

NARROWBAND NOISE INTERPOLATED AND TRANSLATED BY MULTIRATE PROCESSING TECHNIQUES

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**SAN DIEGO STATE
UNIVERSITY**

College of Engineering

Raytheon

MAKE NARROW BANDWIDTH WHITE NOISE

- Wide Range of Bandwidths
- Wide range of Center frequencies
- Make it Inexpensively
- Make it in DSP Land

How Hard Can It Be To Make Noise?



Remember this kind of White Noise



How To Make Noise

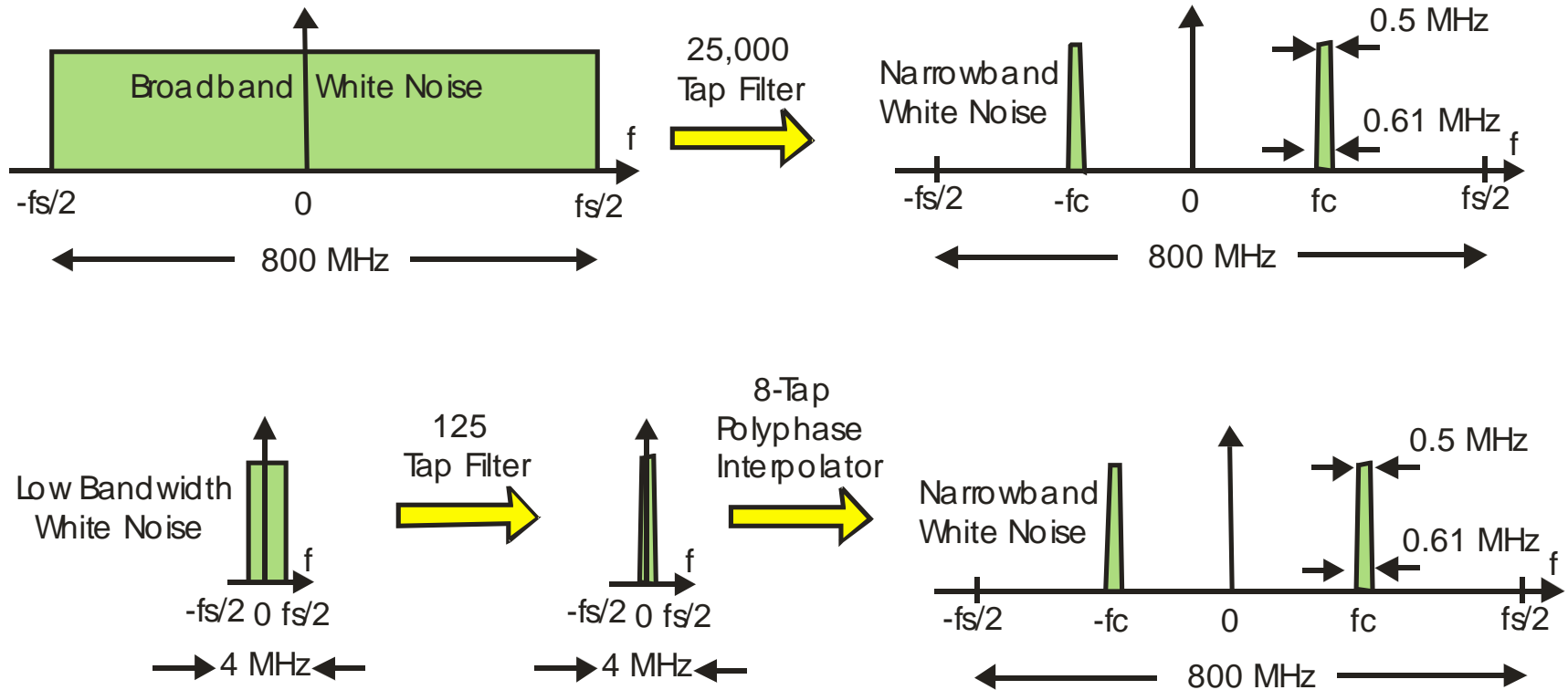
Two Options;

1. Make Broadband Noise at High Sample Rate and Reduce Bandwidth with Very Long Digital Filters
2. Make Narrowband Noise at Low Sample Rate and Increase Sample Rate with Short Interpolating Filters

Sometimes a filter is not the right Solution

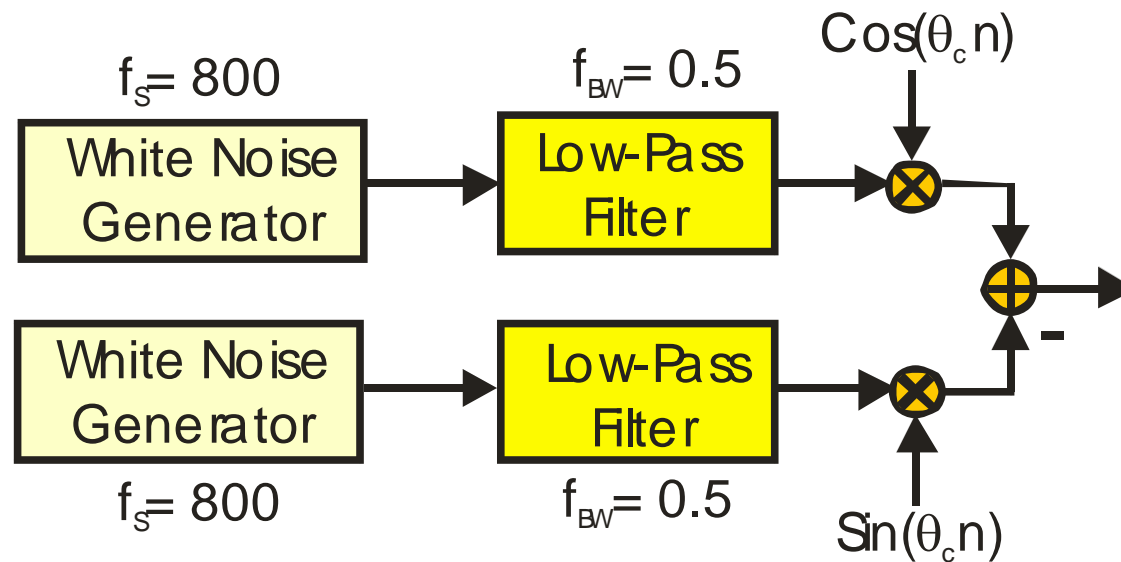


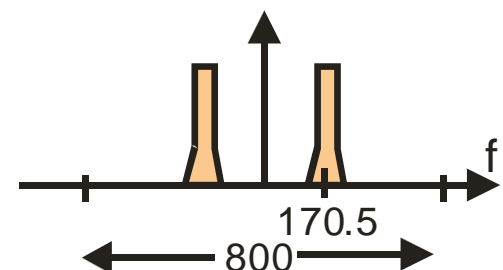
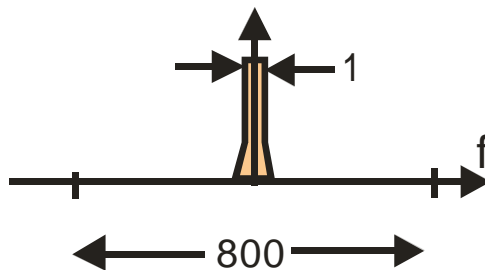
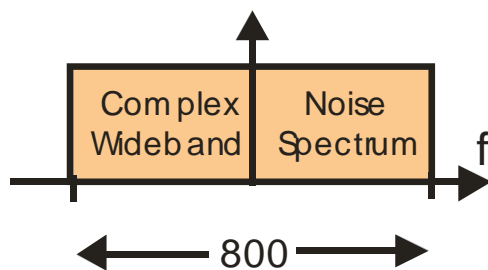
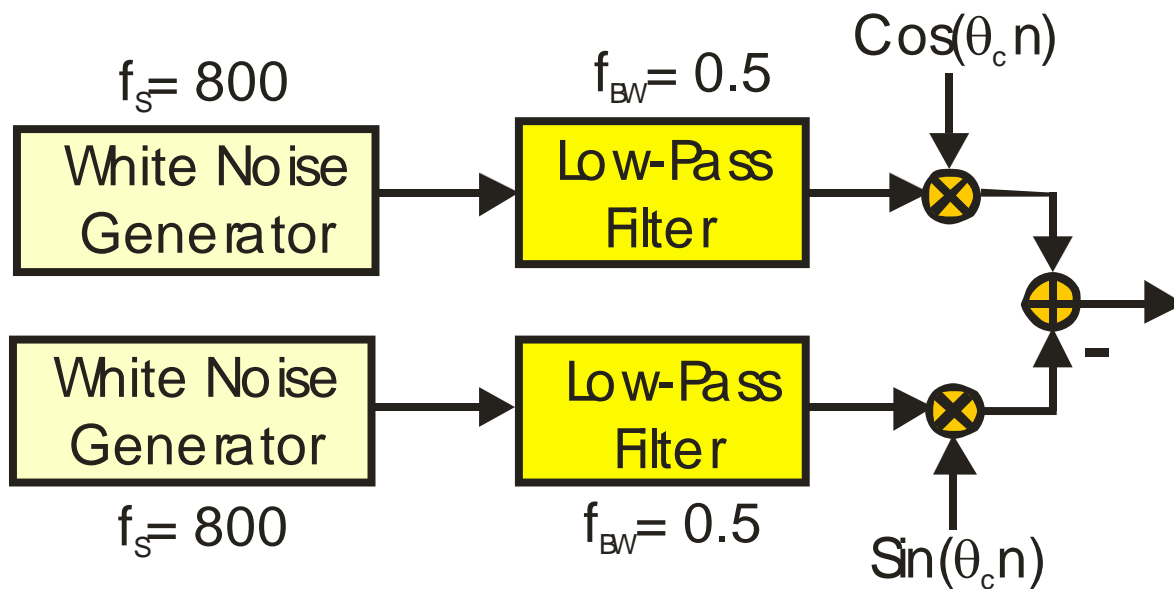
Two Options

