A Novel Carrier Recovery And Receiver Structure For Future Wideband Software Defined Radios

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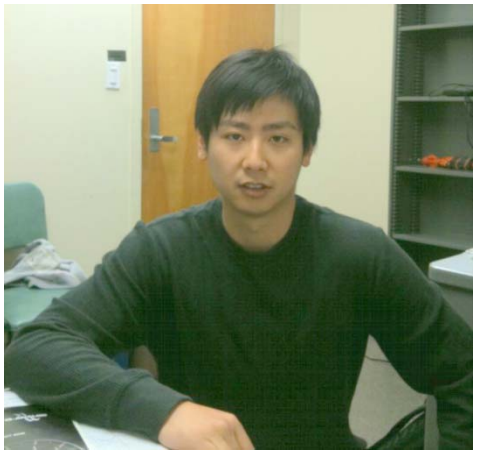
Who we are and what we do…



- Software Defined Radios / **Digital** Modem Design
- Up/Down Conversion
- Synchronization
- Channel Equalization
- Spectral Analysis
- Frequency Hopping Systems
- Efficient Resampling Architectures
- ….

Multirate Signal Processing

The goal of this paper

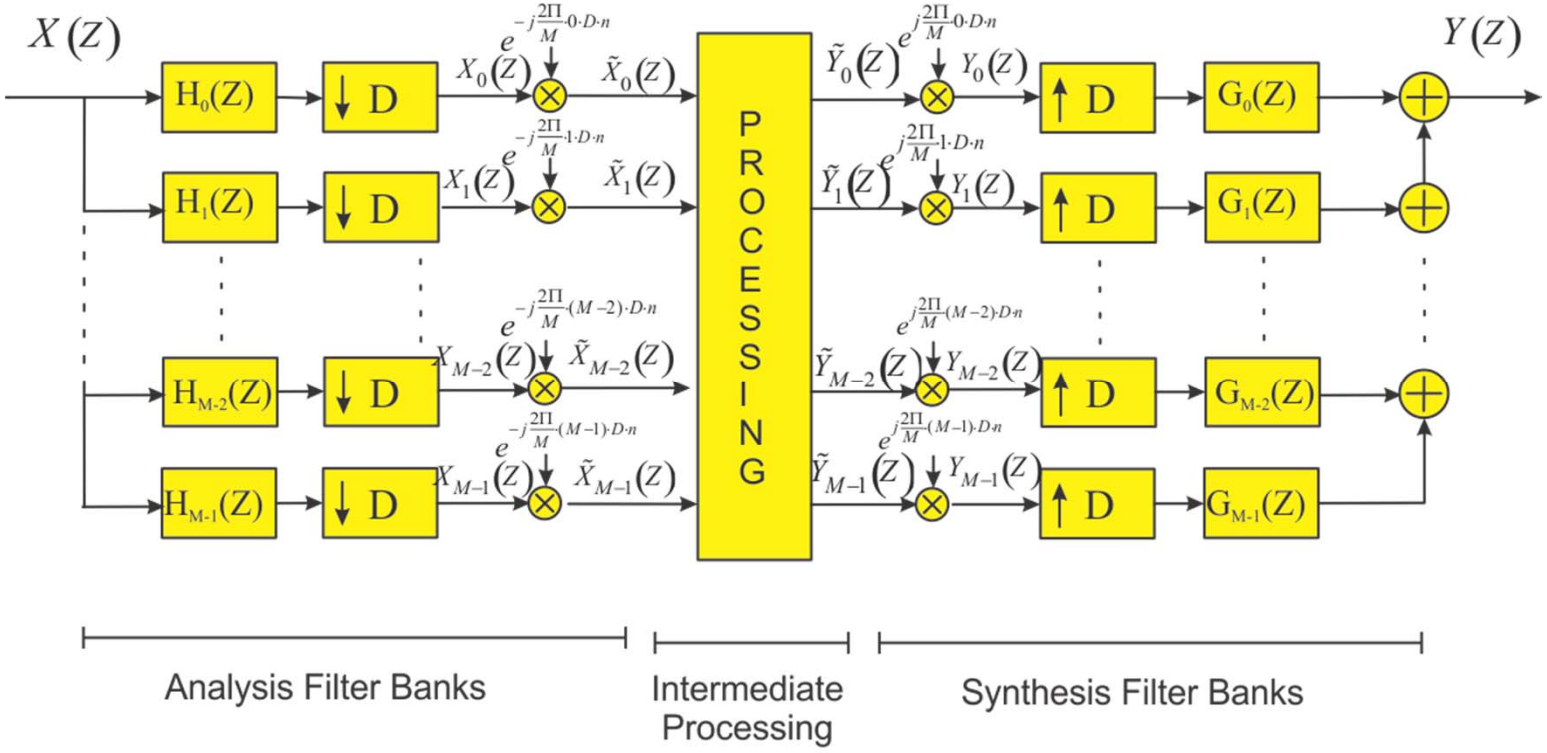
•In this paper the authors propose a **wideband** QAM receiver based on perfect reconstruction (PR) non-maximally decimated filter bank (NMDFB).

