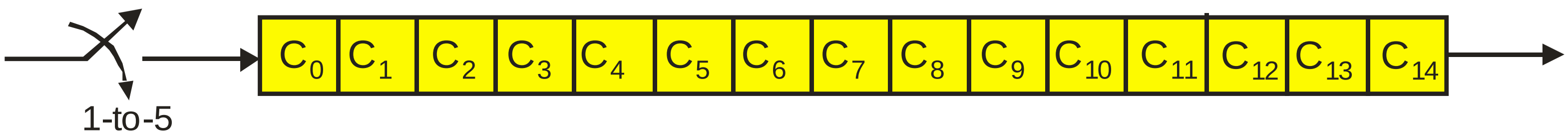


Spectra Of Input, of Zero-Packed, and of Band Pass Filtered Zero-Pack Signal

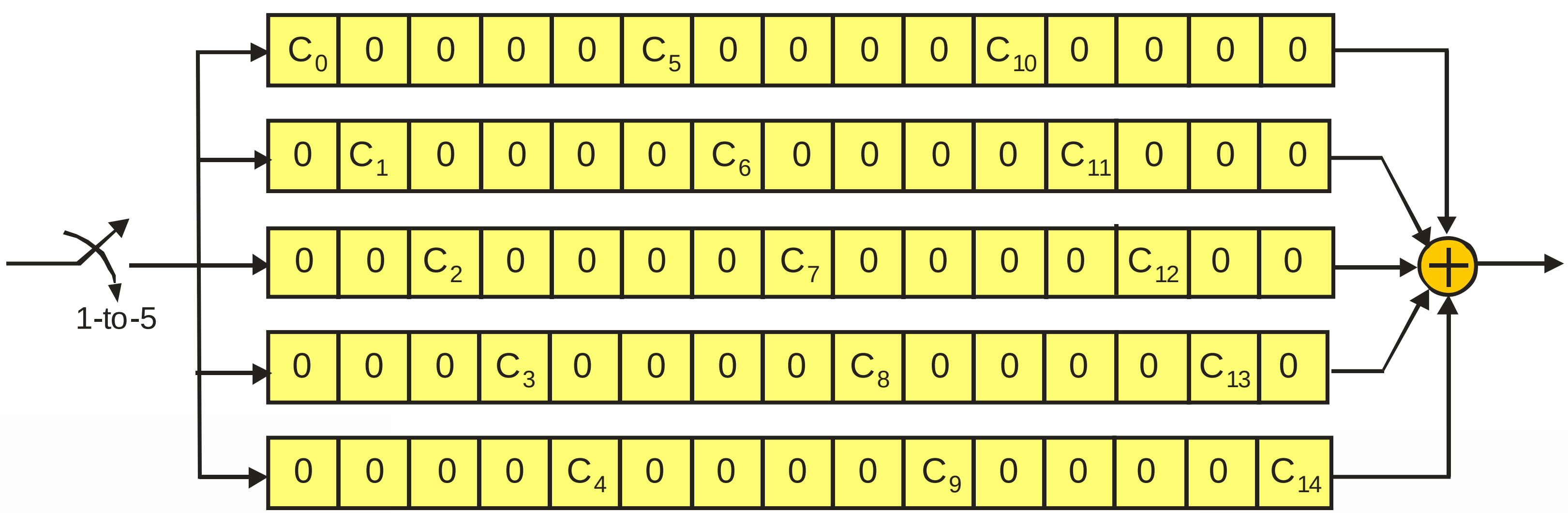


Polyphase Partition of Resampling Filter

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

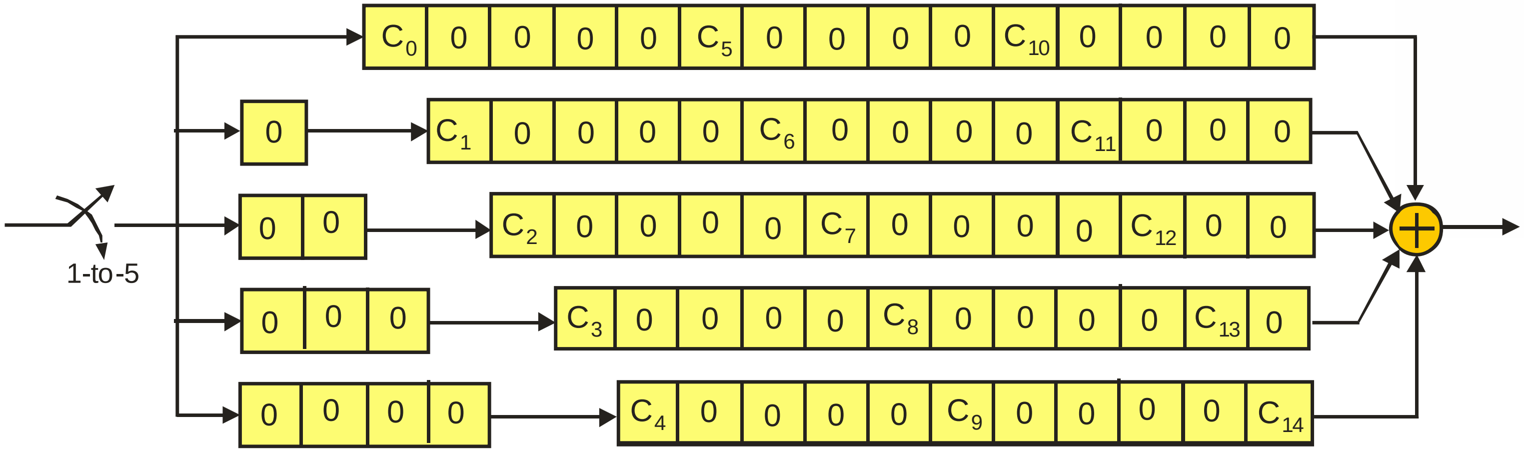


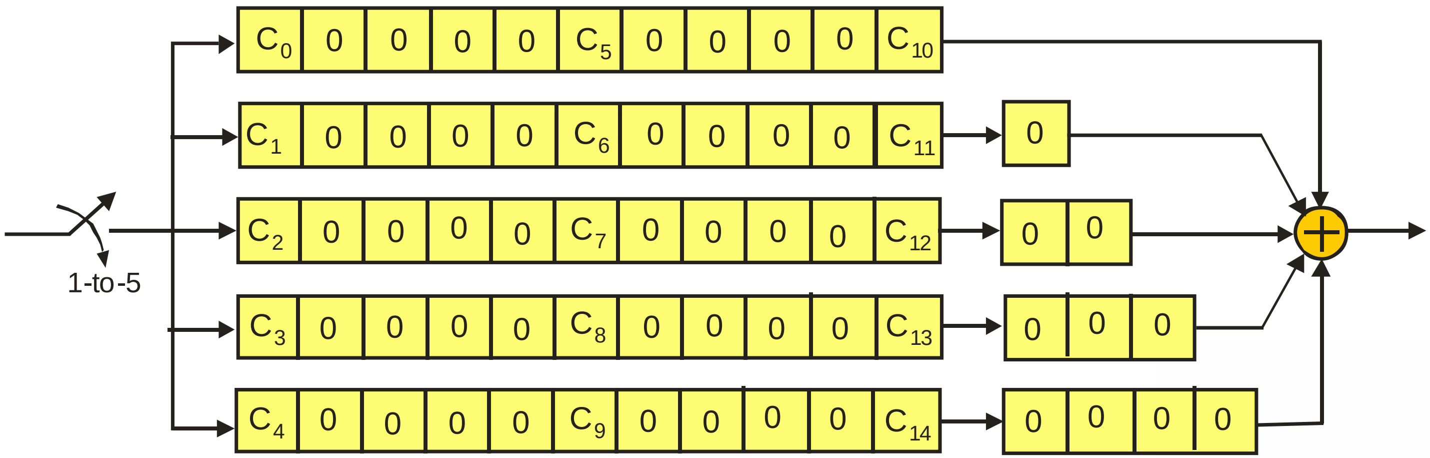
$$H(Z) = \sum_{r=0}^{M-1} \sum_{n=0}^{\frac{N}{M}-1} h(r + nM) Z^{-(r+nM)}$$