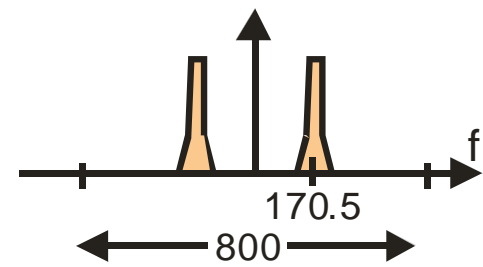
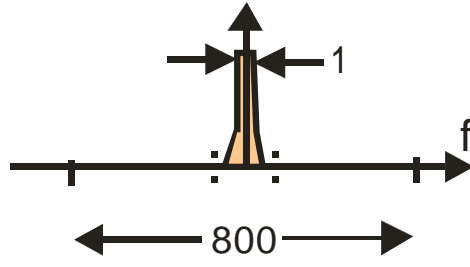
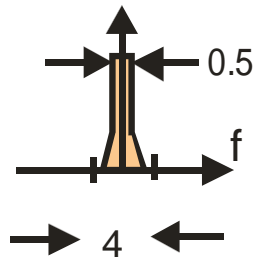
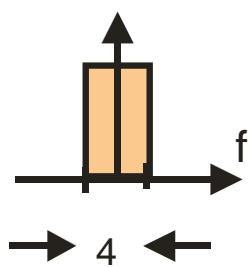
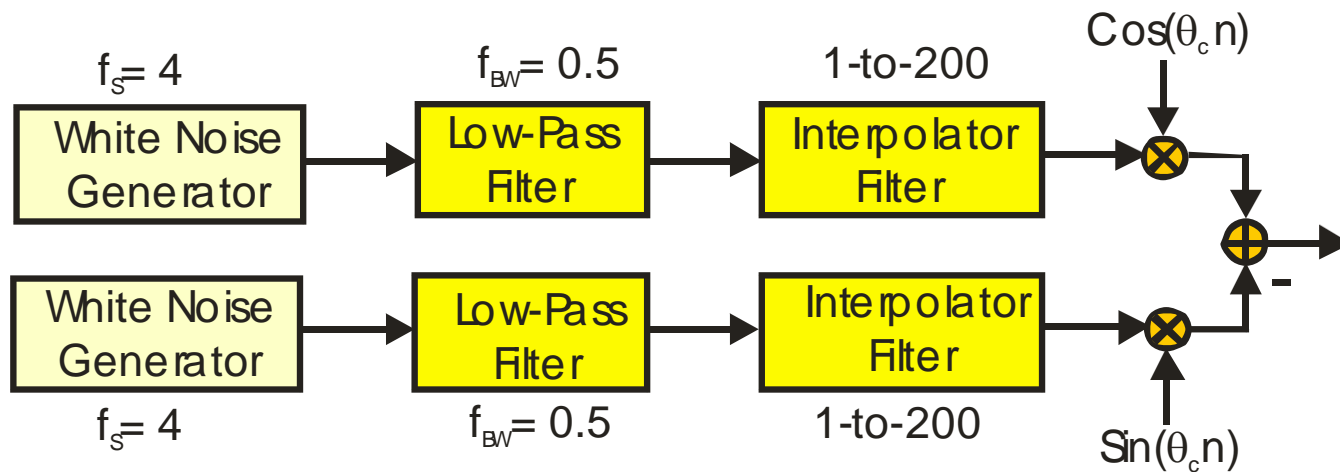


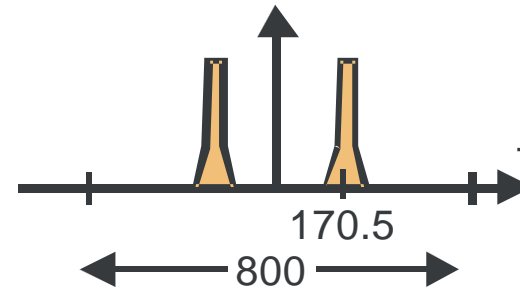
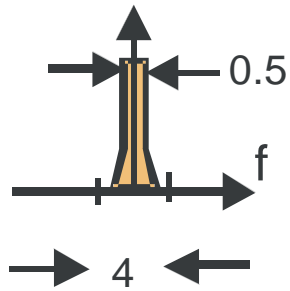
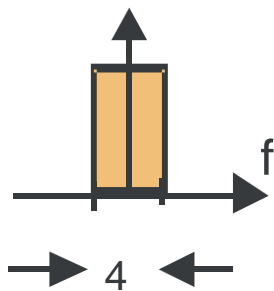
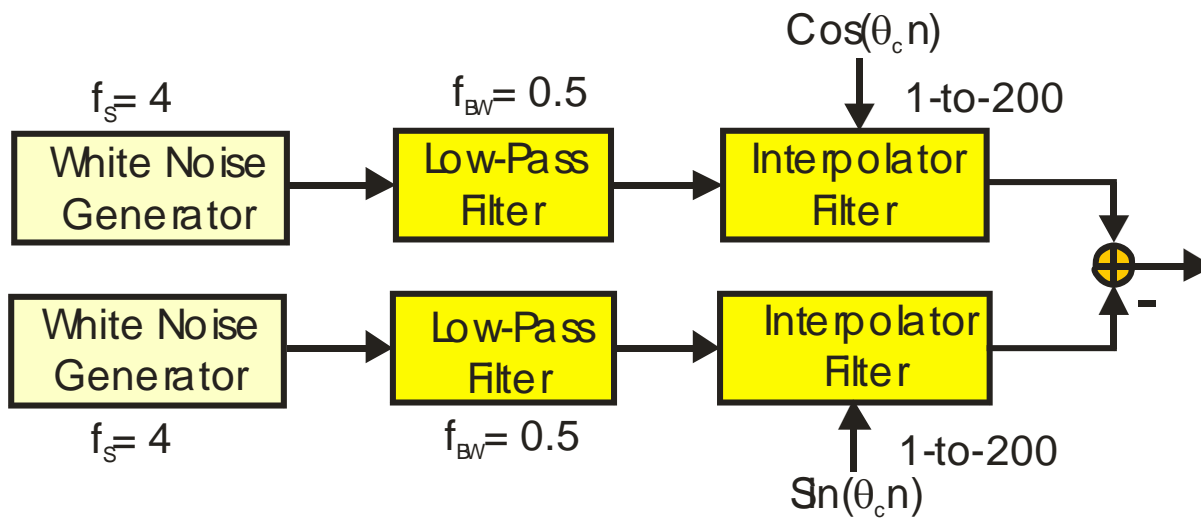
Example