•The main focus is the carrier recovery task, which traditionally requires a pair of band-edge (BE) filters and a square-root raised cosine (SRRC) filter, plus a frequency locked loop (FLL) to drive the carrier offset error to zero.

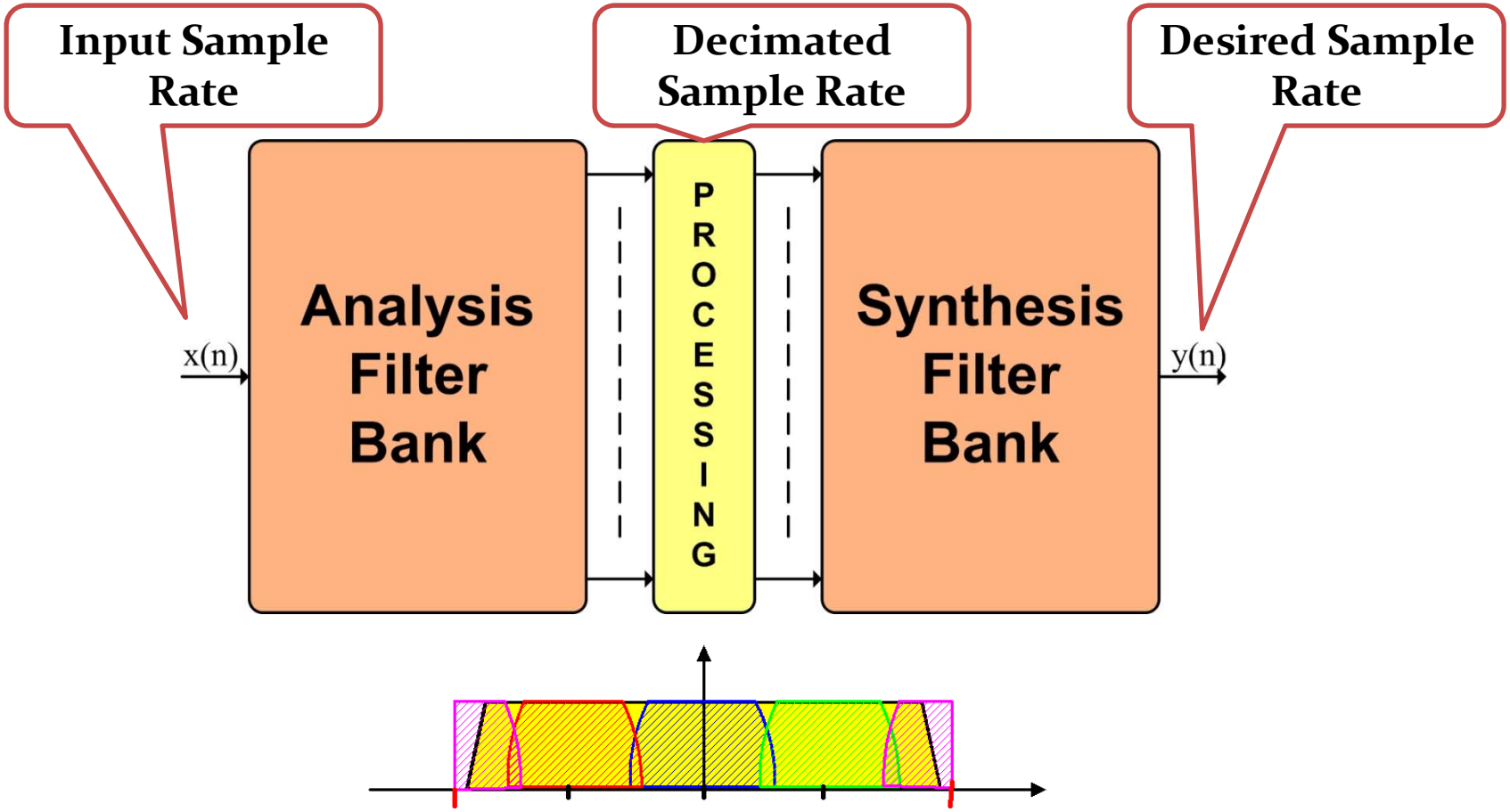
Why it is so difficult to perform carrier recovery in a wideband modem?