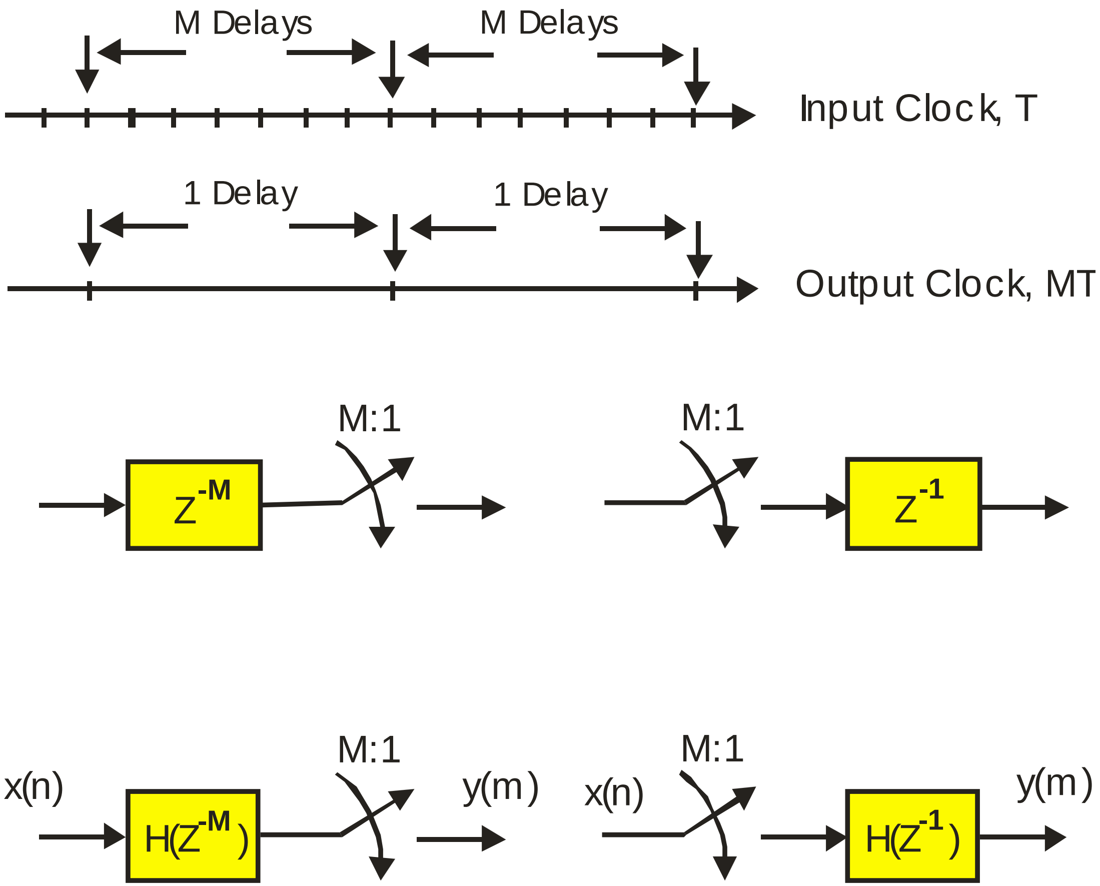
Factor Delays and Rearrange

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

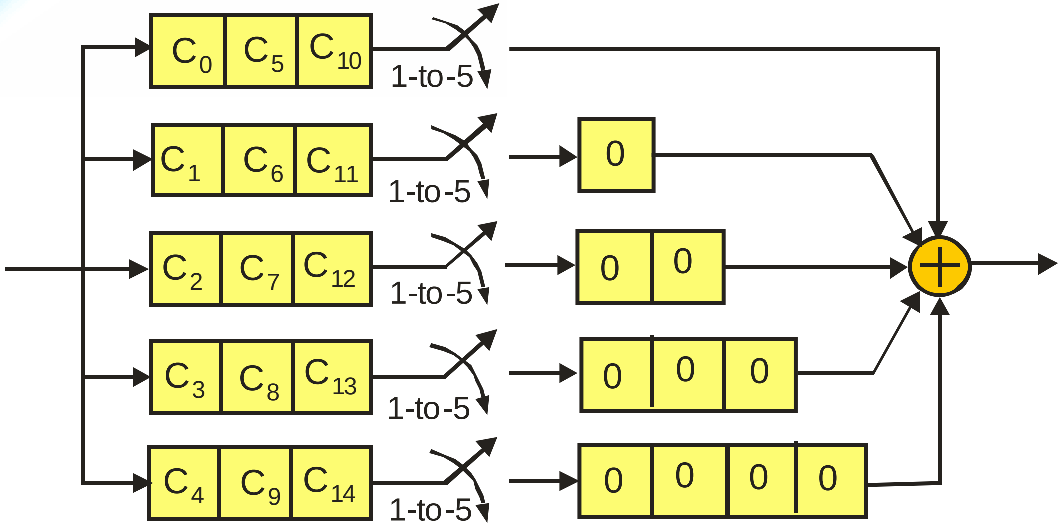




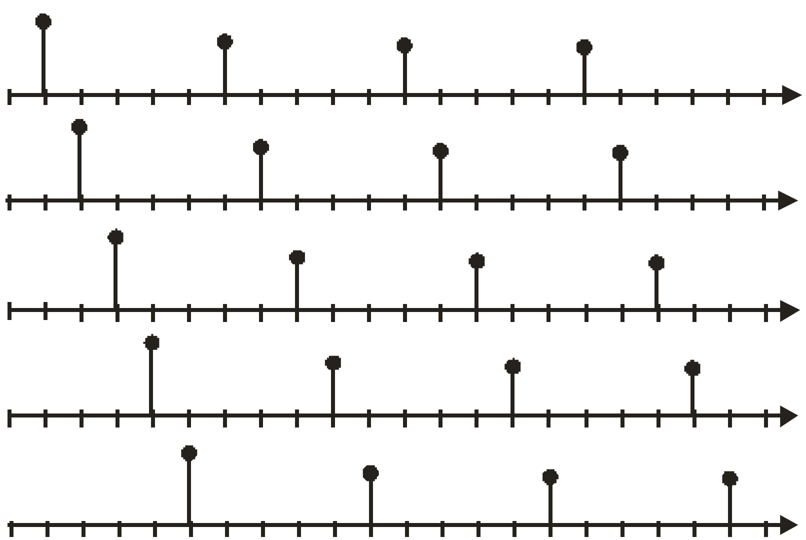
Noble Identity:
Interchange M-Delays with M-to-1 Resample

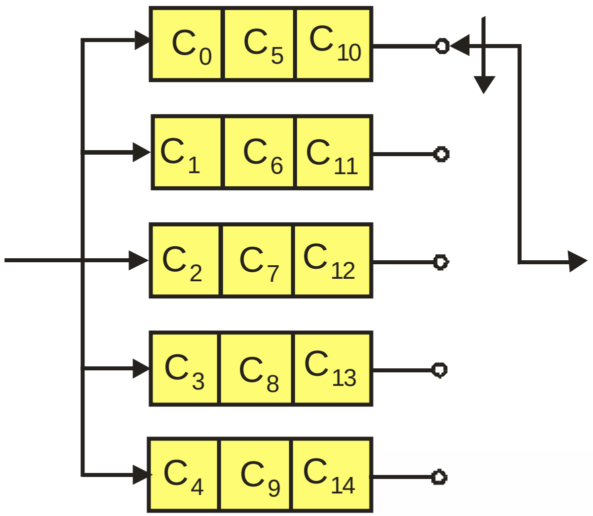


Interchange Filter and Resampler



Replace Up Samplers, Delays, and Summer with M-Port Output Commutator





Low-Pass Replaced by Band-Pass

$$G(Z)=\sum_{n=0}^{N-1} h(n)e^{j\frac{2\pi}{M}kn}Z^{-n}$$

$$G(Z)=\sum_{r=0}^{M-1}\sum_{n=0}^{\frac{N}{M}-1} h(r+nM)e^{j\frac{2\pi}{M}(r+nM)k}Z^{-(r+nM)}$$

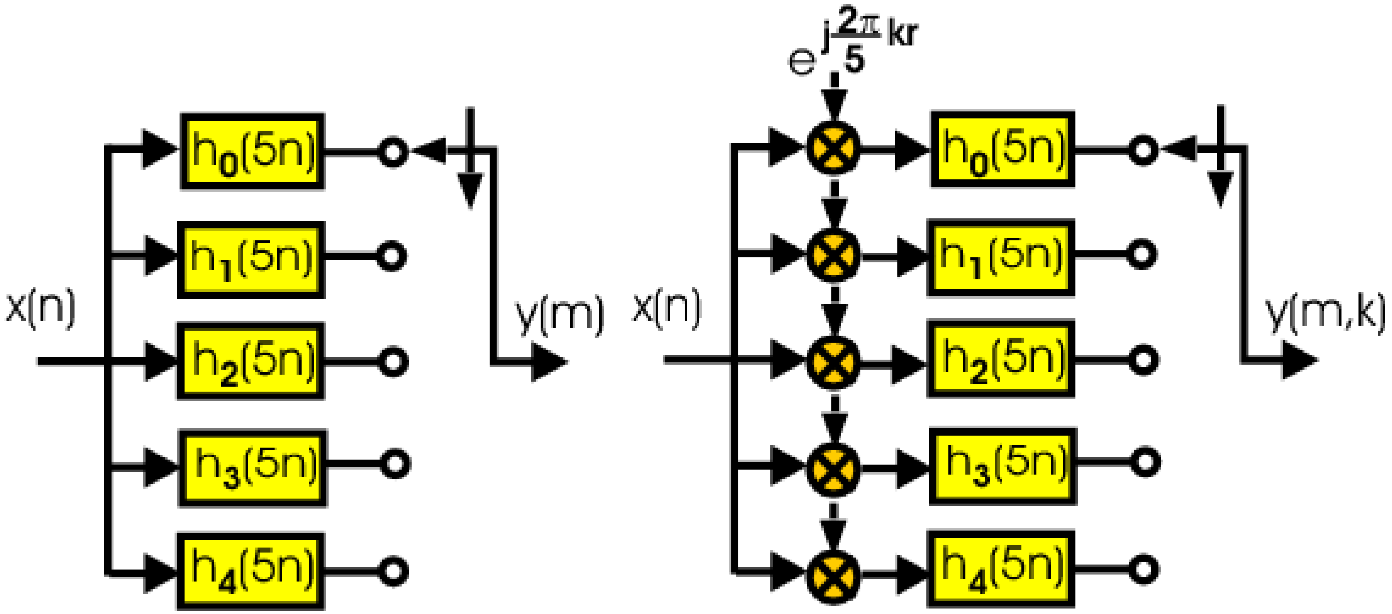
$$G(Z)=\sum_{r=0}^{M-1}Z^{-r}e^{j\frac{2\pi}{M}rk}\sum_{n=0}^{\frac{N}{M}-1} h(r+nM)e^{j\frac{2\pi}{M}nM}Z^{-nM}$$

$$G(Z)=\sum_{r=0}^{M-1}Z^{-r}e^{j\frac{2\pi}{M}rk}\sum_{n=0}^{\frac{N}{M}-1} h(r+nM)Z^{-nM}$$

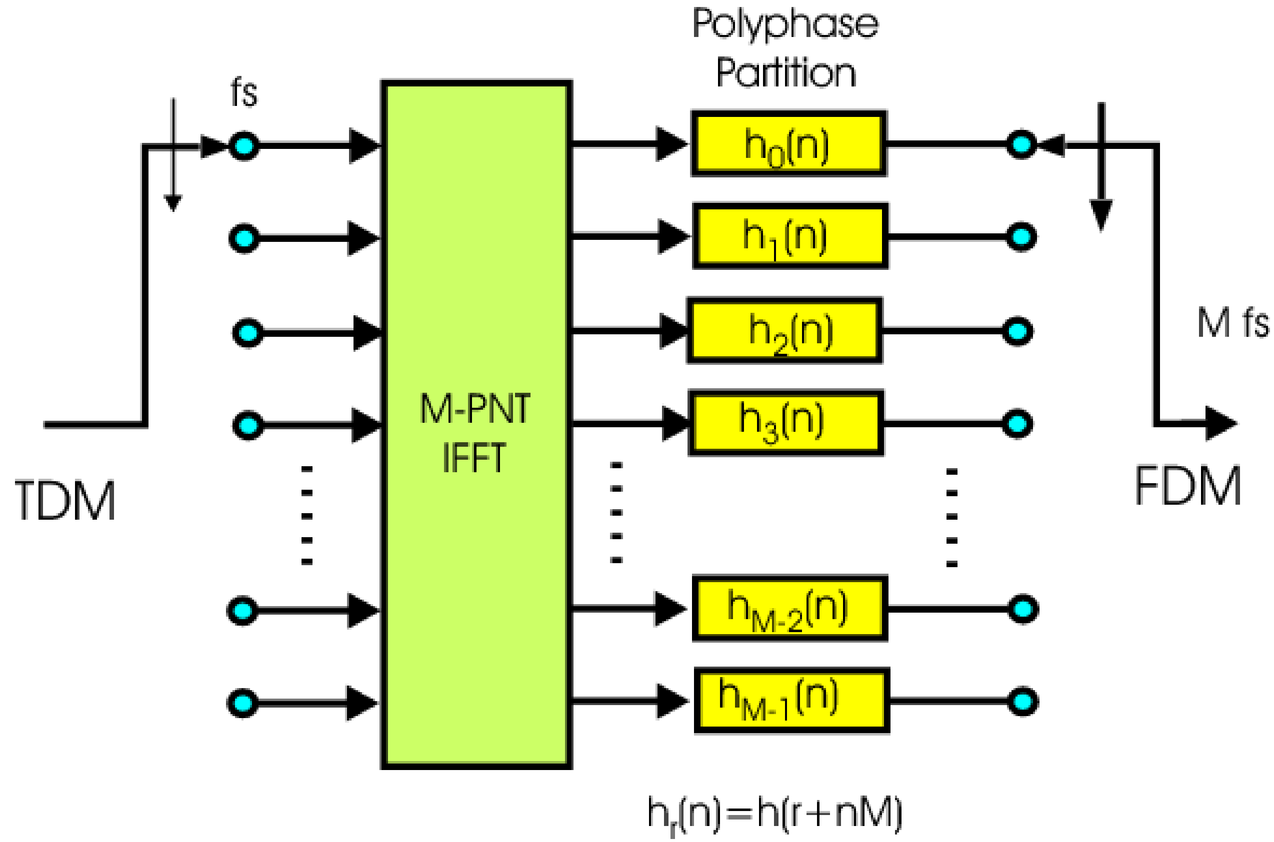
Spin The Delays,

Don’t Touch the M-Path Partitioned Weights

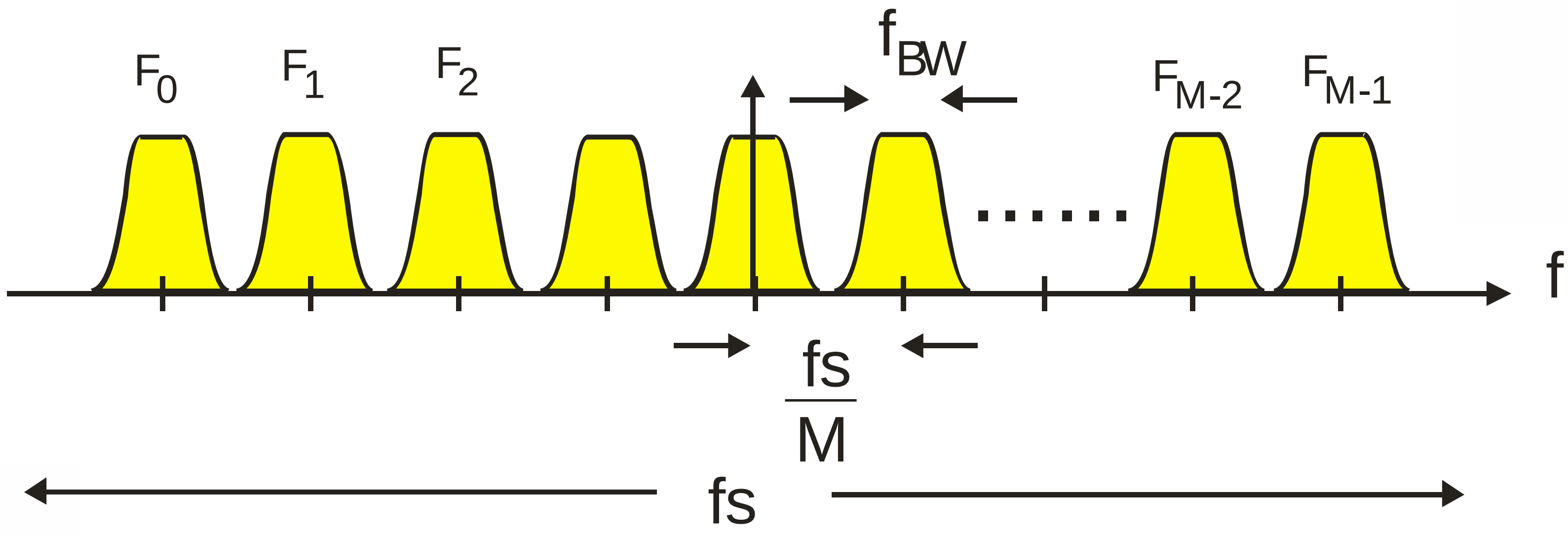
Low-Pass to Band-Pass
1-to-M Up-Sampling Filter