- Bandwidth 0.5-MHz
- Center Frequency 170.5 MHz
- Sample Rate 800.0 MHz

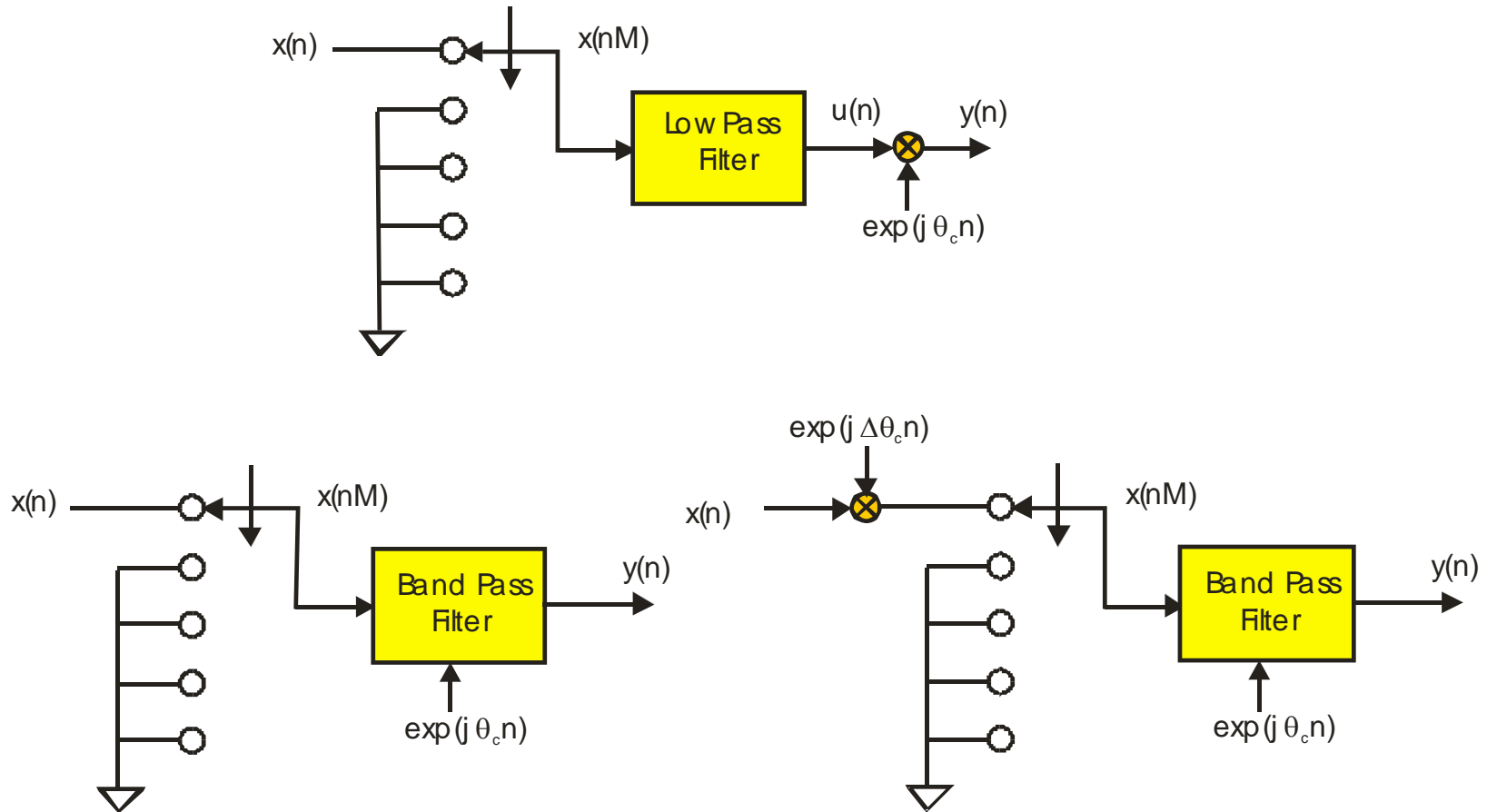




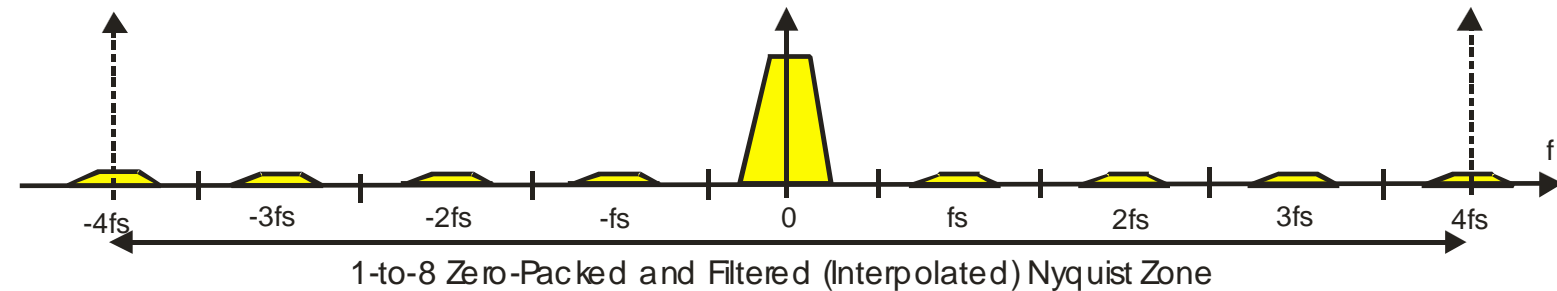
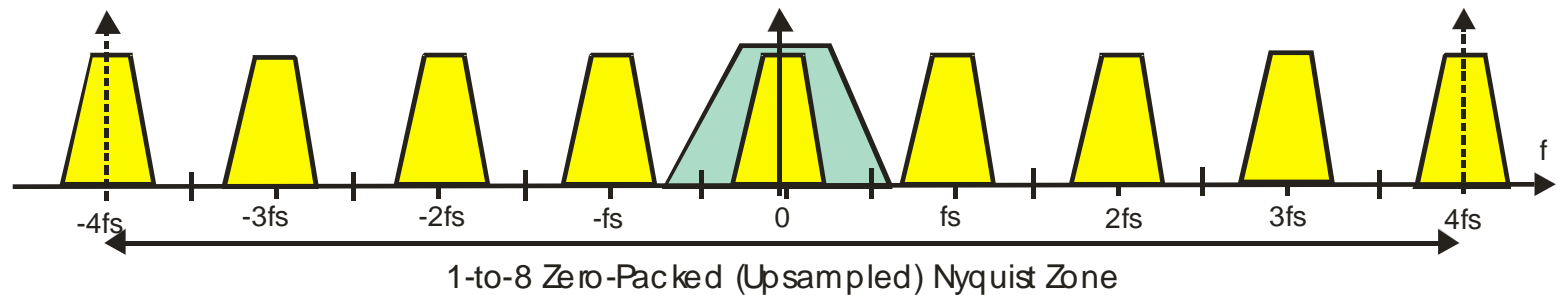
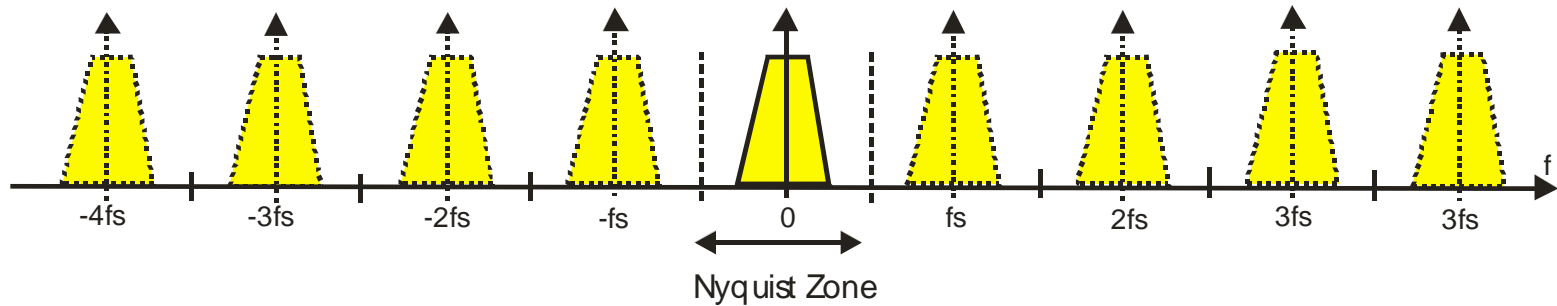




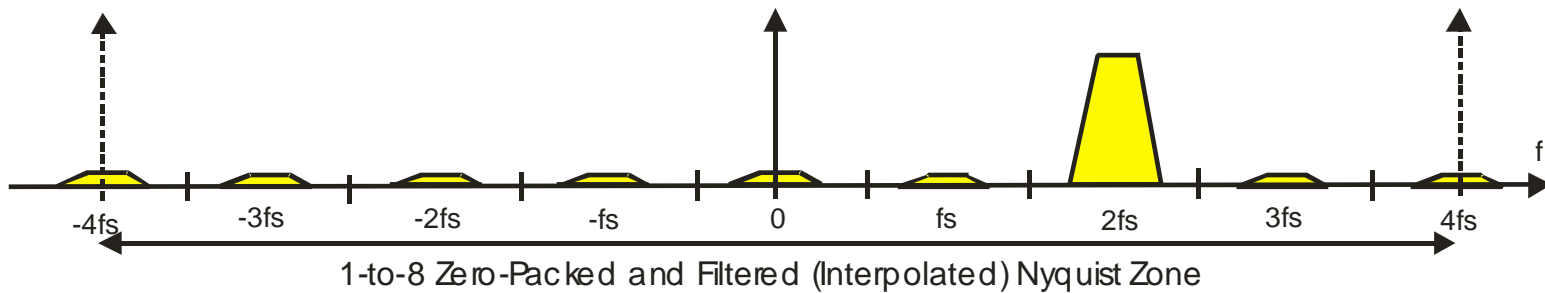
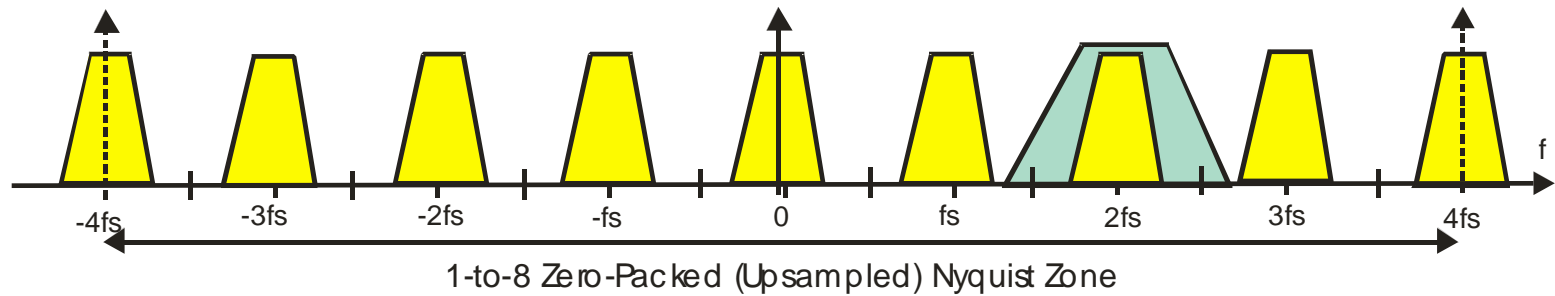
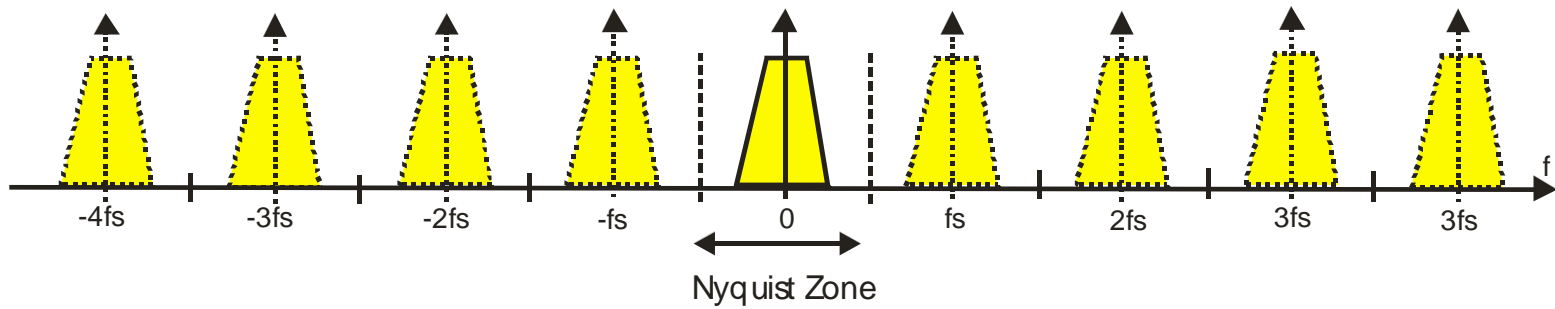
Interpolators 101 (You must also take Interpolators 601)



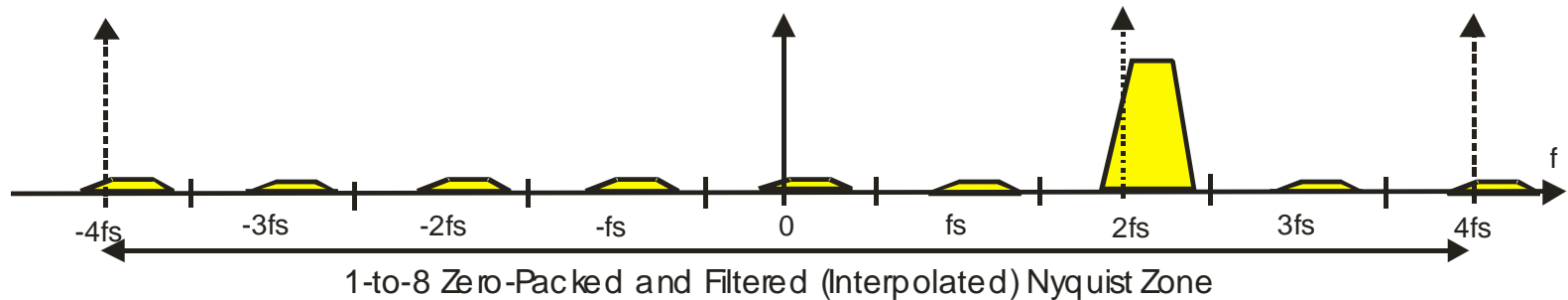
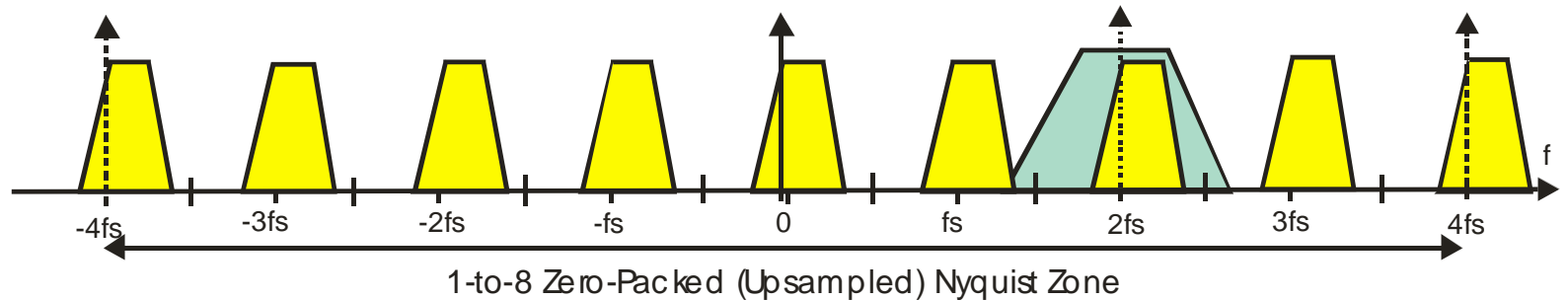
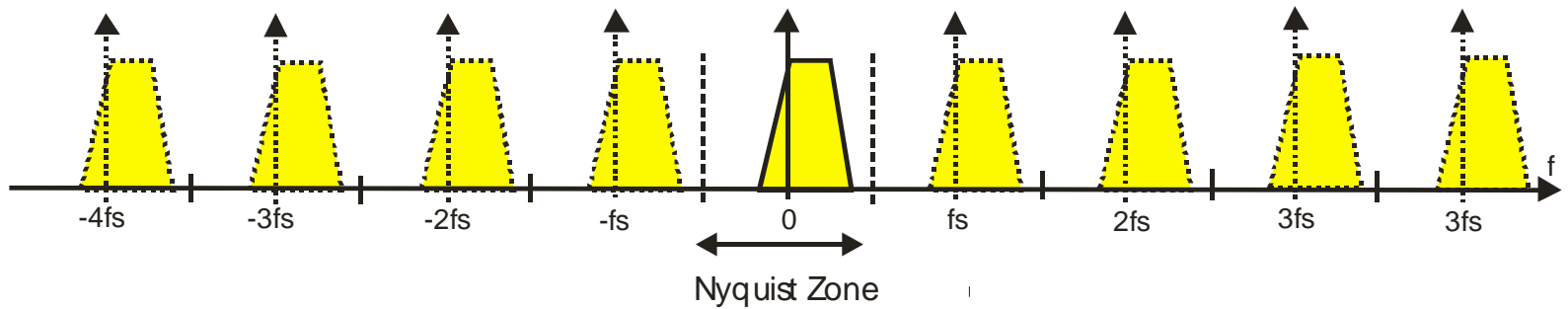
Interpolate by Zero- Packing (We don't really do this)