- Limitations from analog-to-digital converters (ADCs)
- Limitations from the hardware processing speed limits

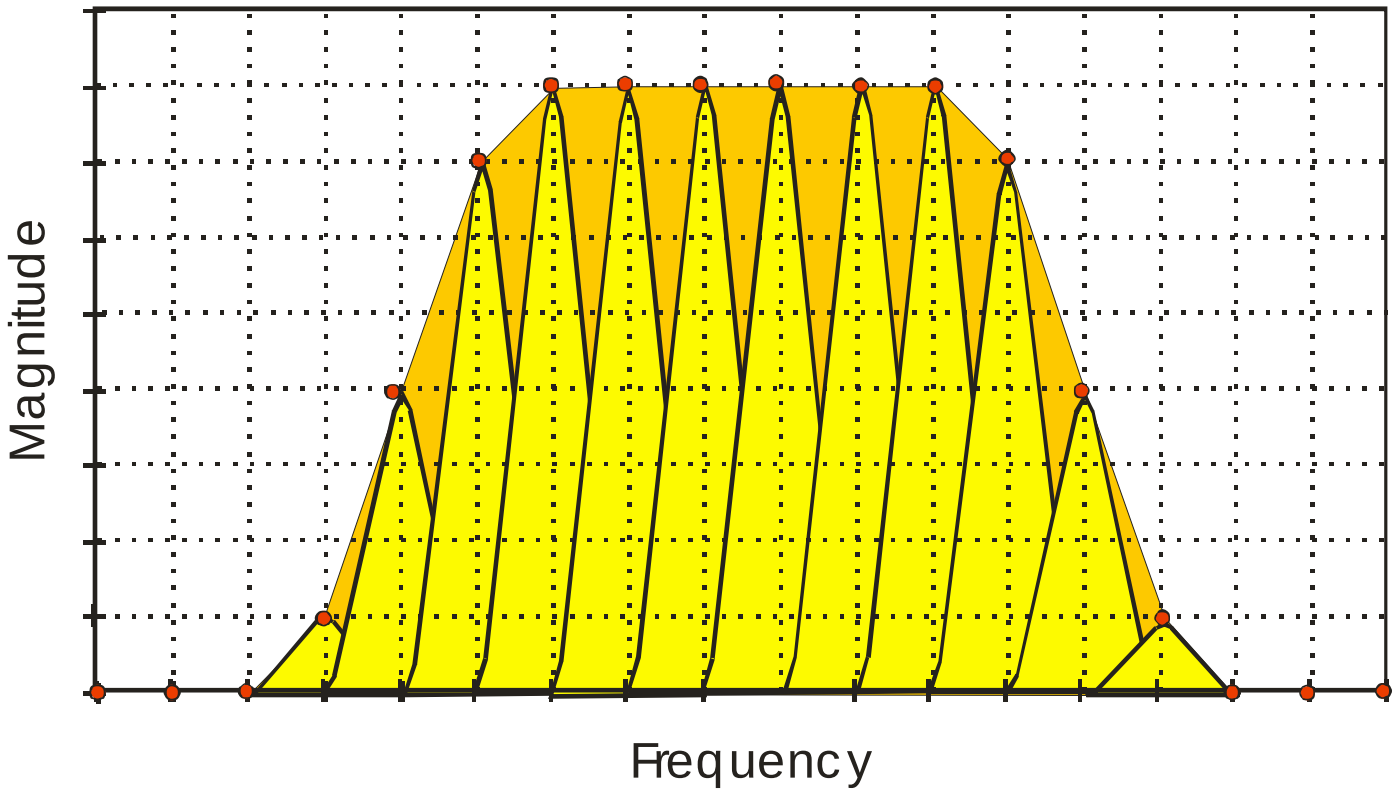
Non-maximally decimated filter bank model (1)



Non-maximally decimated filter bank model (2)