M-Path, M-Channel Channelizer: Spinners are in IFFT



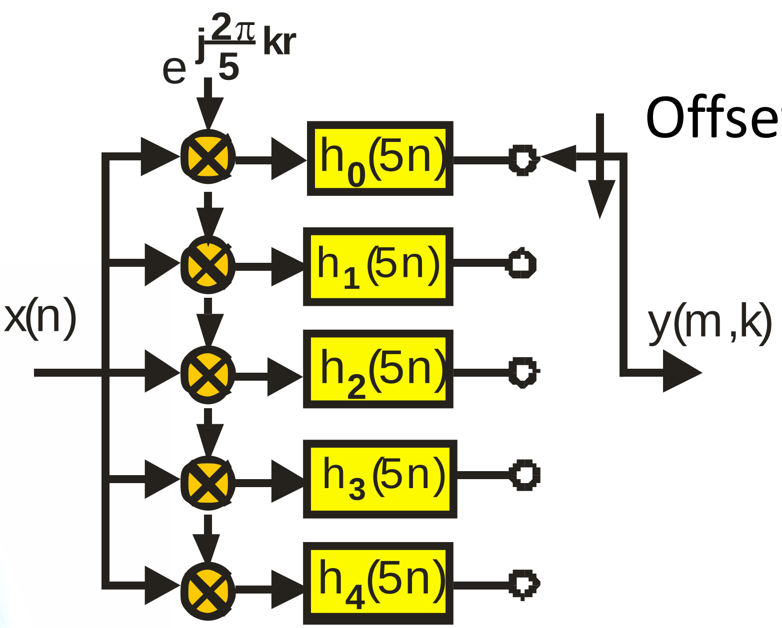
M-Point IFFT Supplies Phase Spinners to Form Up Converters to all Multiples of Input Sample Rate

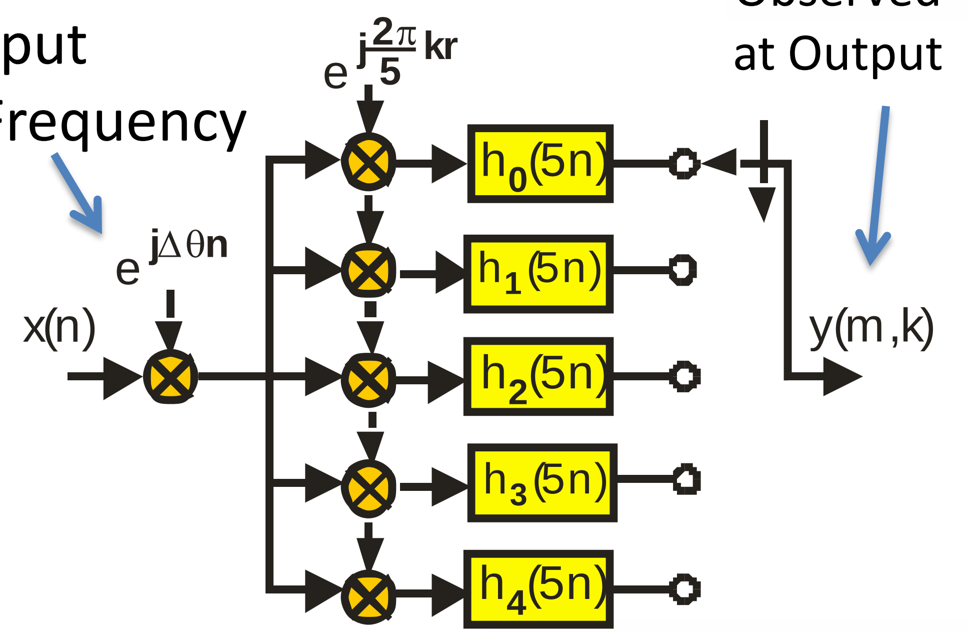


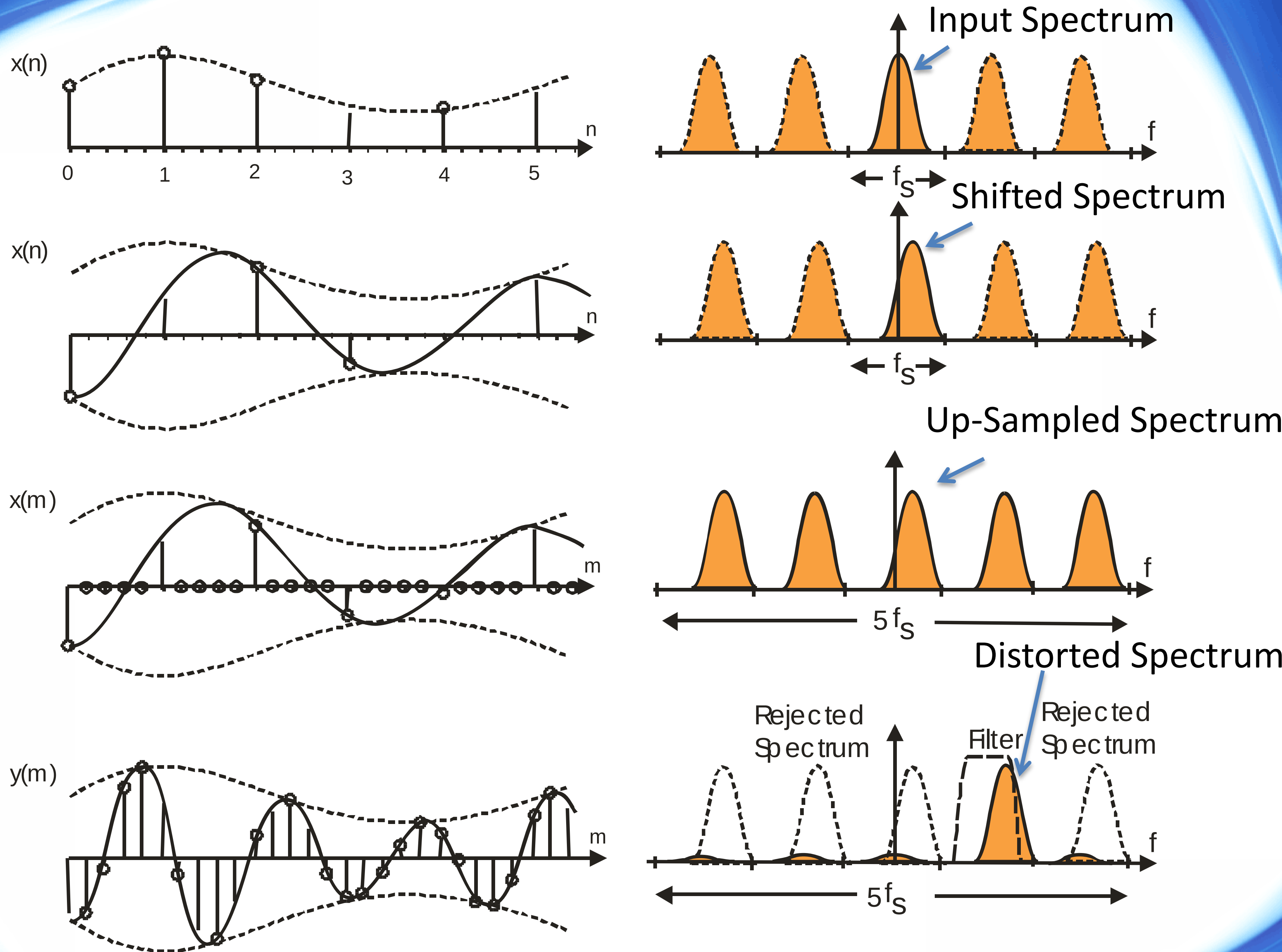
All Output Channels Centered on Multiples of Input Sample Rate

Example: Multiples of 6-MHz

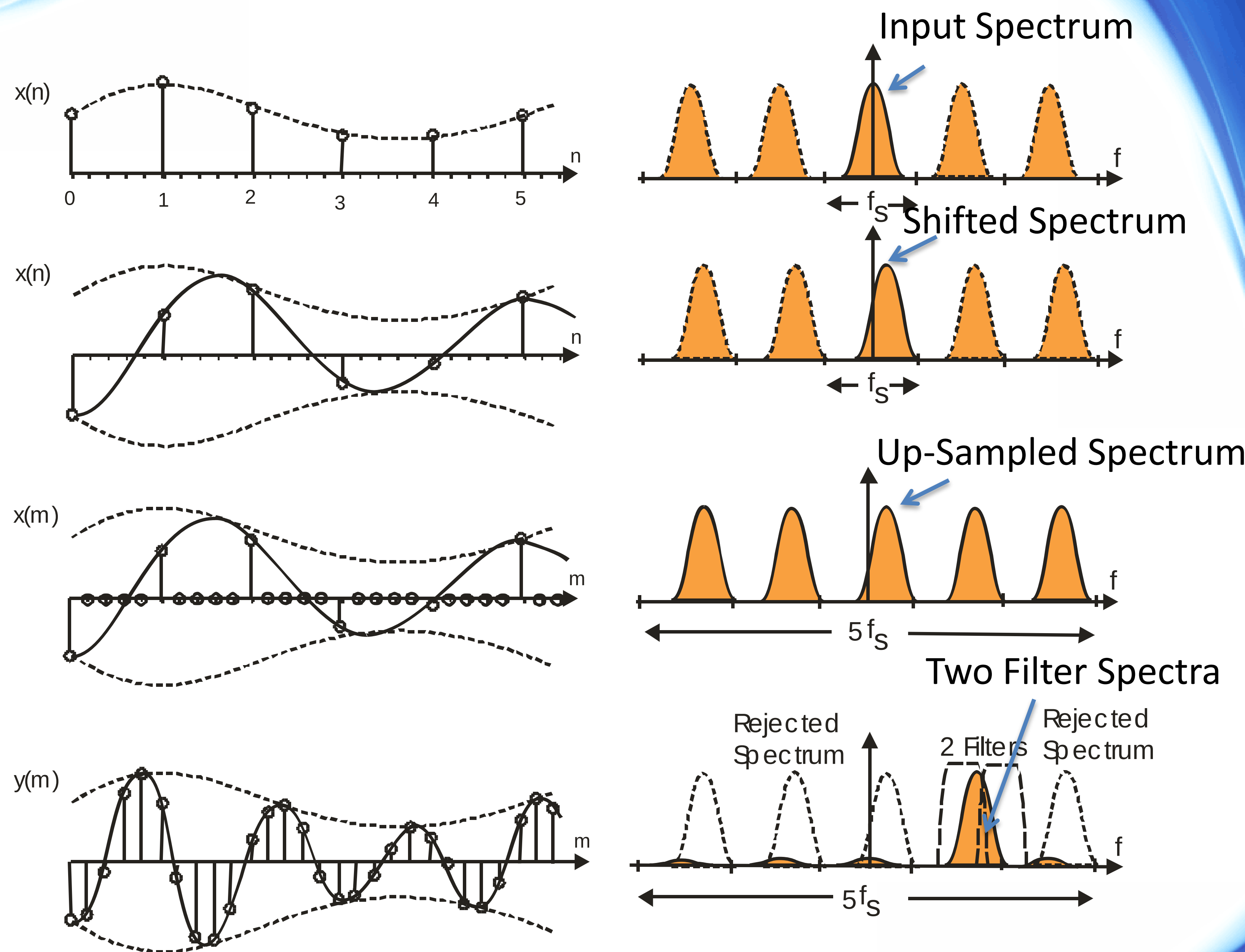
Heterodyne Input Signal a Small Frequency Offset from DC: Channelizer Aliases DC to Channel Center and offset signal from DC is Offset from Channel Center