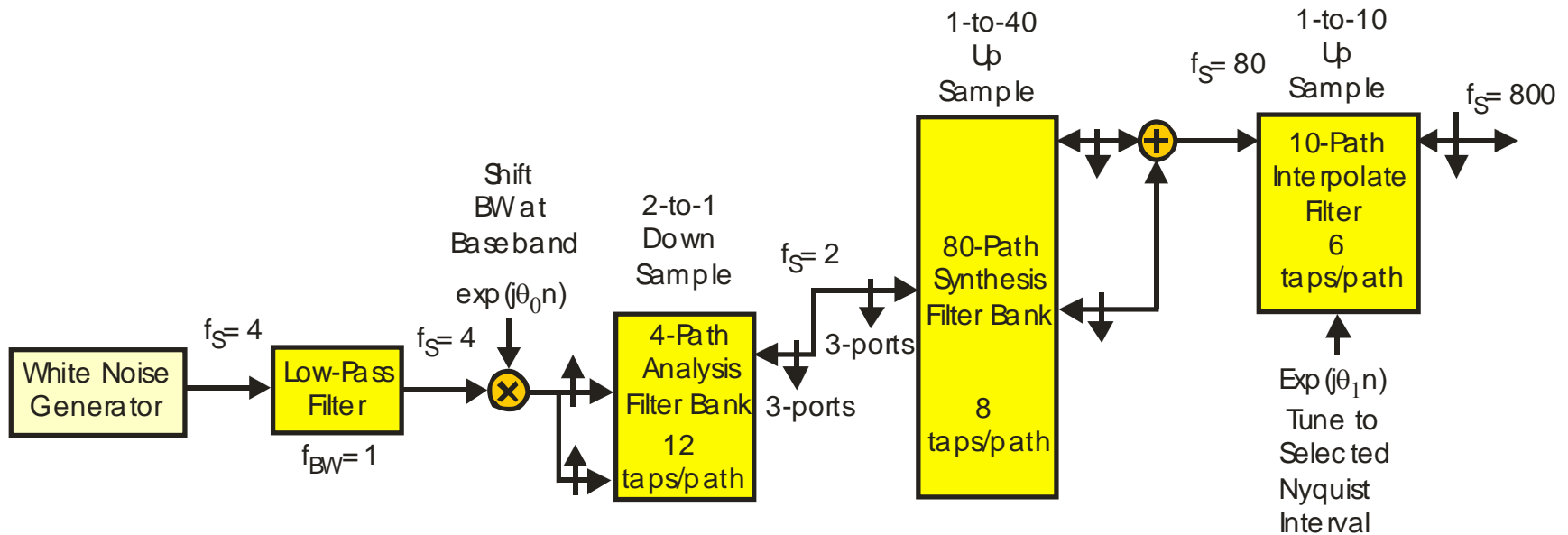
Interpolate and Alias to A higher Nyquist Zone



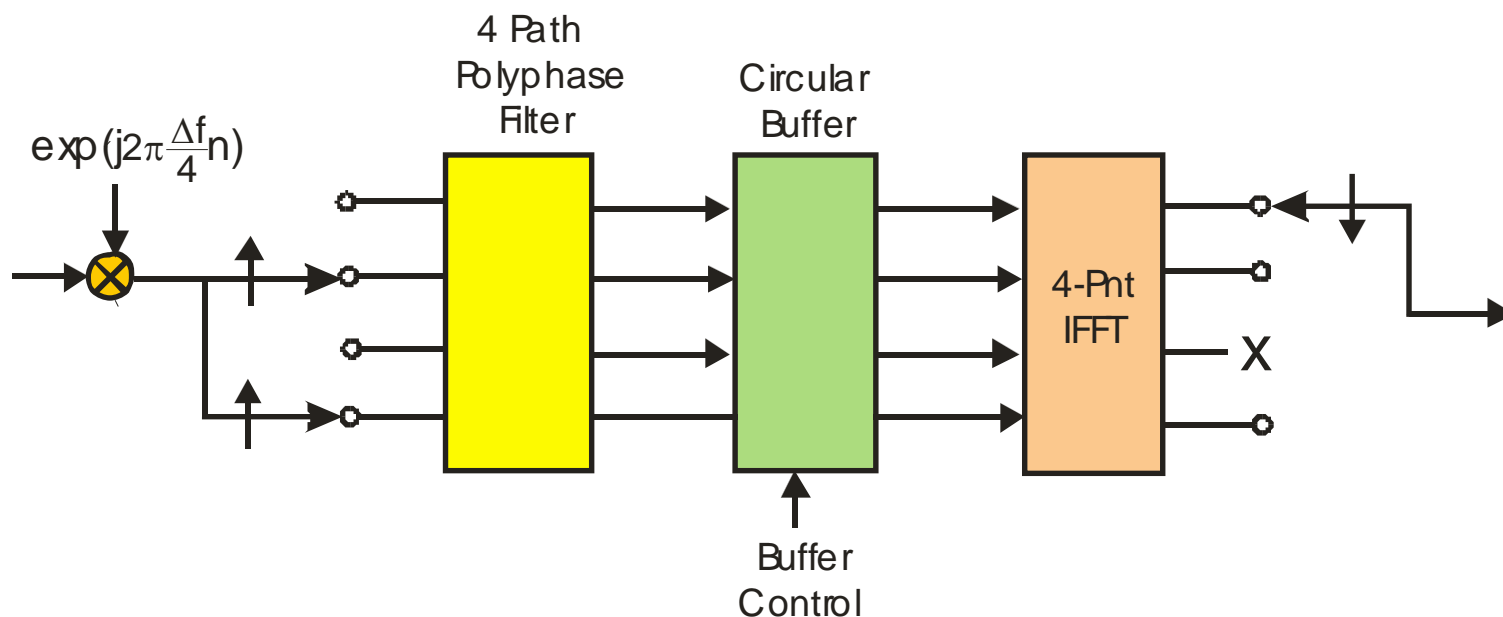
Offset Spectrum at baseband at Low Sample Rate Prior to Interpolate



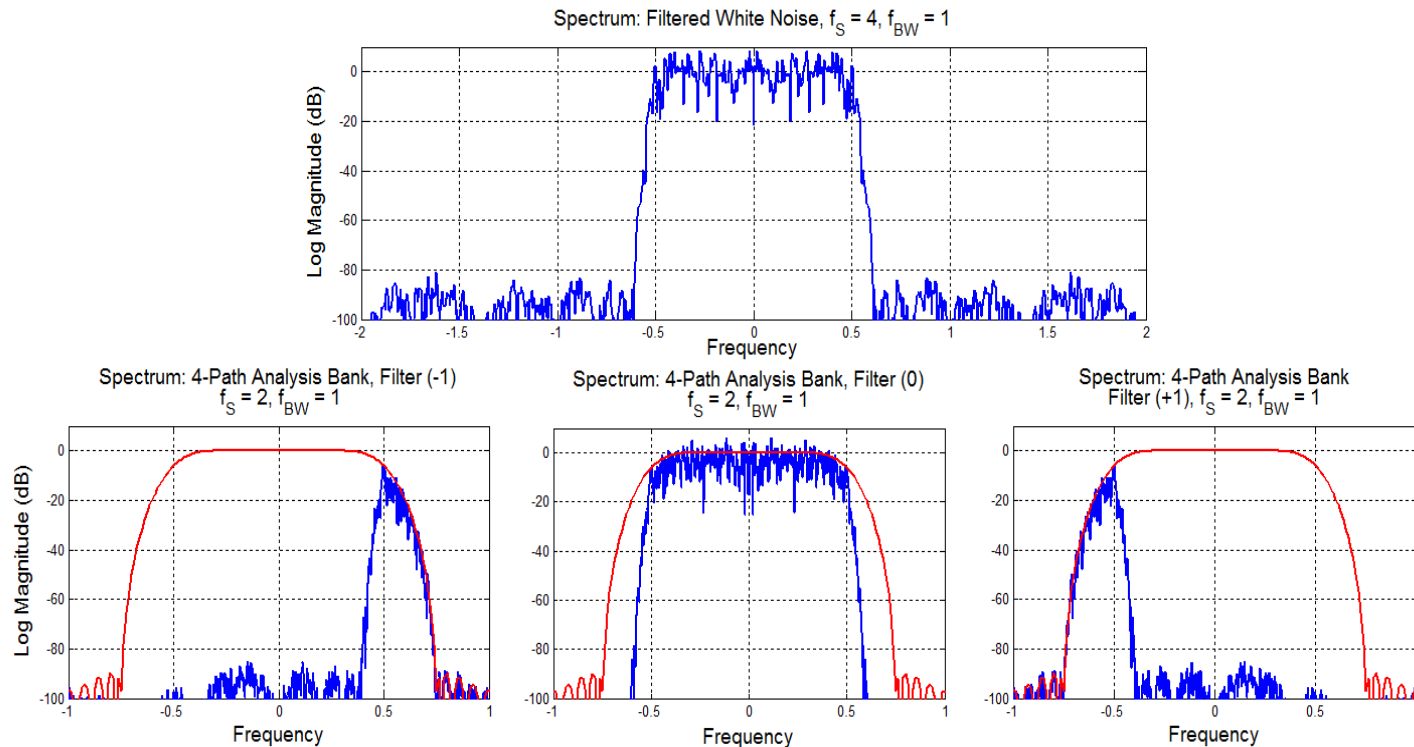
Efficient Interpolation and Translation Scheme