Wideband filtering via NMDFB



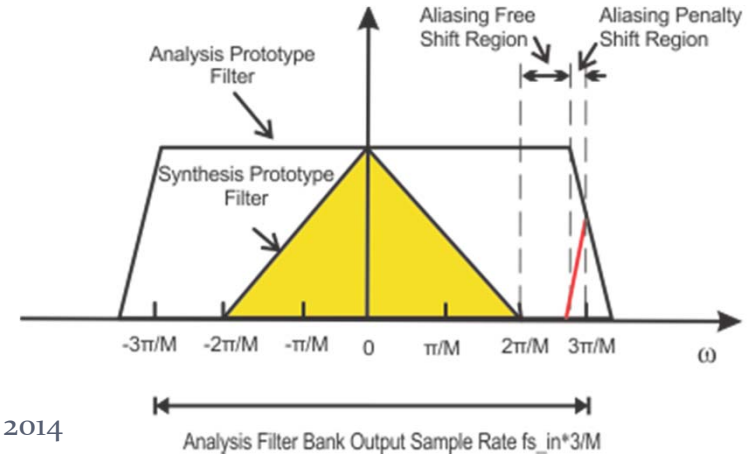
Approximation errors

Approximation errors can be reduced by selecting wisely the low-pass prototype filters

•if the Nyquist pulse is chosen to be *sinc* function, then T_ε becomes the nearest neighbor interpolation error;

•if the Nyquist pulse is chosen to be *sinc* squared, then $T\varepsilon$ becomes the linear interpolation error.

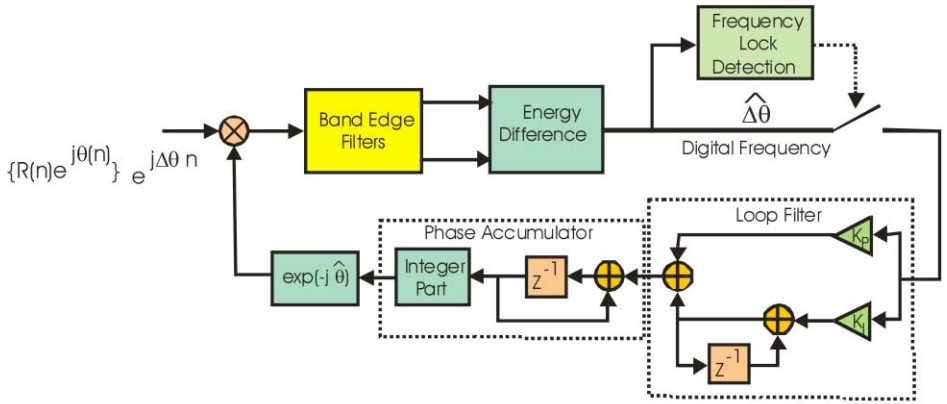
In this paper we select the latter option, which gives us a linear interpolation error and makes H_{NYQ} have triangular shaped frequency response



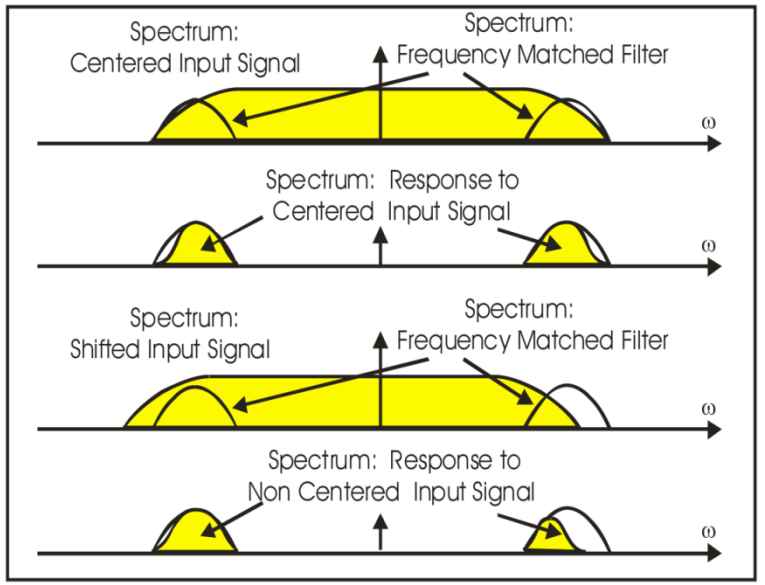
Any filtering process can be approximated in the channelized domain