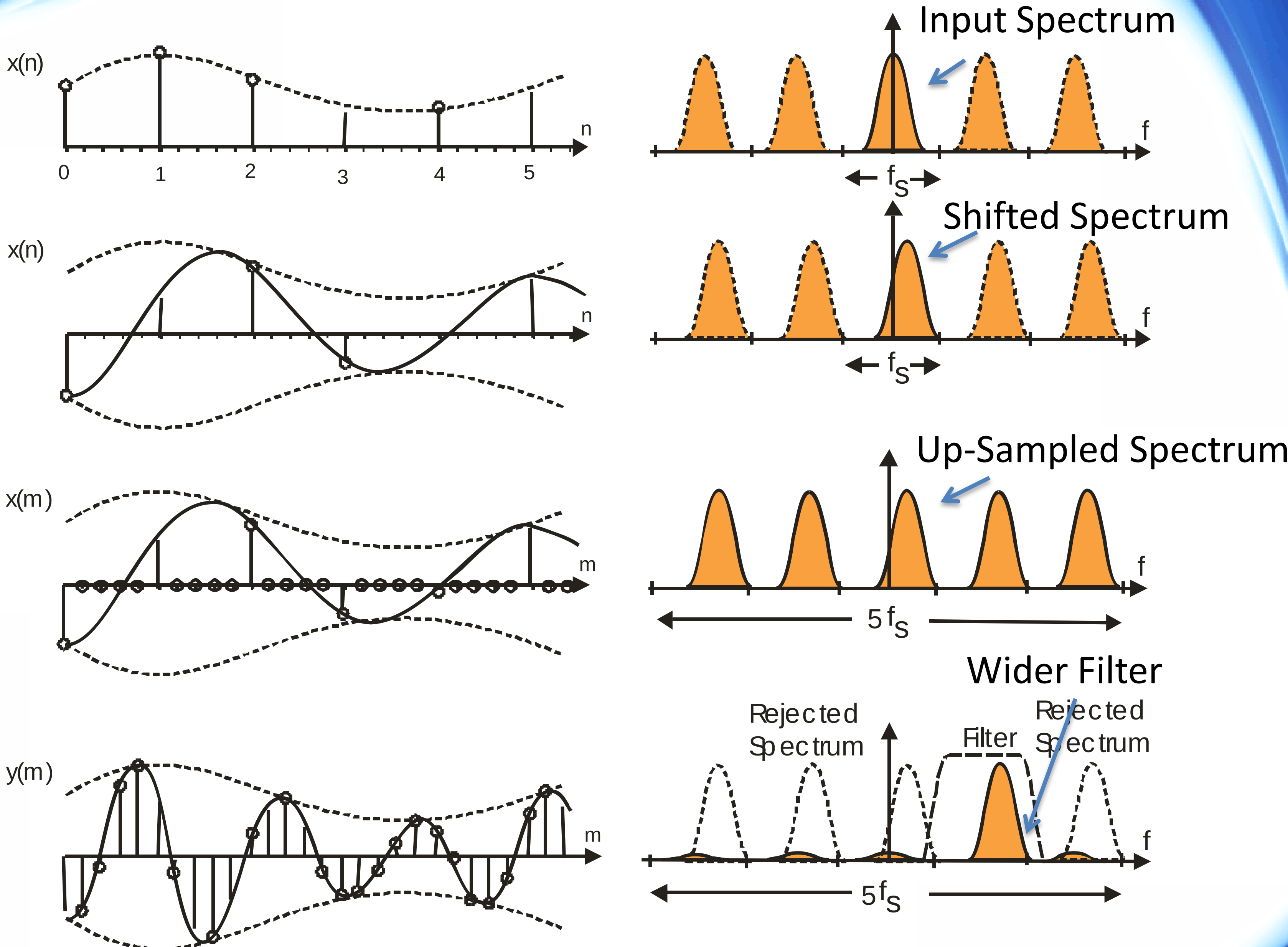




x(n)
n
0
1
2
3
4
5
Input Spectrum
f
f_S
Shifted Spectrum
x(n)
n
f
f_S
Up-Sampled Spectrum
x(m)
m
f
$5 f_S$
Distorted Spectrum
Rejected Spectrum
Filter
Rejected Spectrum
y(m)
m
f
$5 f_S$



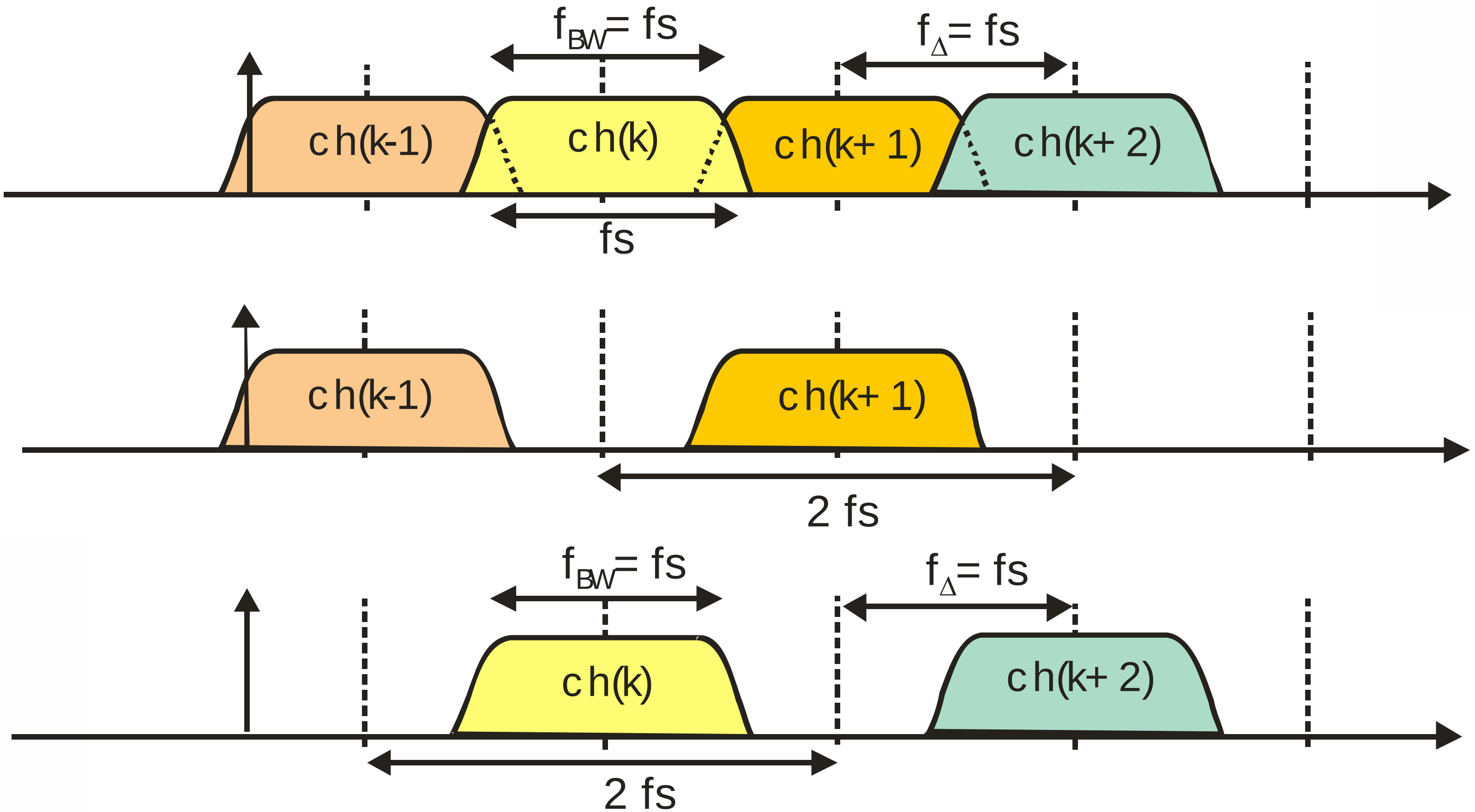
Input Spectrum
Shifted Spectrum
Up-Sampled Spectrum
Two Filter Spectra
x(n)
x(n)
x(m)
y(m)
0
1
2
3
4
5
n
m
f
f_s
$5f_s$
Rejected Spectrum
2 Filters
Rejected Spectrum



Input Spectrum
Shifted Spectrum
Up-Sampled Spectrum
Wider Filter
x(n)
x(n)
x(m)
y(m)
n
m
0
1
2
3
4
5
f
f_s
$5f_s$
Rejected Spectrum
Filter
Rejected Spectrum

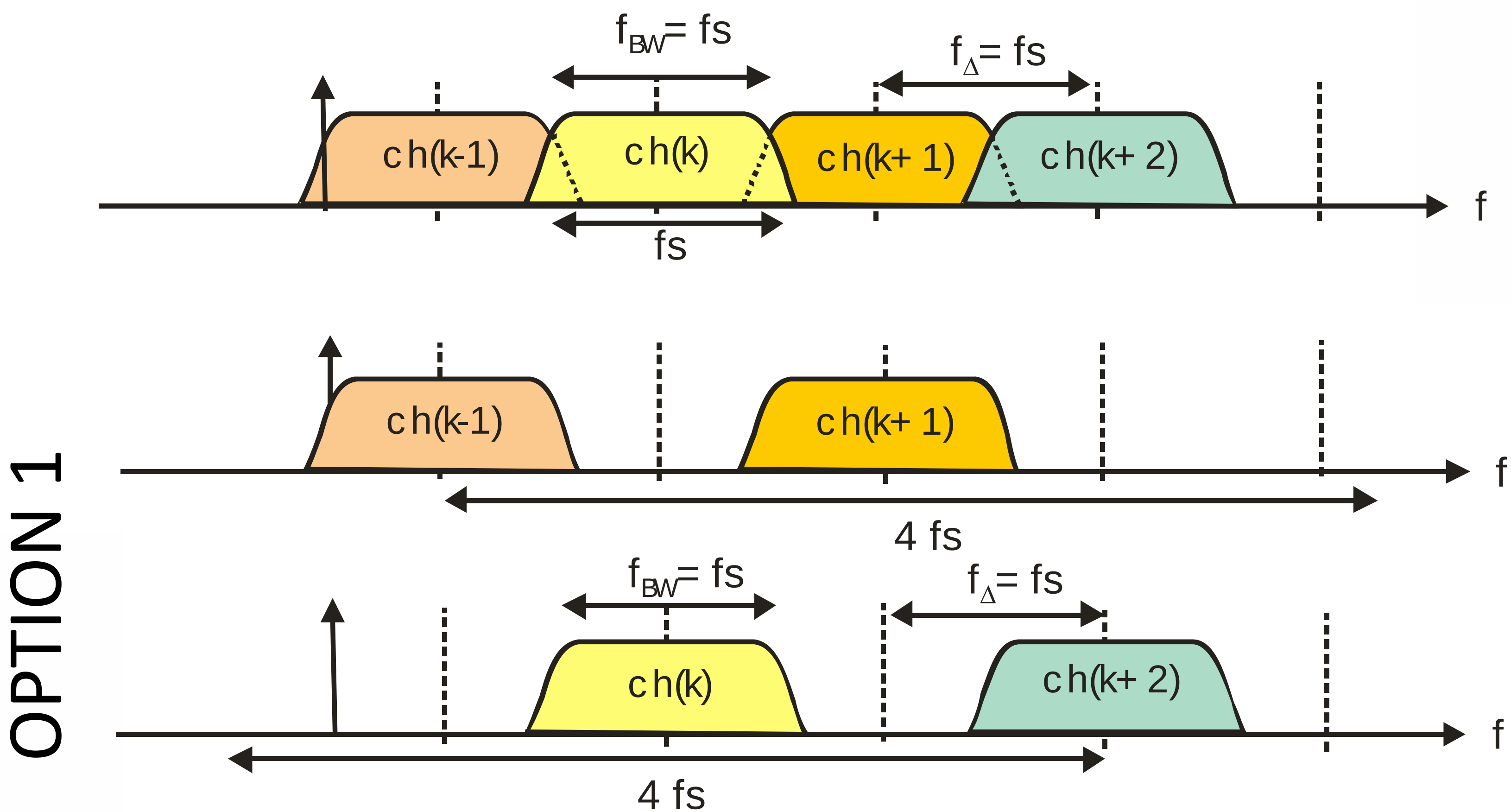
Channel BW = Channel Spacing
Sample Rate = Channel Spacing