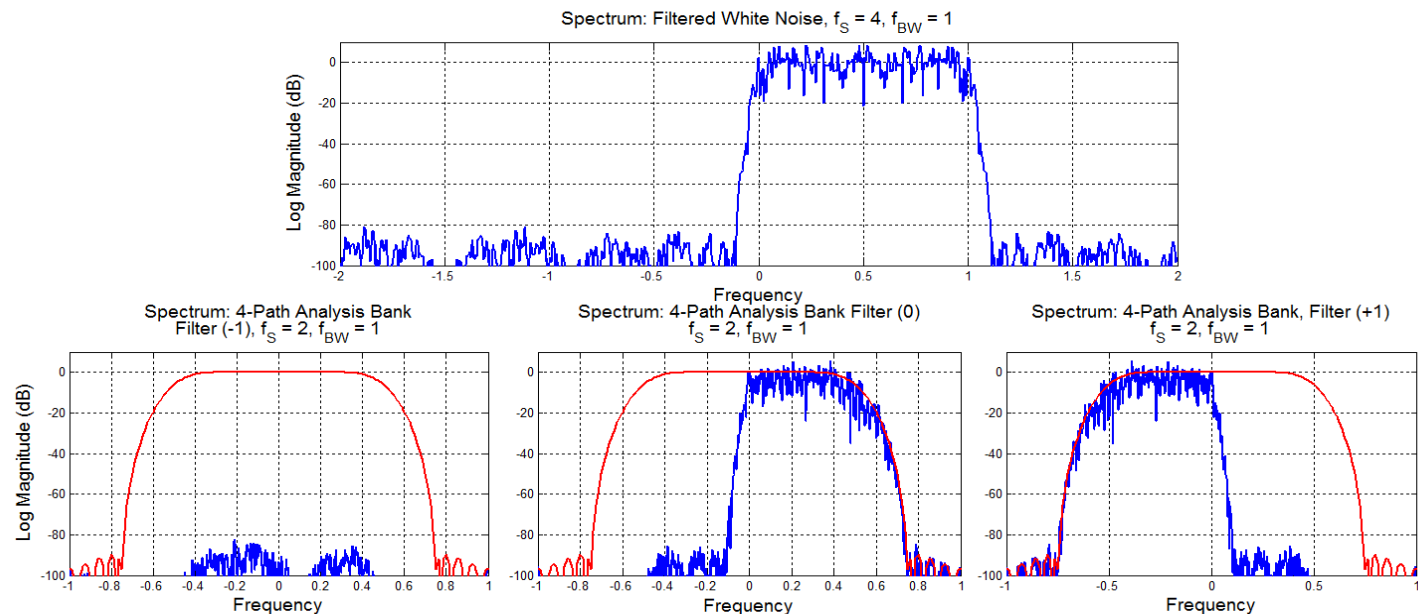
Analysis Filter Bank
4-Path, 12 Real Coefficients per Path
2-to-1 Down-Sample, Coupled to 4-point IFFT
Outputs Three 1-MHz Bandwidth Channels,
from -1, 0, & +1 MHz Channel Centers, at 2-MHz Sample Rate



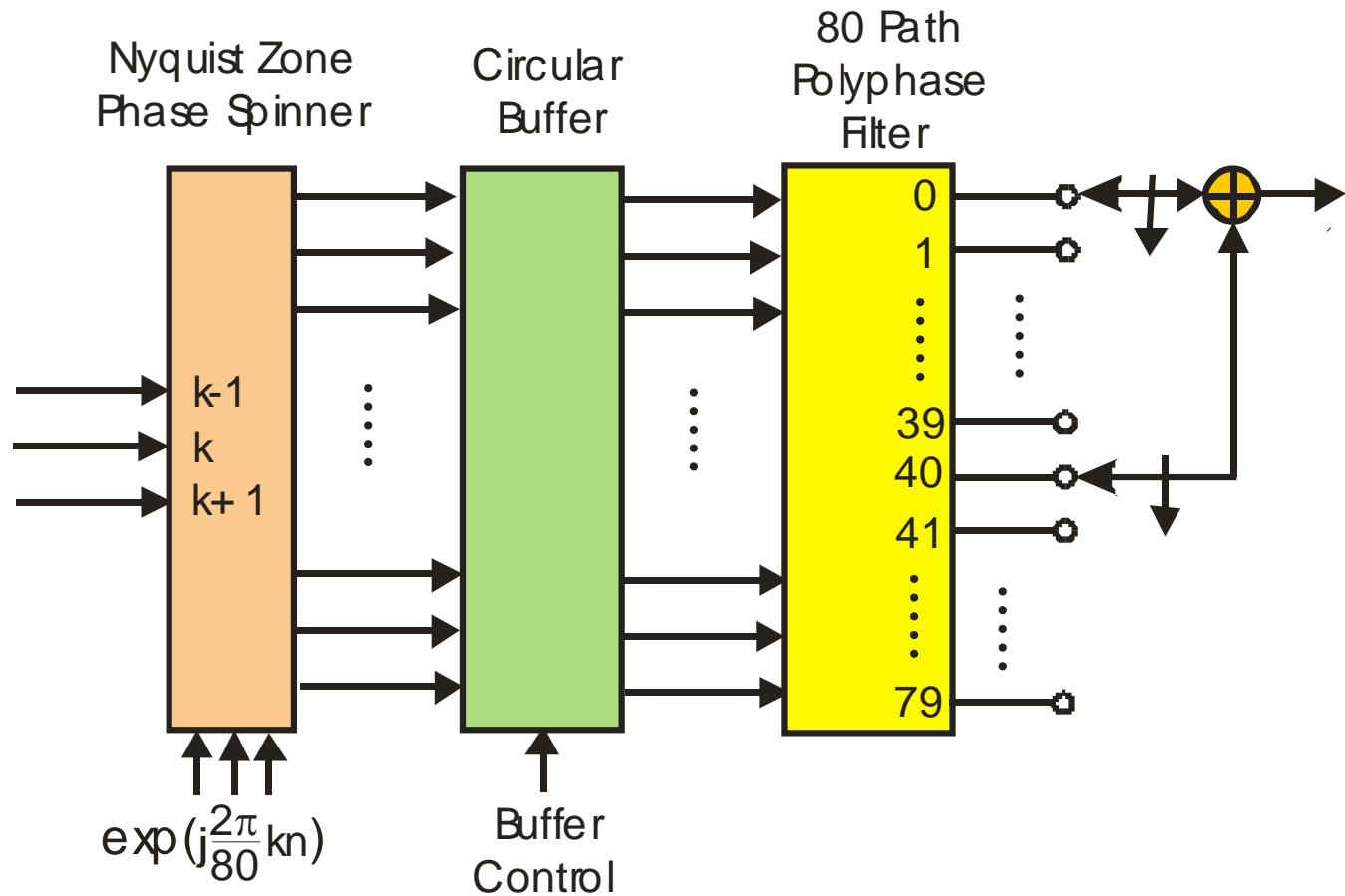
Input Bandwidth Wider Than Interpolating Channel Bandwidths



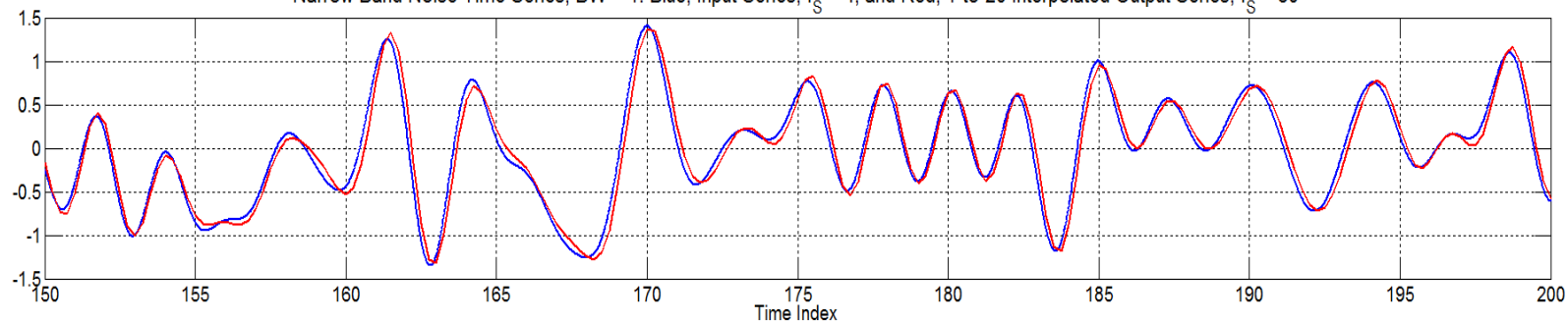
Baseband Frequency Offset Greater Than Interpolating Channel Bandwidth



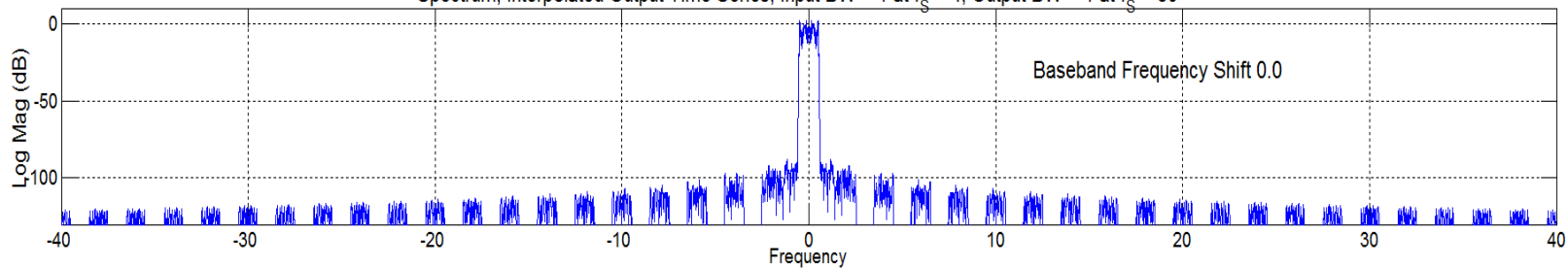
Second Interpolator Filter
80-Path, 1-to-40 Up-Sample,
8 Real Coefficients per Path
80 Offset Channels at Multiples of 2-MHz
Channel Center Frequency Determined by Complex Input Vector