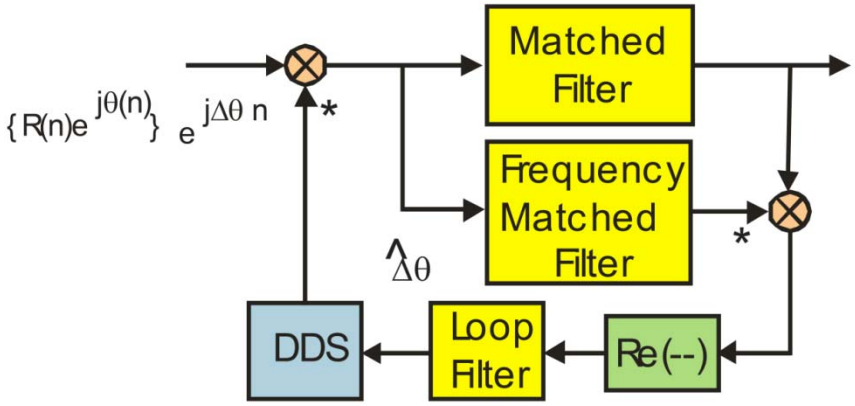
The wideband receiver can be fully designed in the channelized domain !

The traditional carrier recovery architecture

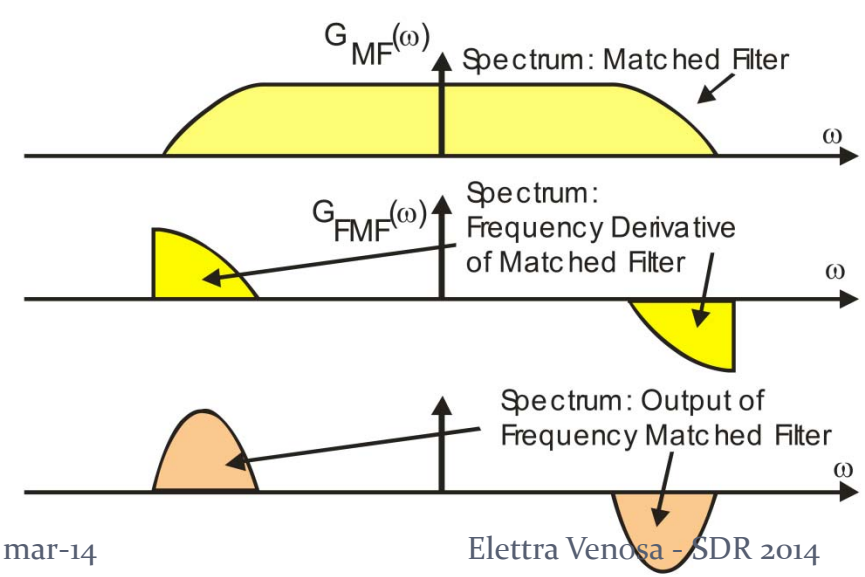


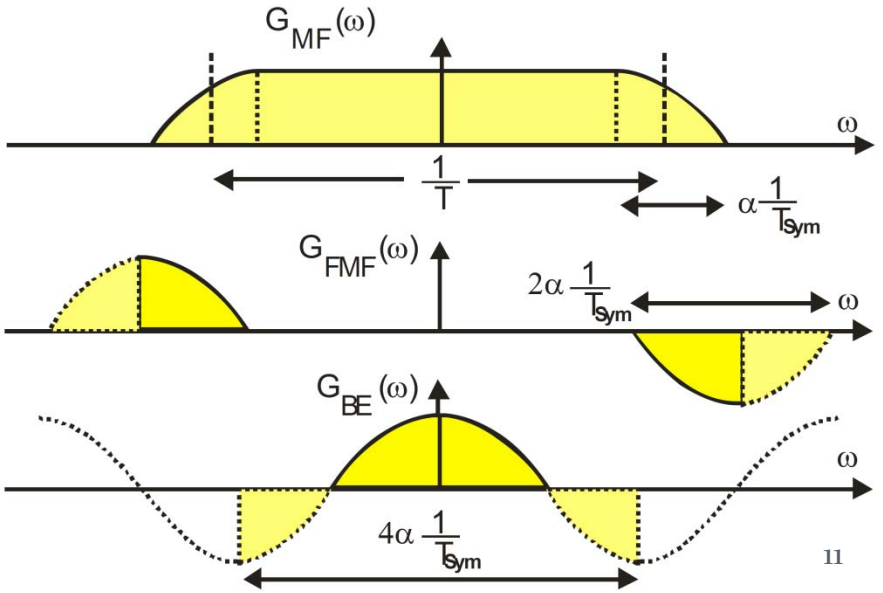
Looking at the frequency response, we quickly understand why the frequency matched filter is often called a band edge filter.