OPTION 0



Channel BW = Channel Spacing
Sample Rate = 2 Channel Spacing

Channel BW = Channel Spacing
Sample Rate = Channel Spacing

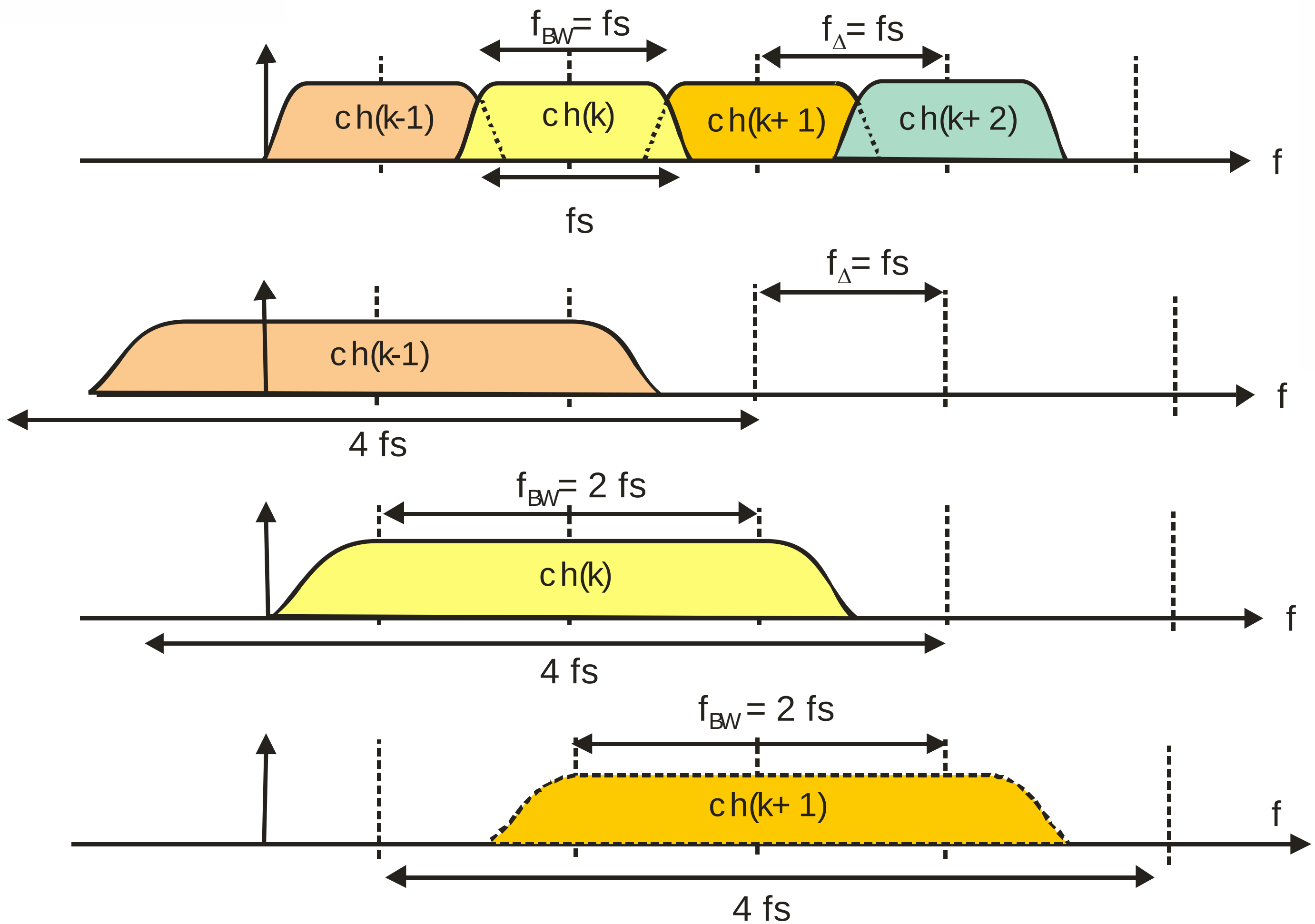


Channel BW = Channel Spacing
Sample Rate = 4 Channel Spacing

Channel Bandwidth = Channel Spacing

Sample Rate = Channel Spacing

OPTION 2

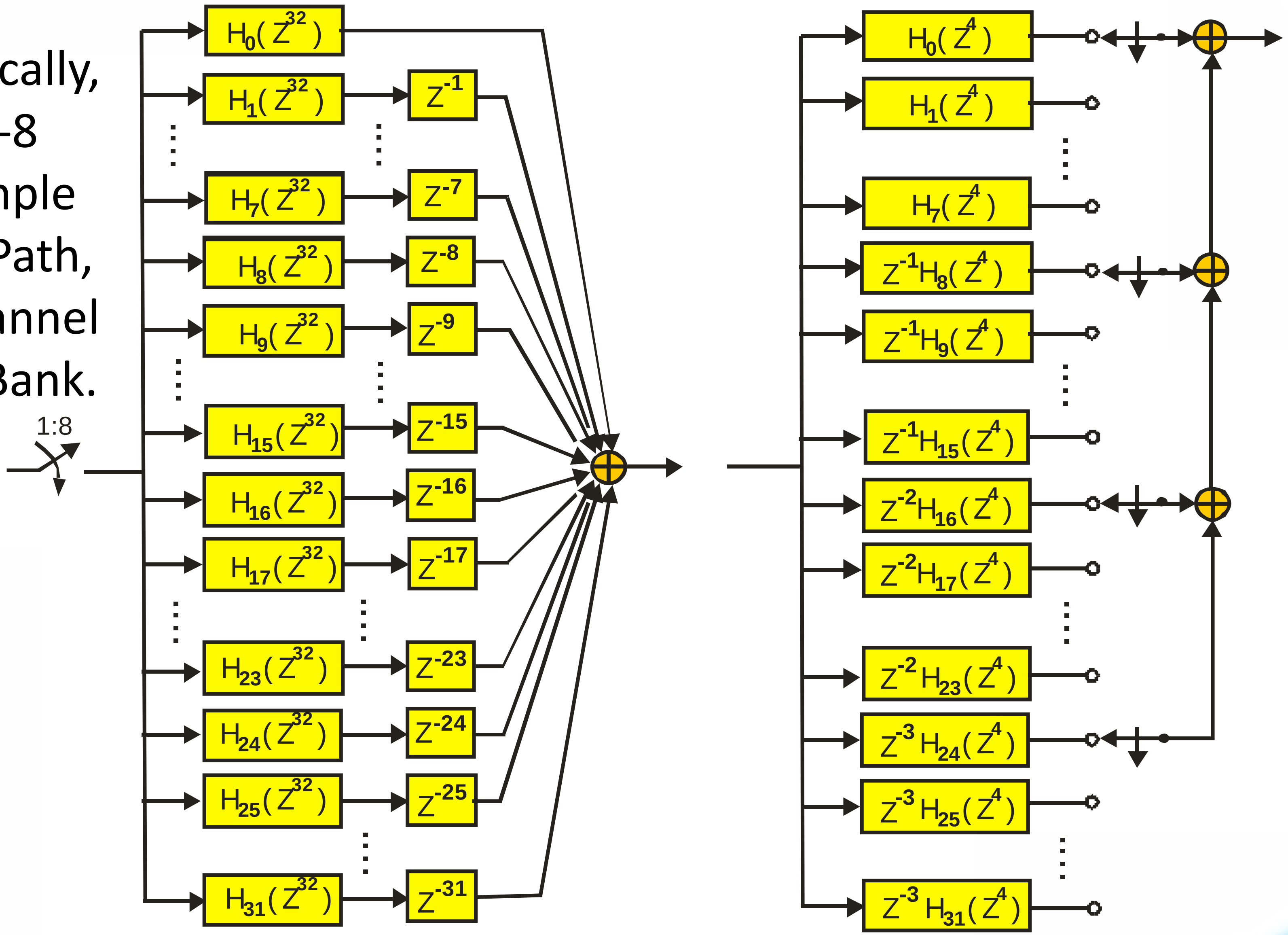


Channel Bandwidth = 2 Channel Spacing

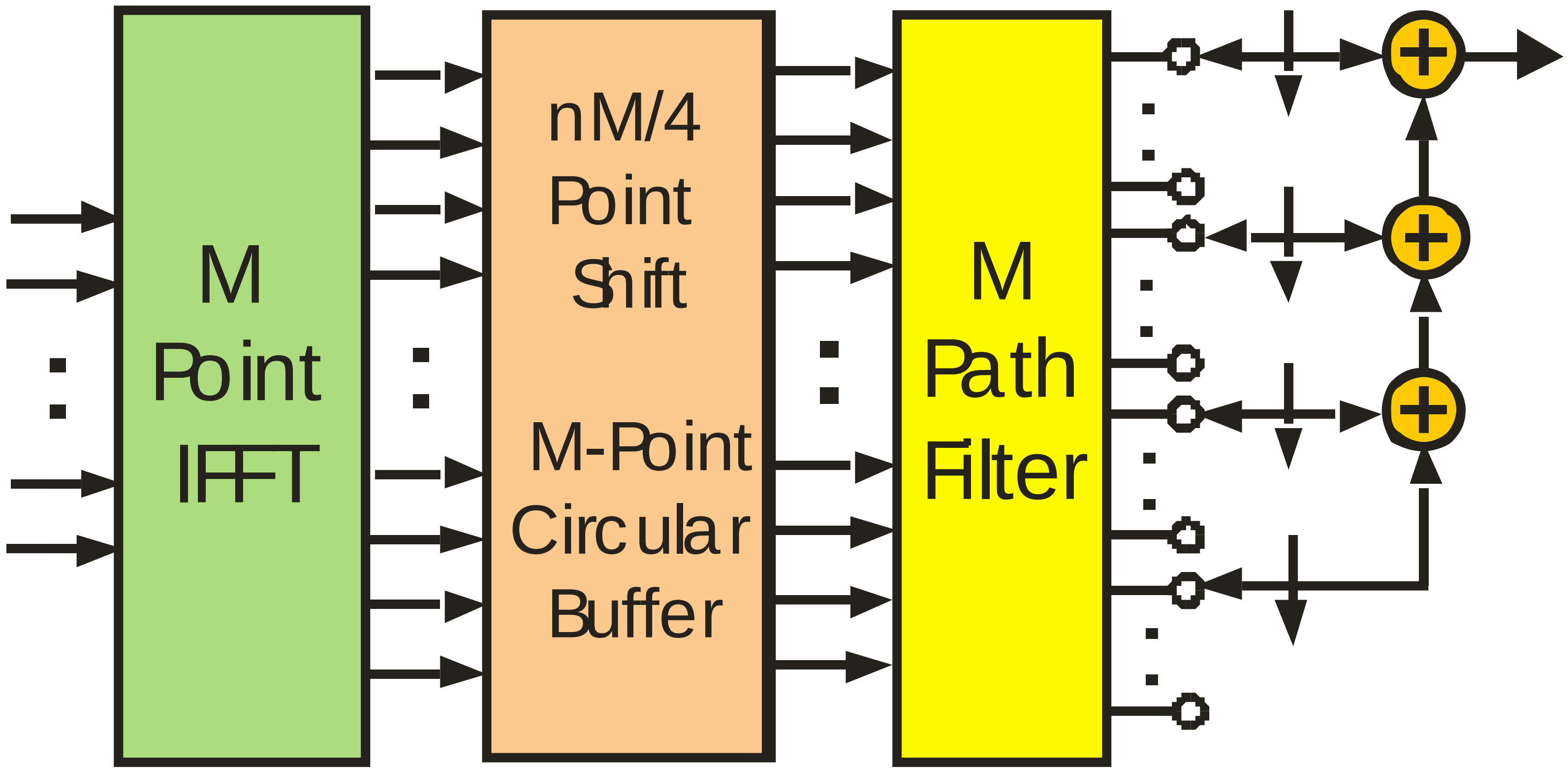
Sample Rate = 4 Channel Spacing

1-to-M/4 Resample in M-Path Filter

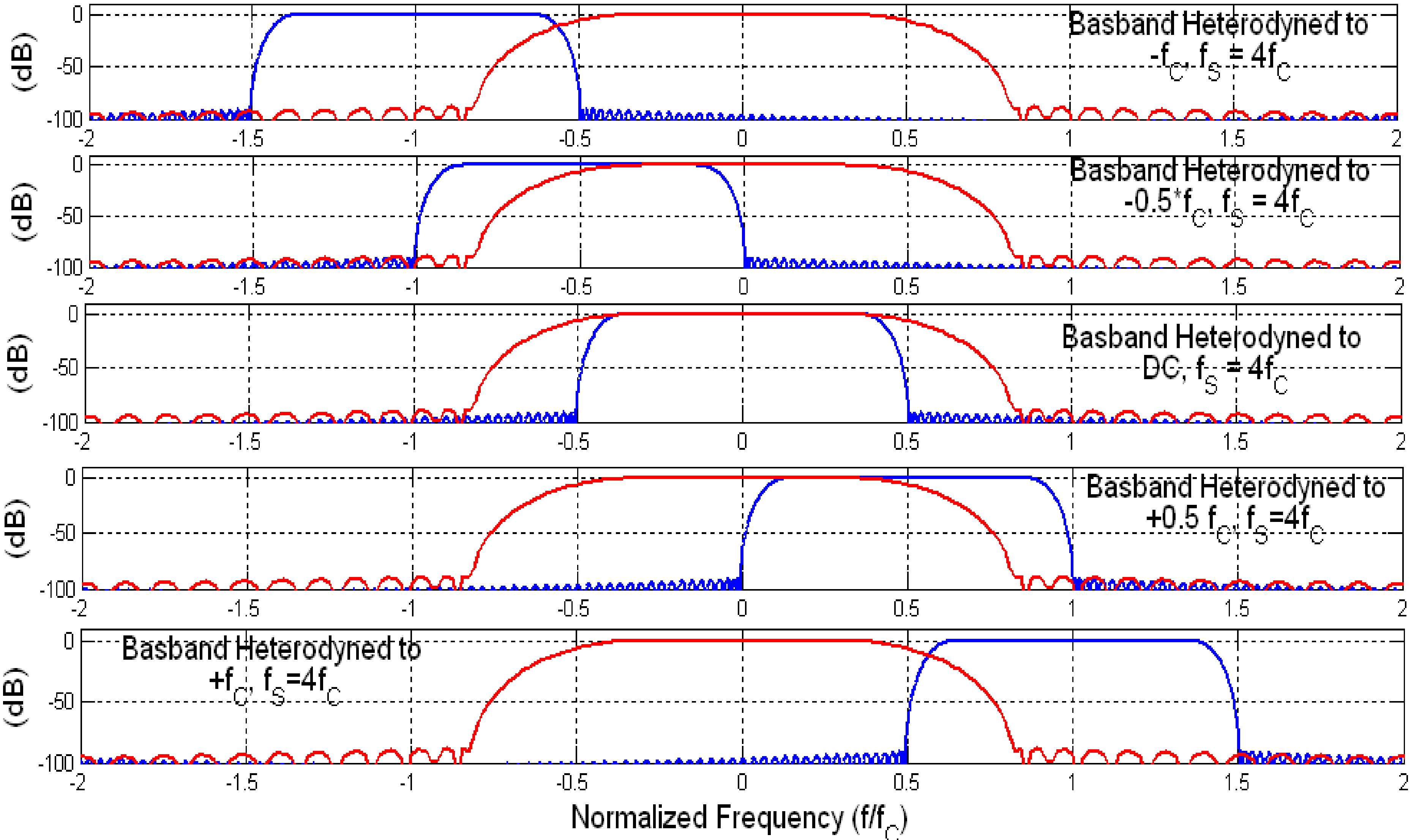
Specifically,
1-to-8
Resample
In 32-Path,
32-Channel
Filter Bank.