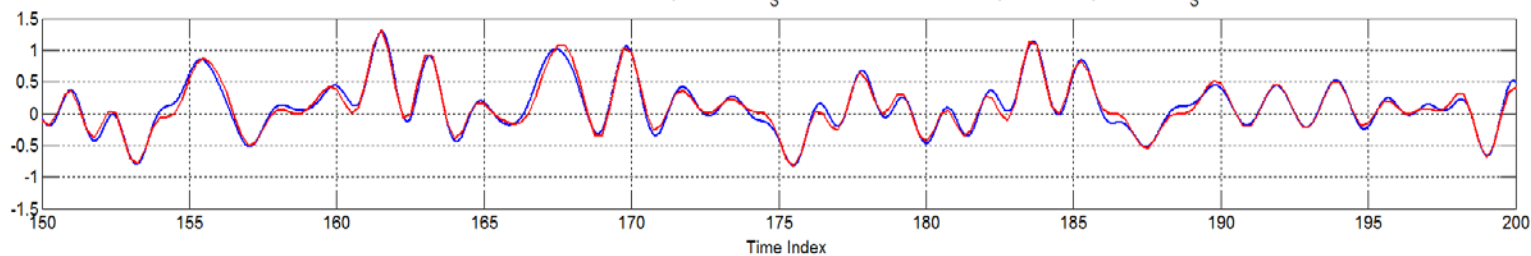
Narrow Band Noise Time Series, BW = 1: Blue, Input Series, $f_s = 4$, and Red, 1-to-20 Interpolated Output Series, $f_s = 80$



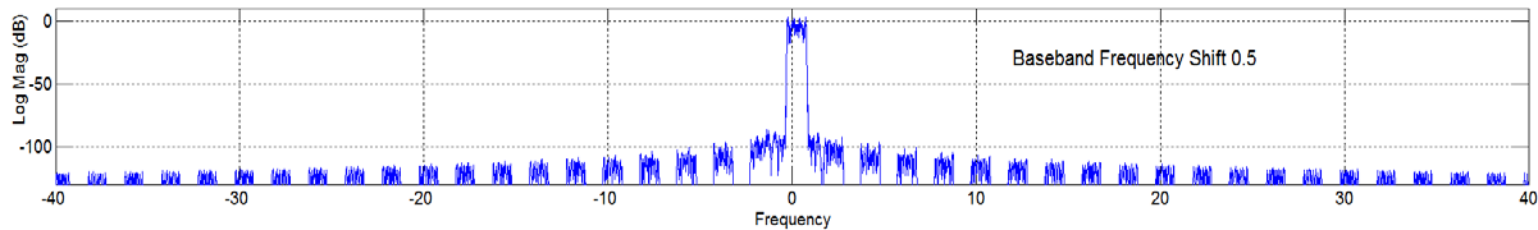
Spectrum, Interpolated Output Time Series, Input BW = 1 at $f_s = 4$, Output BW = 1 at $f_s = 80$

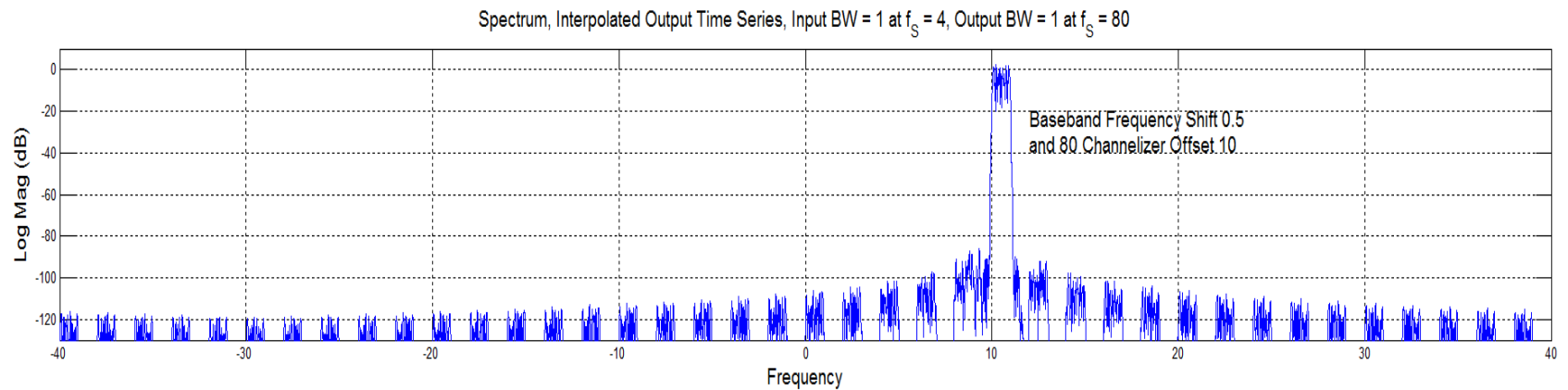
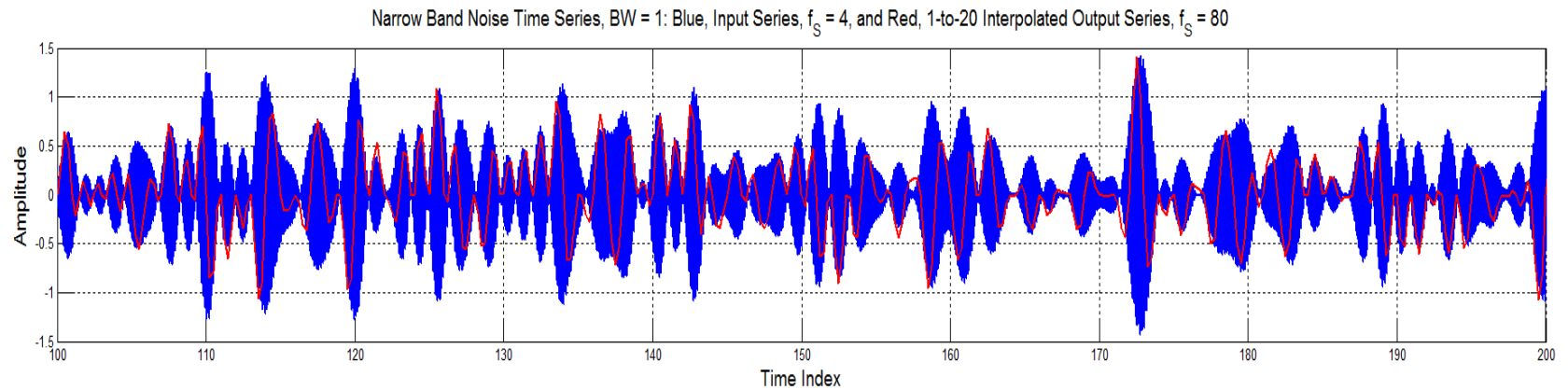


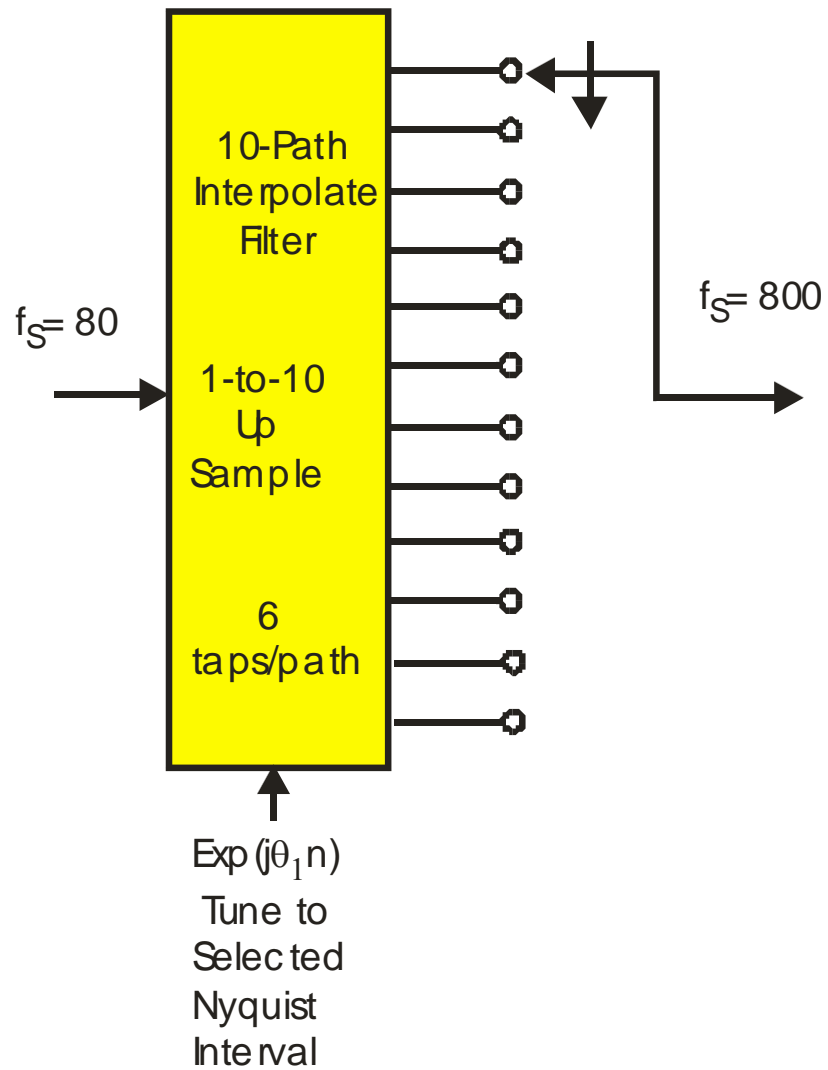
Narrow Band Noise Time Series, BW = 1: Blue, Input Series, $f_s = 4$, and Red, 1-to-20 Interpolated Output Series, $f_s = 80$



Spectrum, Interpolated Output Time Series, Input BW = 1 at $f_s = 4$, Output BW = 1 at $f_s = 80$