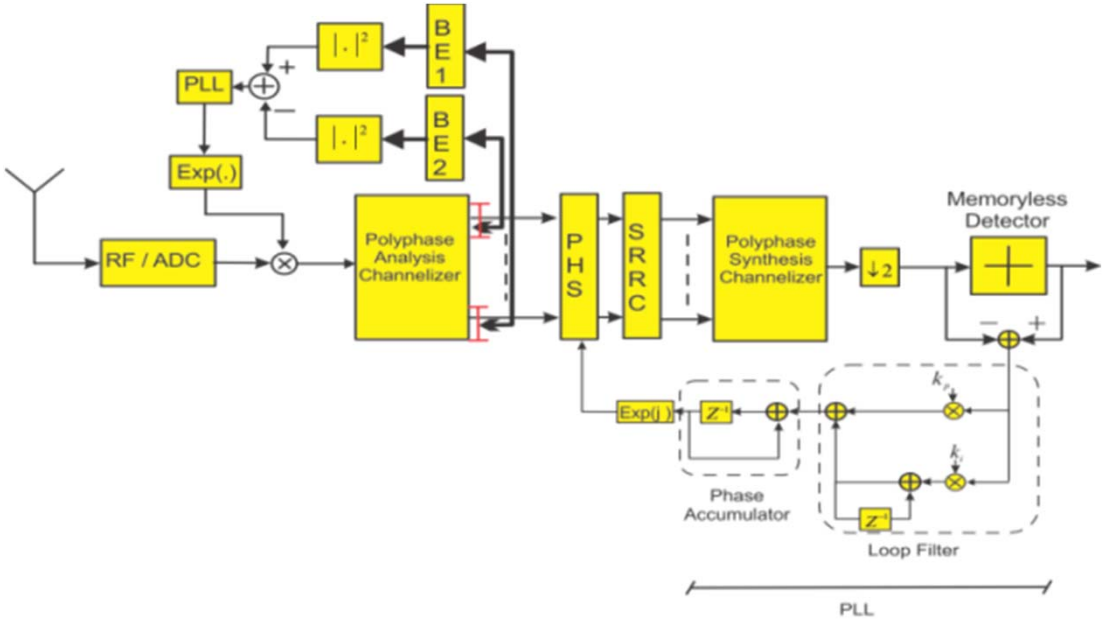


Our approach to implement this filter is to continue the spectral shapes past the discontinuity to form a half cycle of the spectral cosine.