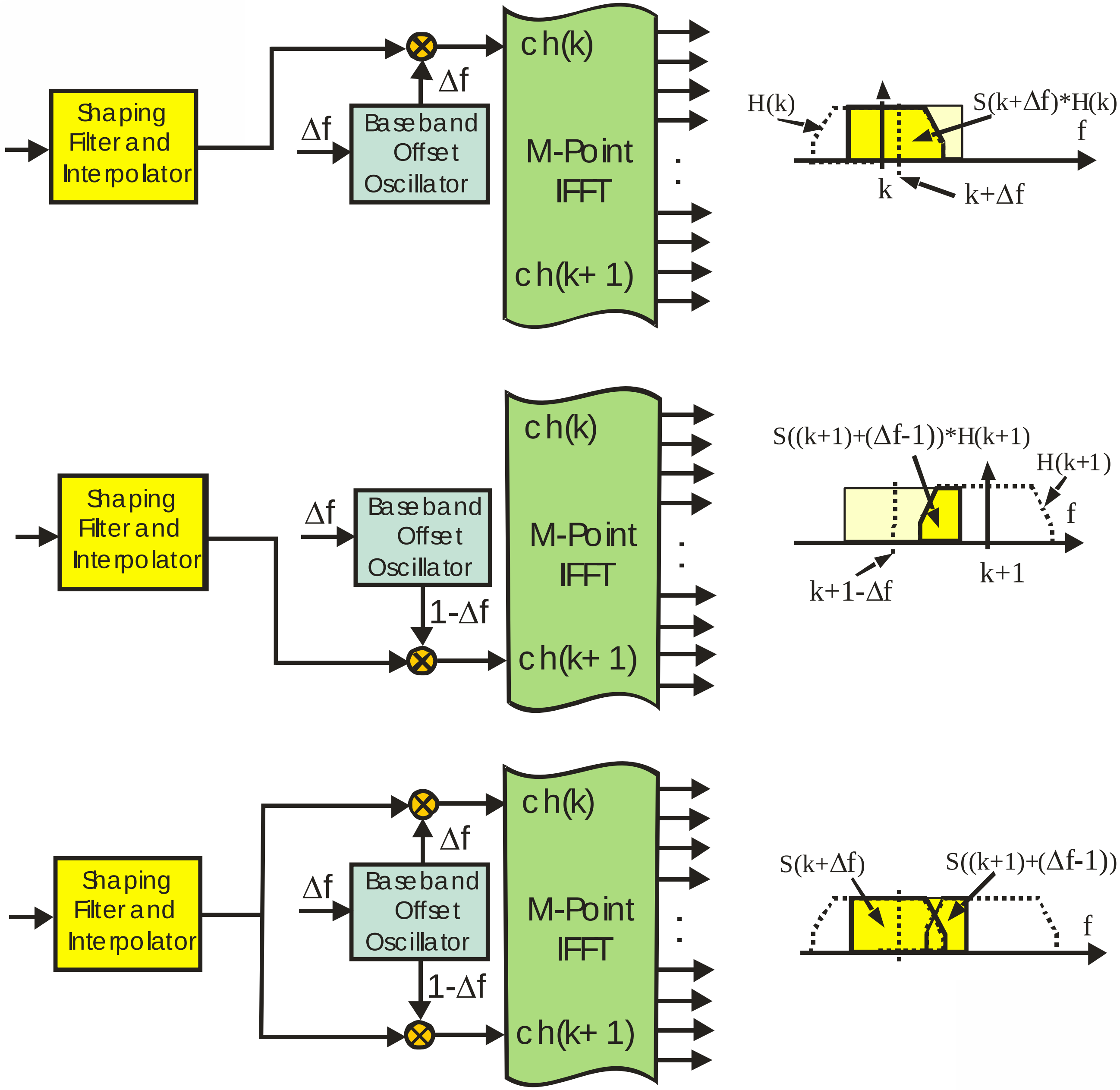


Modified M-Path Channelizer Performs 1-to-M/4 Resampling



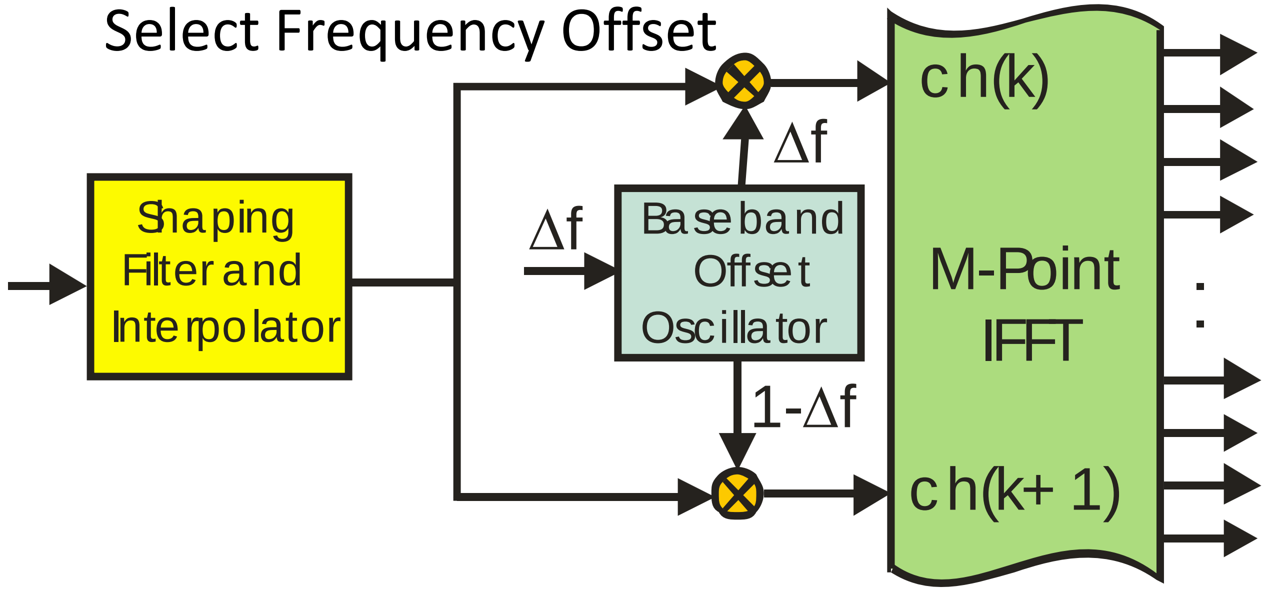
Baseband Signal Can Be Heterodyned: $-f_C<f_{HET}<+f_C$



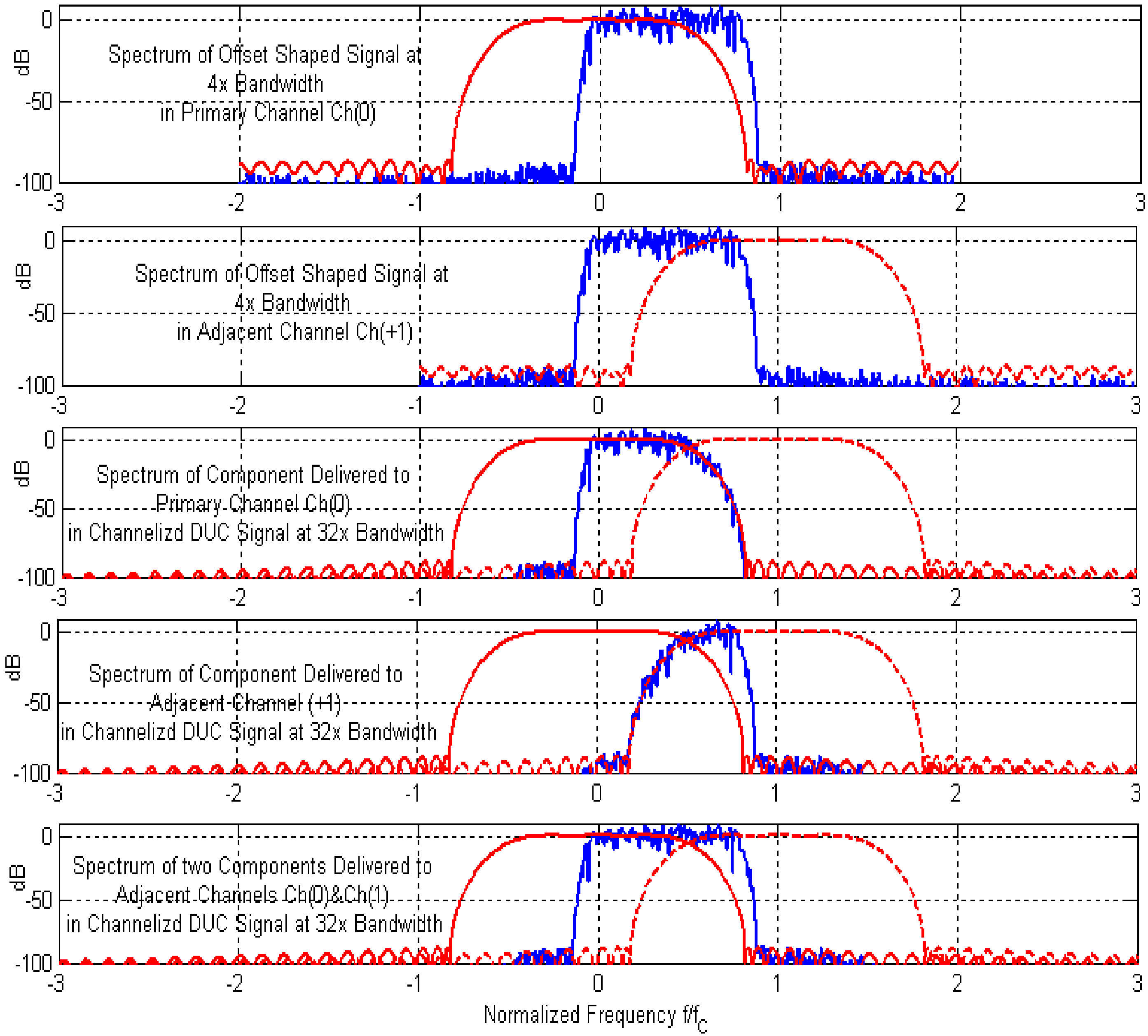

Shaping Filter and Interpolator
Δf
Baseband Offset Oscillator
Δf
ch(k)
M-Point IFFT
ch(k+ 1)
H(k)
S(k+Δf)*H(k)
f
k
k+Δf
Shaping Filter and Interpolator
Δf
Baseband Offset Oscillator
1-Δf
ch(k)
M-Point IFFT
ch(k+ 1)
S((k+1)+(Δf-1))*H(k+1)
H(k+1)
f
k+1-Δf
k+1
Shaping Filter and Interpolator
Δf
Baseband Offset Oscillator
Δf
1-Δf
ch(k)
M-Point IFFT
ch(k+ 1)
S(k+Δf)
S((k+1)+(Δf-1))
f