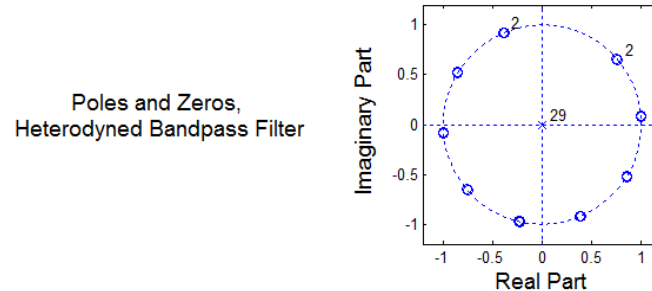
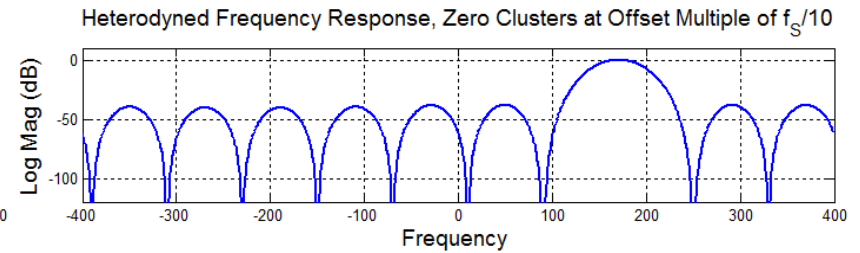
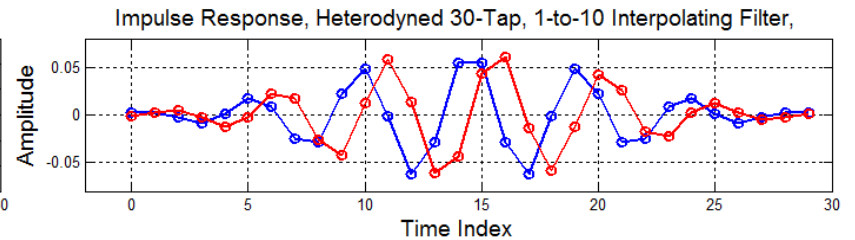
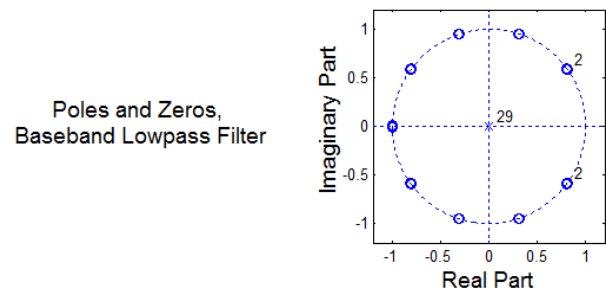
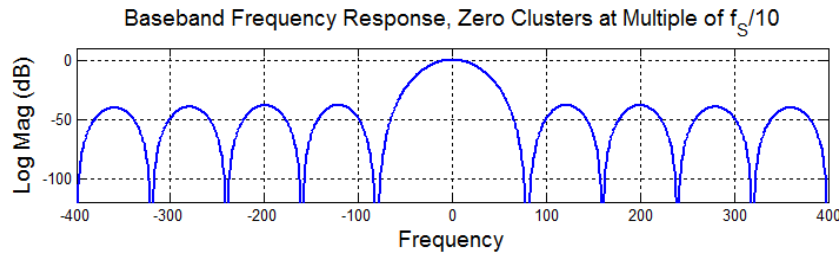
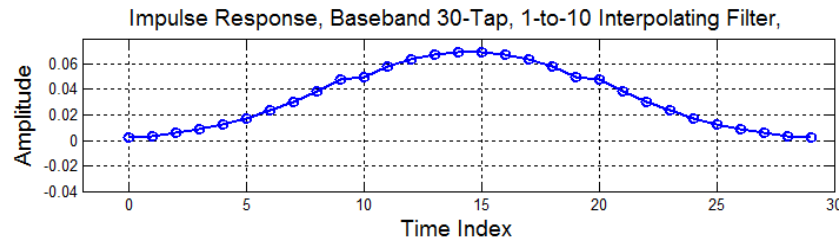




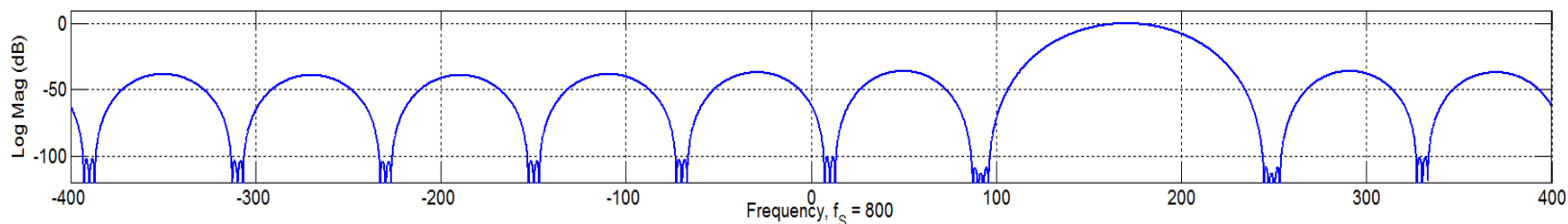
Third Interpolator Filter

10-Path, 1-to-10 Up-Sample, 3 Complex Coefficients per Path

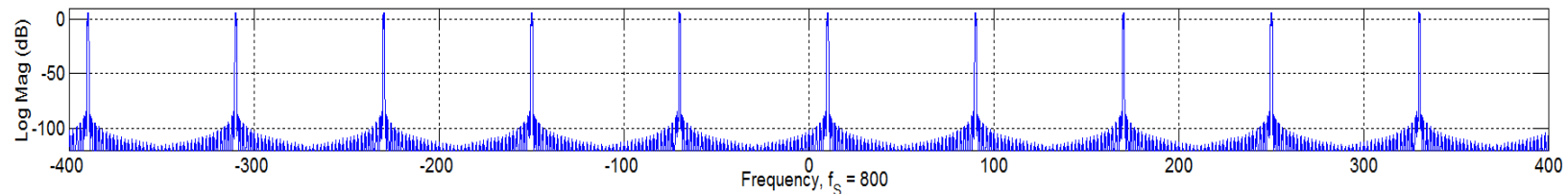
Main Lobe Tunable to any Center Frequency



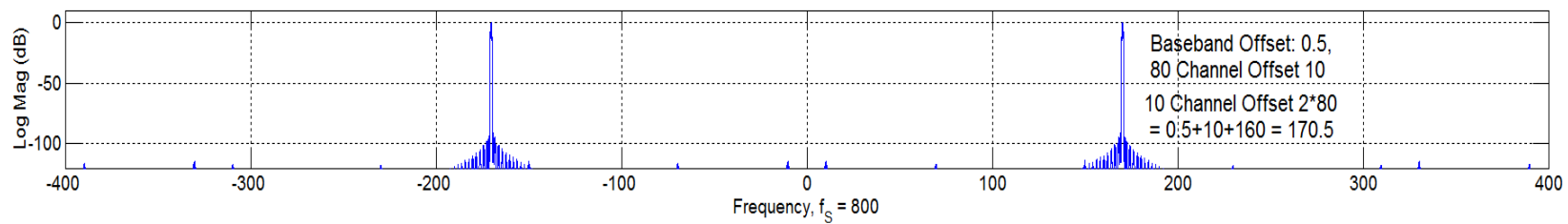
Frequency Response; Centered at $f_c = 170.5$, 1-to-10 Interpolator, 30-Complex Tap, 10-Path Filter, 6-Real Coefficients per Path



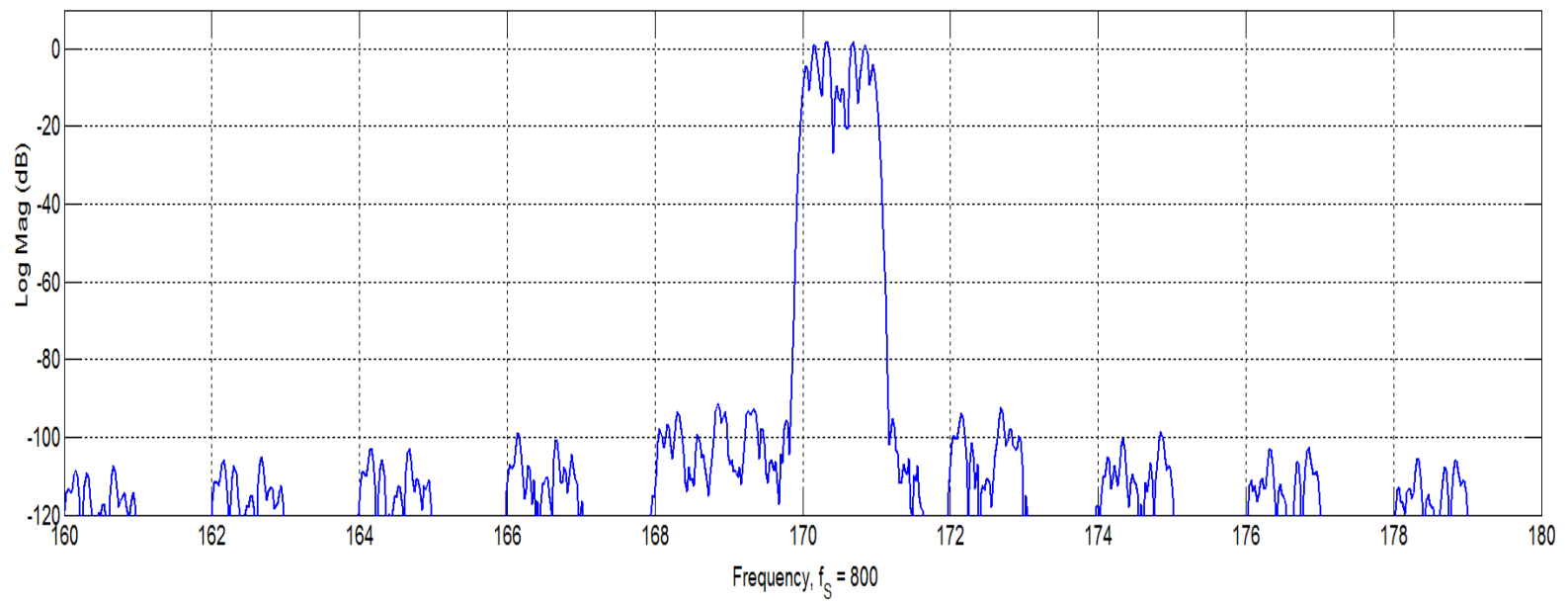
Spectrum: 1-to-10 Zero Packed Input Time Series. Non-Zero-Packed Time Series Up-Sampled in 10-Path Filter, 6-Real Coefficients per Path