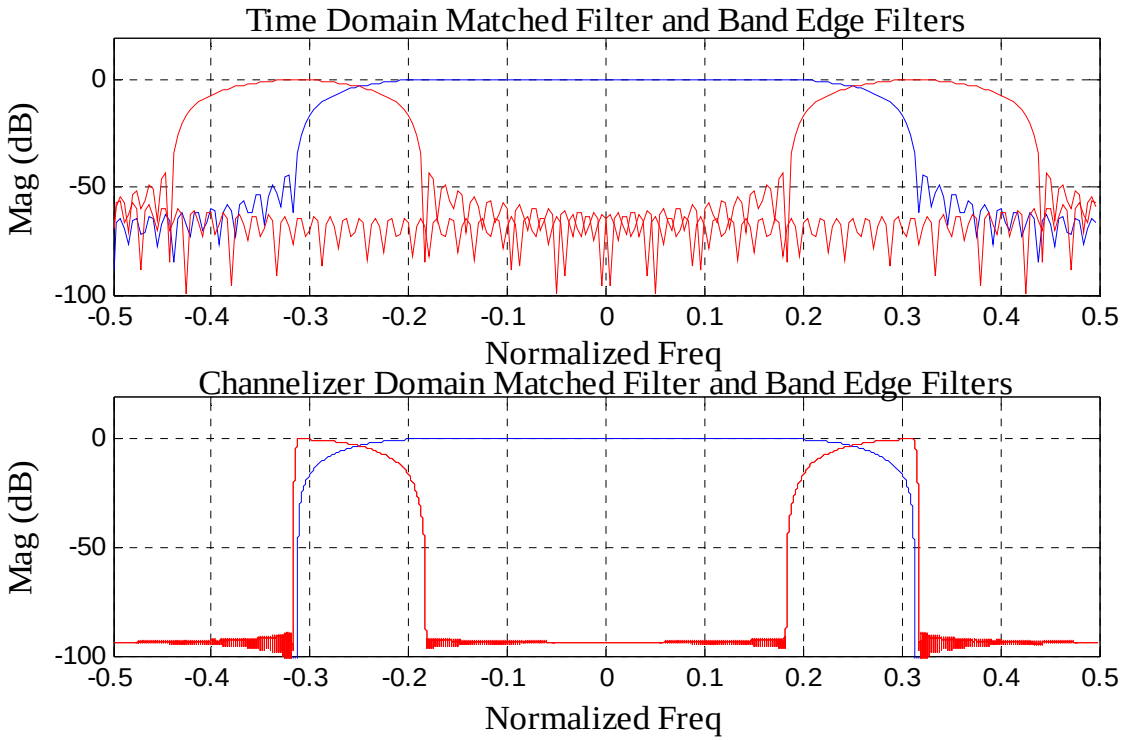


Carrier recovery in the channelized domain



It is important to perform the following two operations in the appropriate order: offset compensation and filtering. The way to proceed is to correct the signal frequency offset at first and then filter the frequency translated signal. Reversing the order of those tasks will impact the functionality of the proposed architecture which will not match the functionality of its time-domain companion.

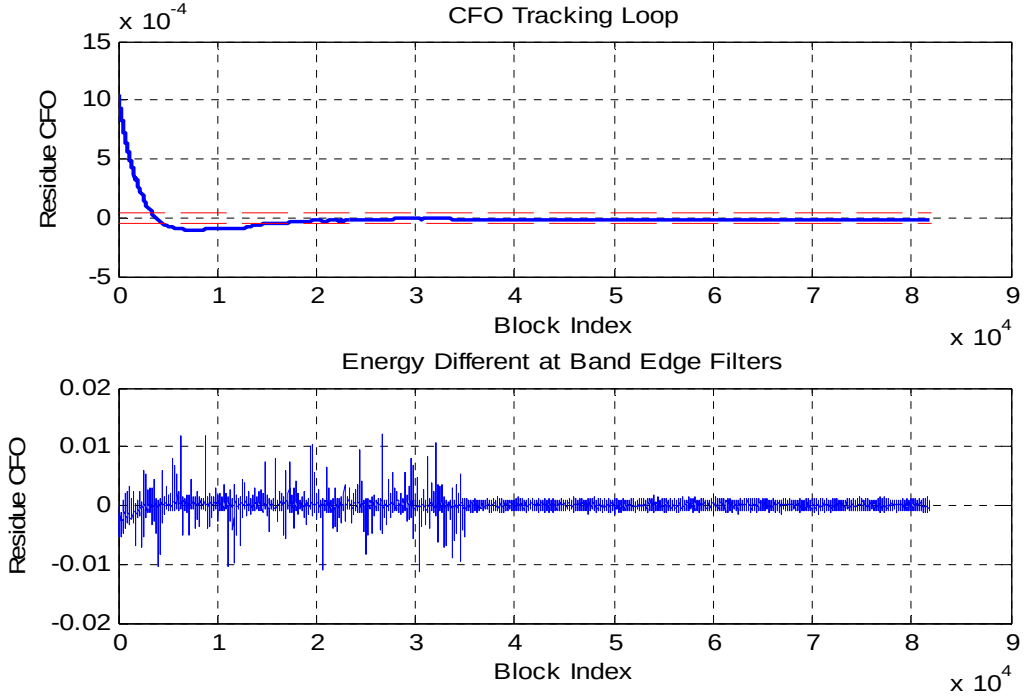
Simulation results (1)



Matched Filter and BE Filters in the Conventional Time Domain (Upper Subplot) and in the Channelized Domain (Lower Subplot).