Course Frequency Offset
Select Center Frequency

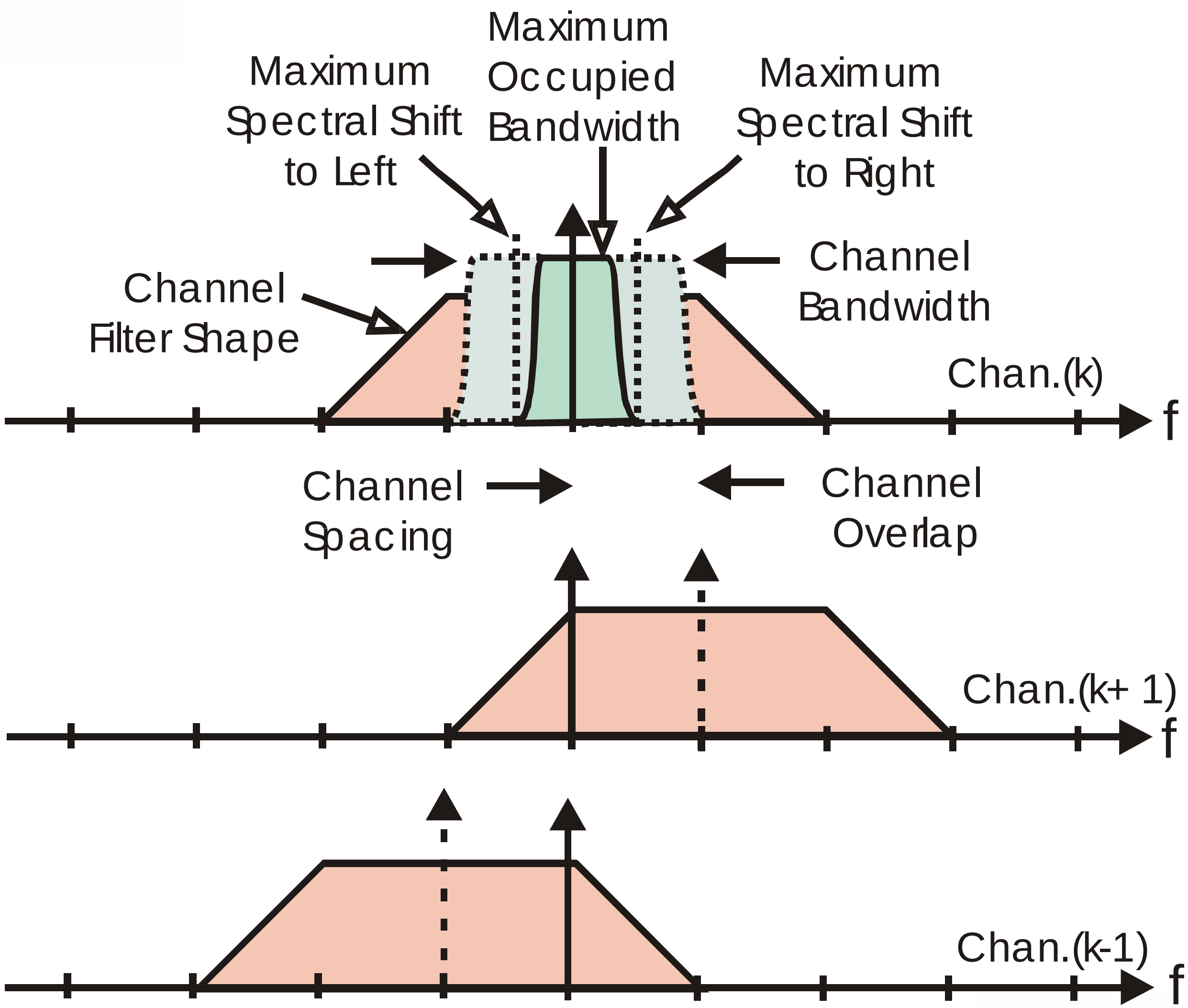
Fine Frequency Offset
Select Frequency Offset



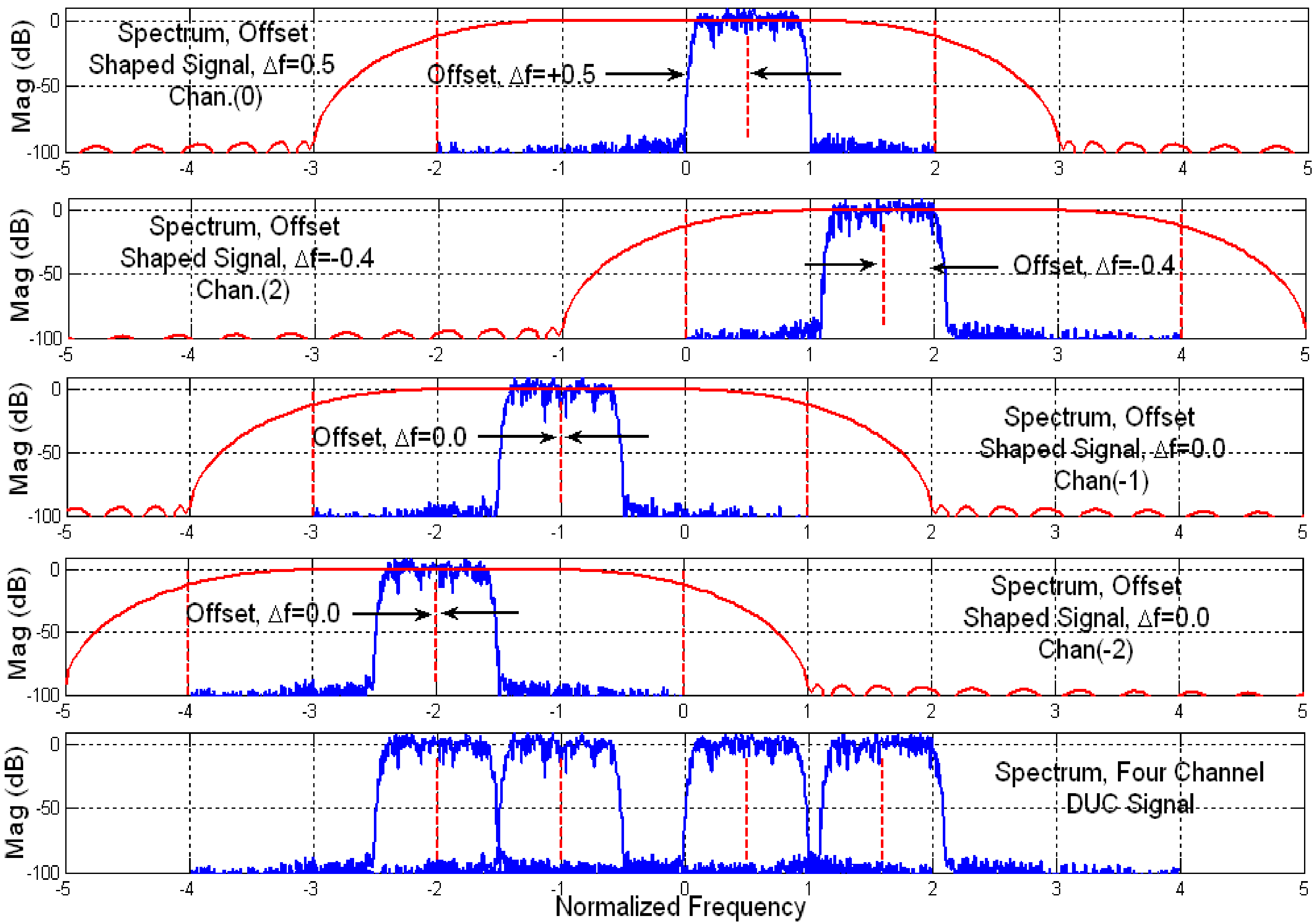
Offset Spectrum Spans Two Filter Widths



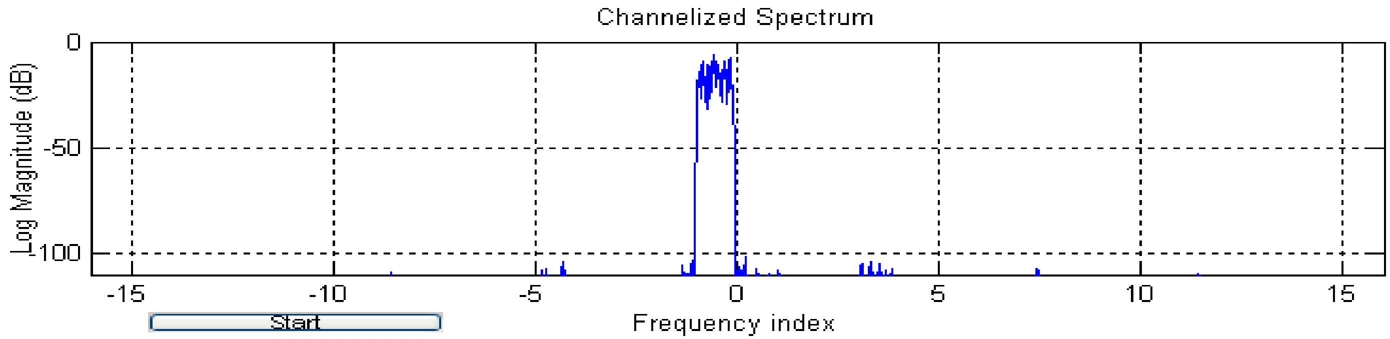
Second Option: Wider Filter Rather Than 2-Filters



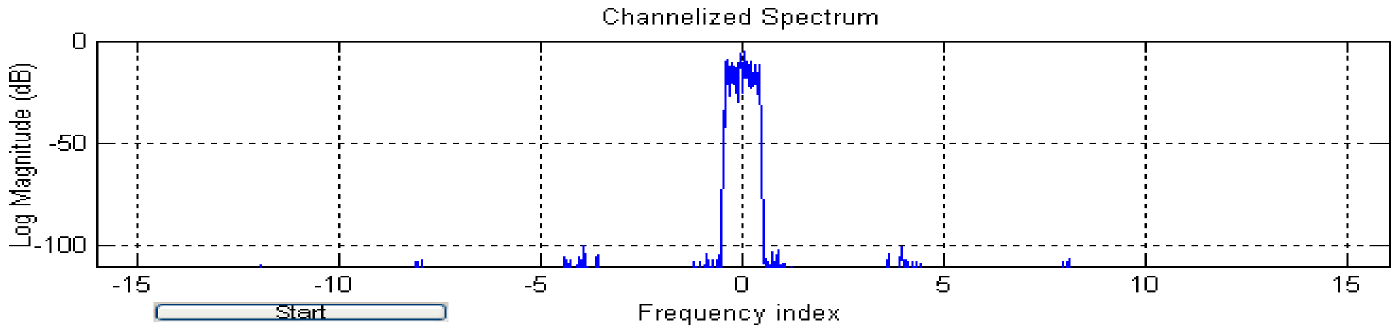
Offset Spectra in Double Width, 50% Overlapped Channel Filters