Spectrum: Real part of 1-to-10 up-Sampled and Filtered Output Time Series



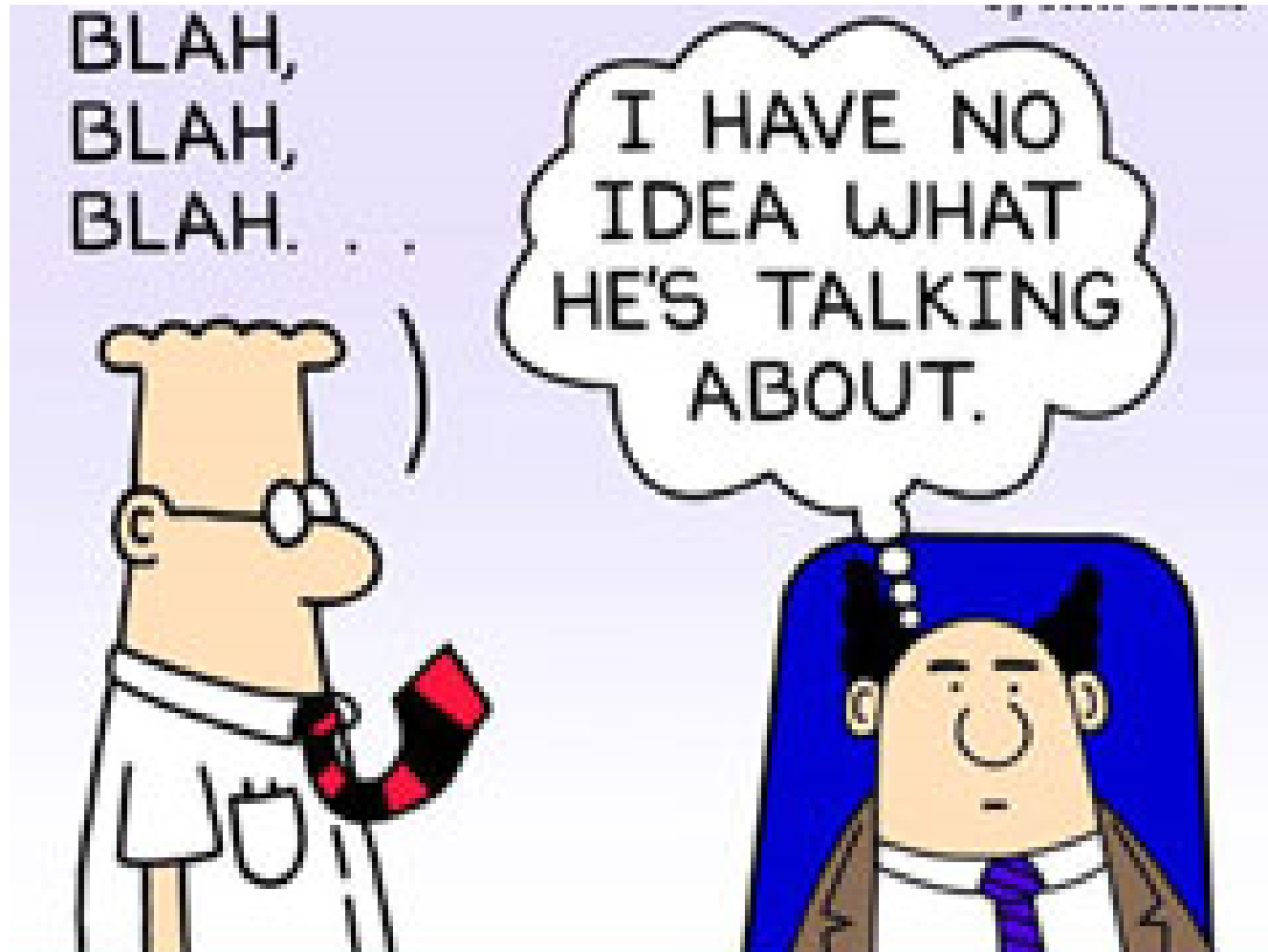
Spectrum: Real part of 1-to-10 up-Sampled and Filtered Output Time Series



HERE POINTED HAIR BOSS. THIS REPORT EXPLAINS HOW A SMALL FREQUENCY OFFSET AT THE INPUT SAMPLE RATE IS CONVERTED TO THE SAME FREQUENCY OFFSET FROM THE CHANNEL CENTER FREQUENCY AT THE HIGH OUTPUT SAMPLE RATE.



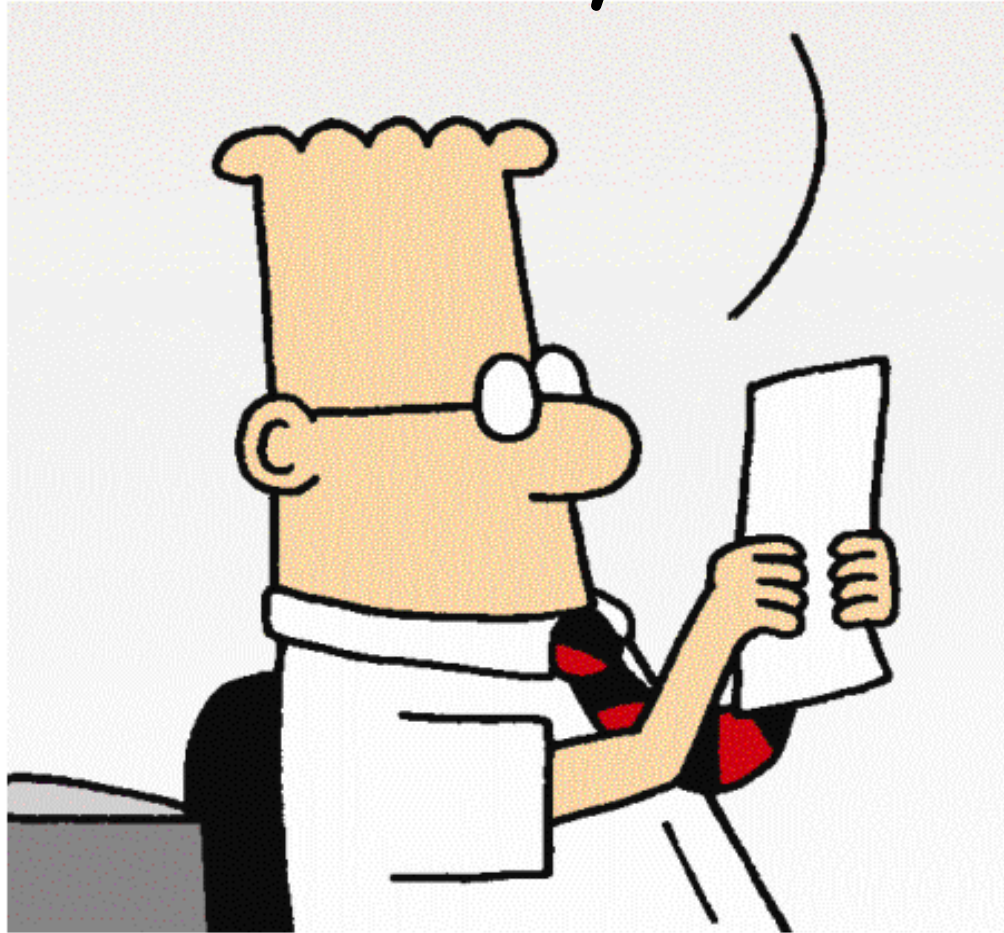
SUSPICIONS CONFIRMED!



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



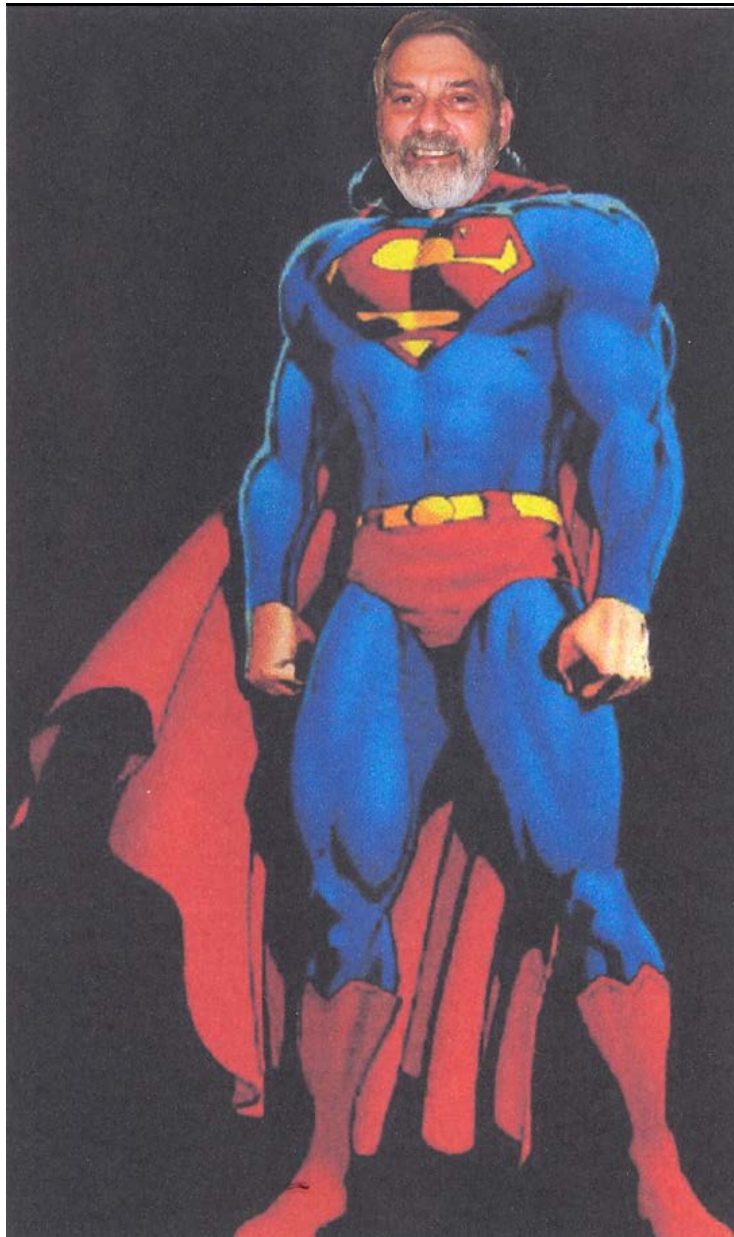
Is There any Doubt???



SPEAKING OF RANDOM NOISE



"ABOUT THIS EXPERIMENT FOR GENERATING RANDOM NUMBERS - EACH TIME YOU DO IT, IT COMES OUT DIFFERENT."



SOFTWARE DEFINED RADIO MAN

Is Open For Questions