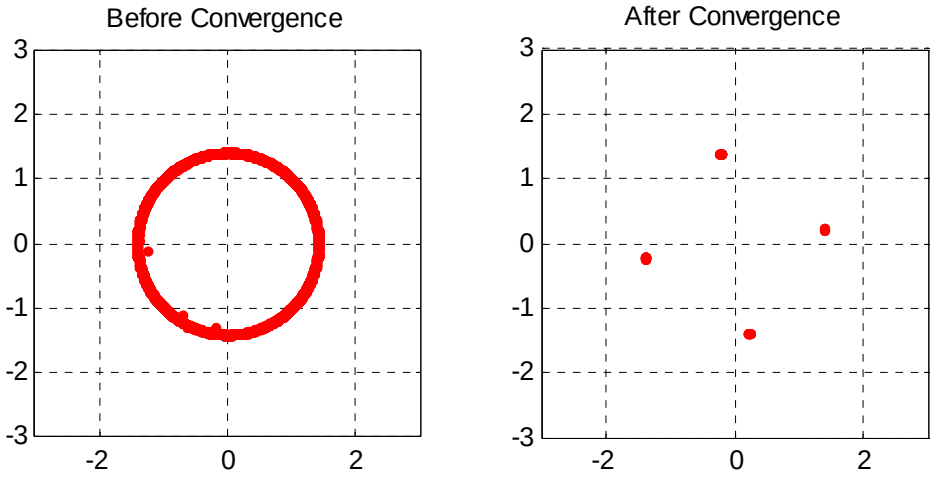
Simulation results (2)

For demonstration purposes we simulated an M = 240, D = 80, triangular shaped PR-NMDFB. The received signal is an SRRC shaped QPSK constellation without channel and noise.



Carrier Recovery Loop Behavior (Upper Subplot) and Energy Difference at the Output of The BE Filters (Lower Subplot).

Simulation results (3)



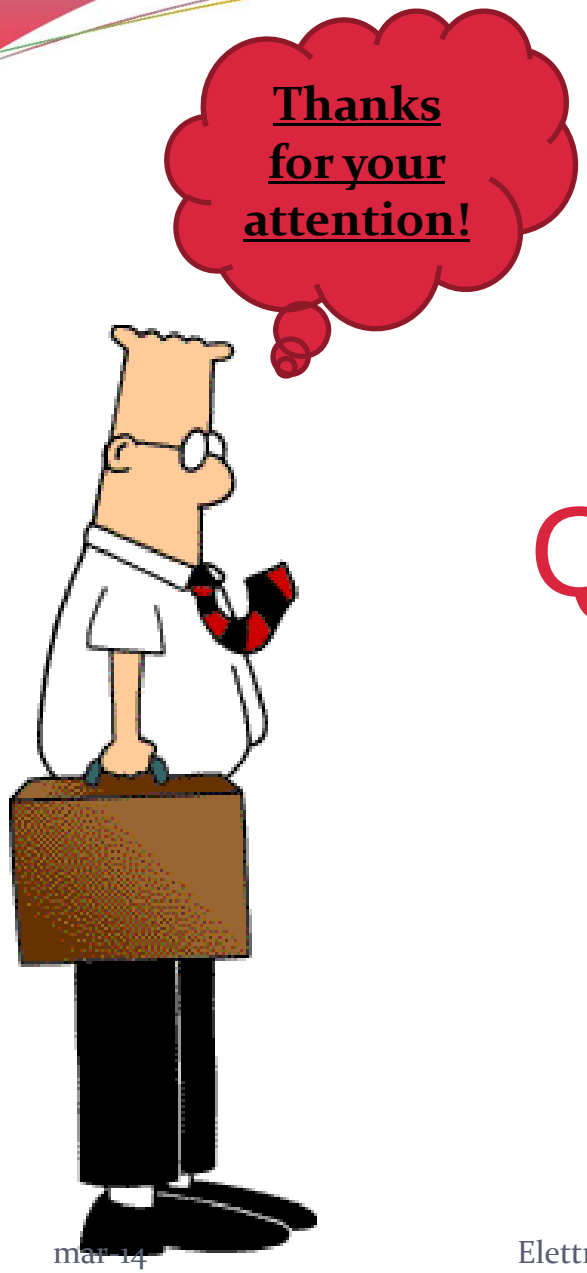
Signal Constellation Before (Left Subplot) and After (Right Subplot) CFO Tracking Loop Convergence.

Advantages of the proposed architecture

The proposed structure provides advantages in performance and power consumption when compared to the conventional architecture.

•PR-NMDFB based approach is able to perform both carrier recovery and SRRC matched filtering. We should not forget that PR-NMDFBs work at much lower processing speed when compared to traditional time domain architectures.

•The PR-NMDFB based filtering technique allows implementing near optimal band-edge filters while the conventional approach adopts the suboptimal band-edge in order to avoid building very long FIR filters.



Questions?