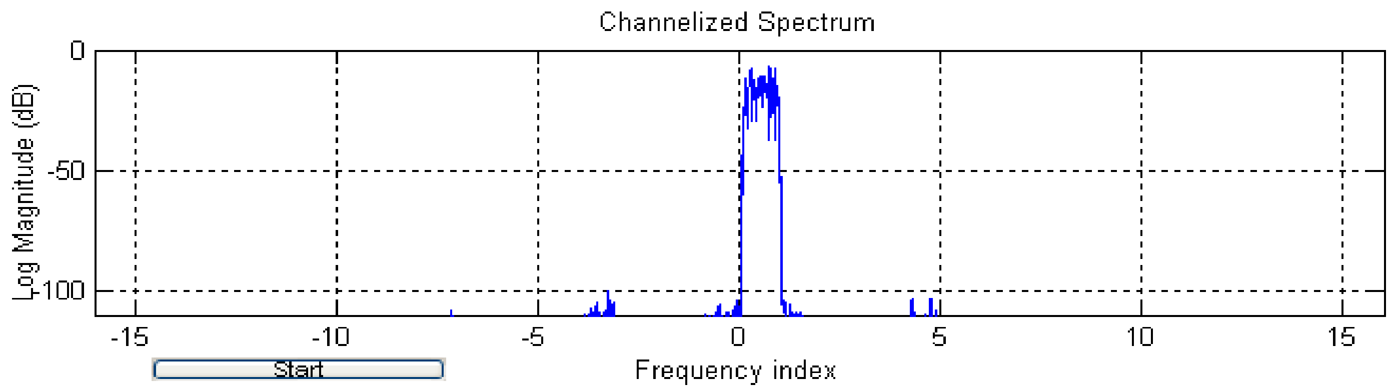
Channel Zero, Maximum Negative, Zero, And Maximum Positive Baseband Shift



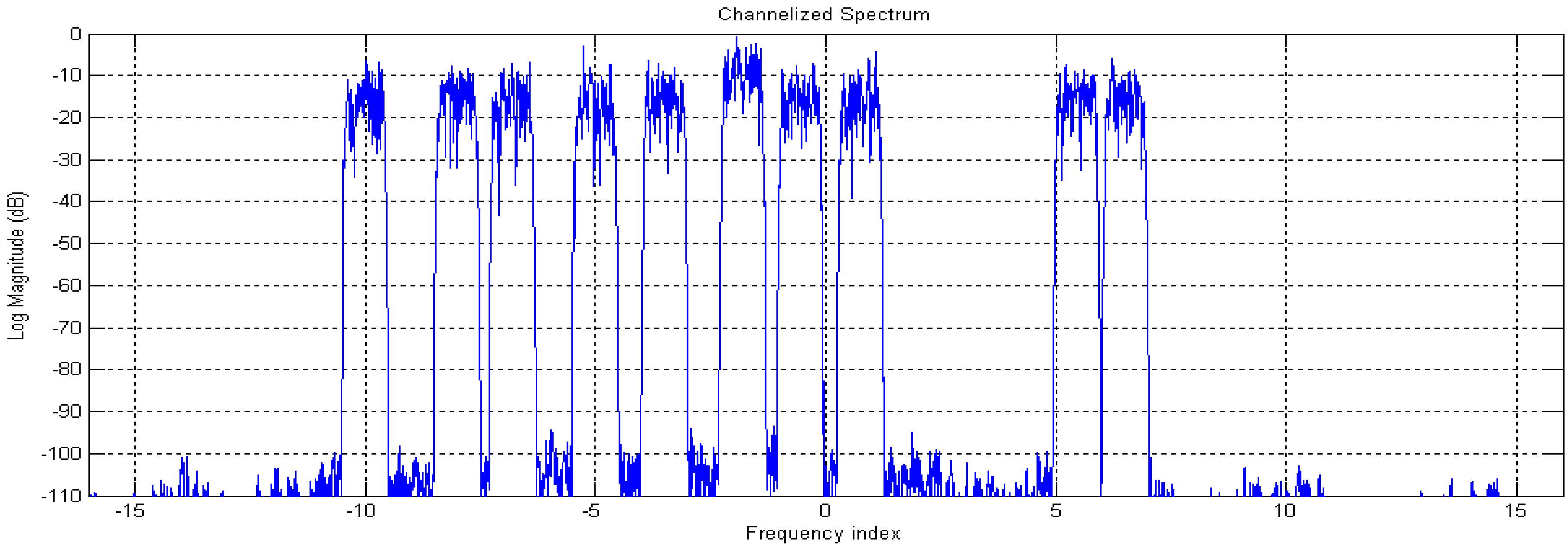
Offset	0	0	0	0	0	0	0	0	0	0	-0.55	0	0	0	0	0	0	0	0	0	0
on/off	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Channel	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	-0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10



Offset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
on/off	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Channel	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	-0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10



Offset	0	0	0	0	0	0	0	0	0	0	0.55	0	0	0	0	0	0	0	0	0	0
on/off	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Channel	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	-0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

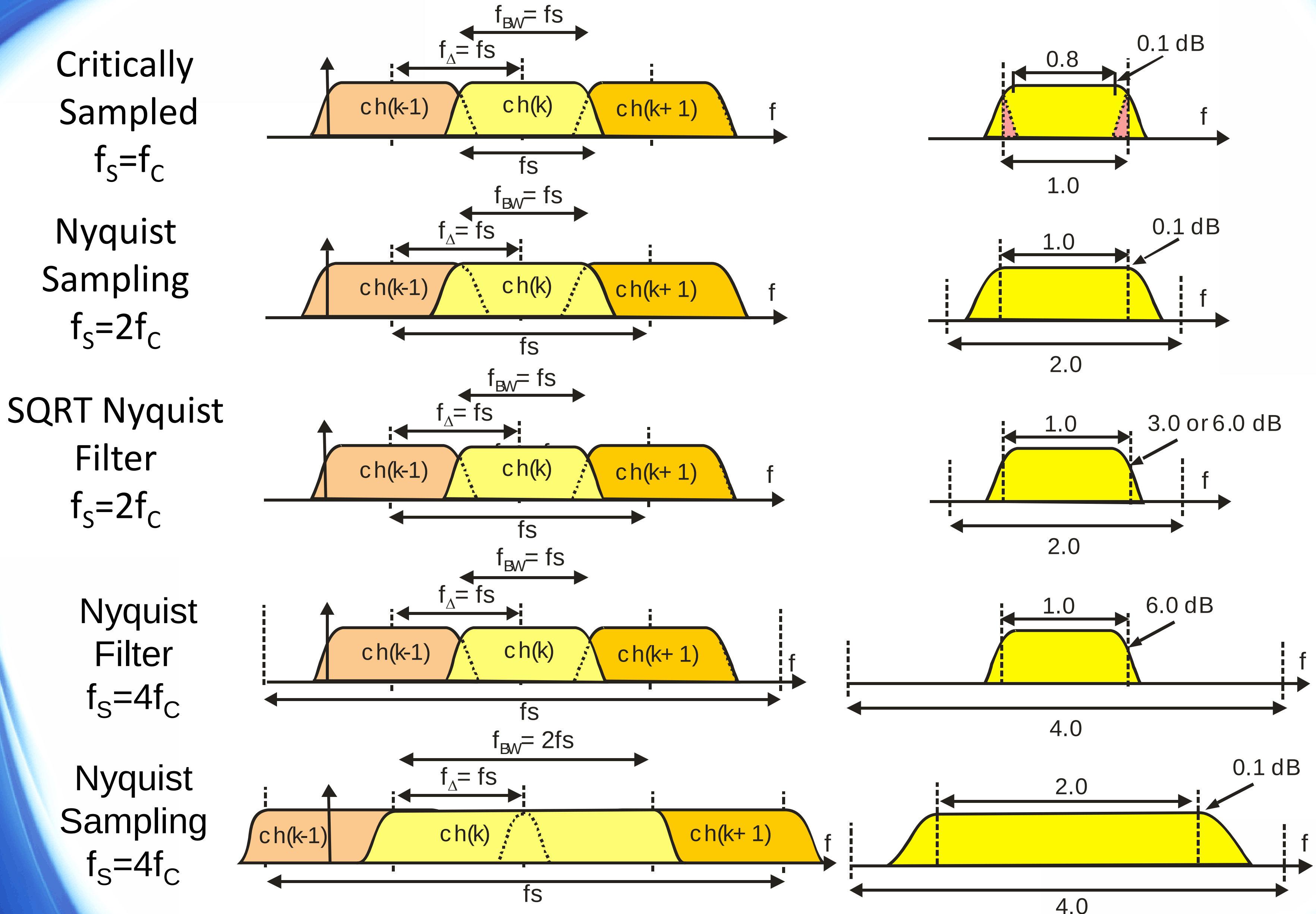


Start

Offset	0	0	0	0.2	0	0	0.5	0	0.2	0	-0.55	-0.25	0	0	0	0.45	0.5	0	0	0	0
on/off	1	0	1	1	0	1	1	0	2	0	1	1	0	0	0	1	1	0	0	0	0
Channel	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	-0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

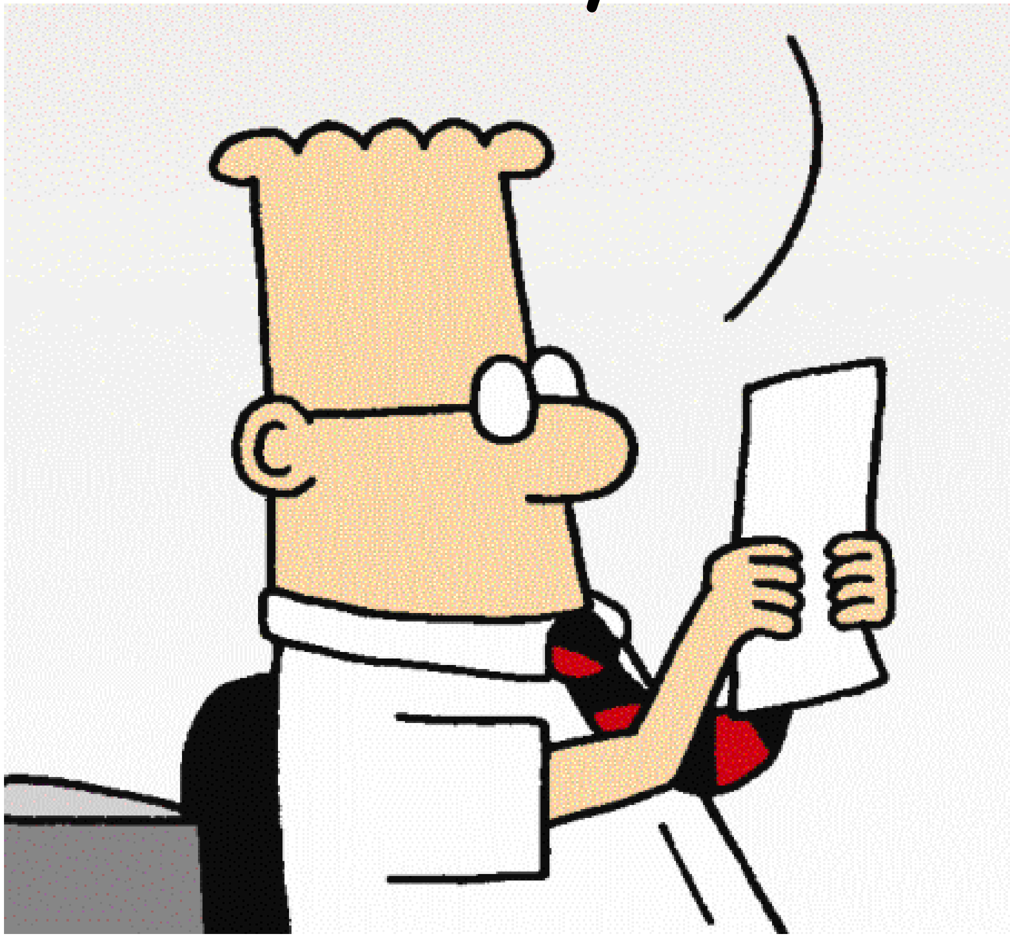
Multiple Baseband Shifts Become Same Shifts at Channel Center Frequencies

Various Filter-Channelizer Configurations




Dilbert, is it true that DSP makes the world go around but multirate signal processing supplies the music for the ride?

Is There any Doubt???



We are now Open For Questions