

A Novel Spectrum Re-Planning Technique for Wideband Single Carrier Transmission

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Presentation Outline

- **Why Use Single Carrier Transmission?**
- **Review Existing Solution**
- **NMDFB Based Solution**
- **Proposed Spectrum Re-Planning Technique**
- **Simulation Results**
- **Conclusion**

Single Carrier (SC) V.S Multi-Carrier (MC)

Pros:

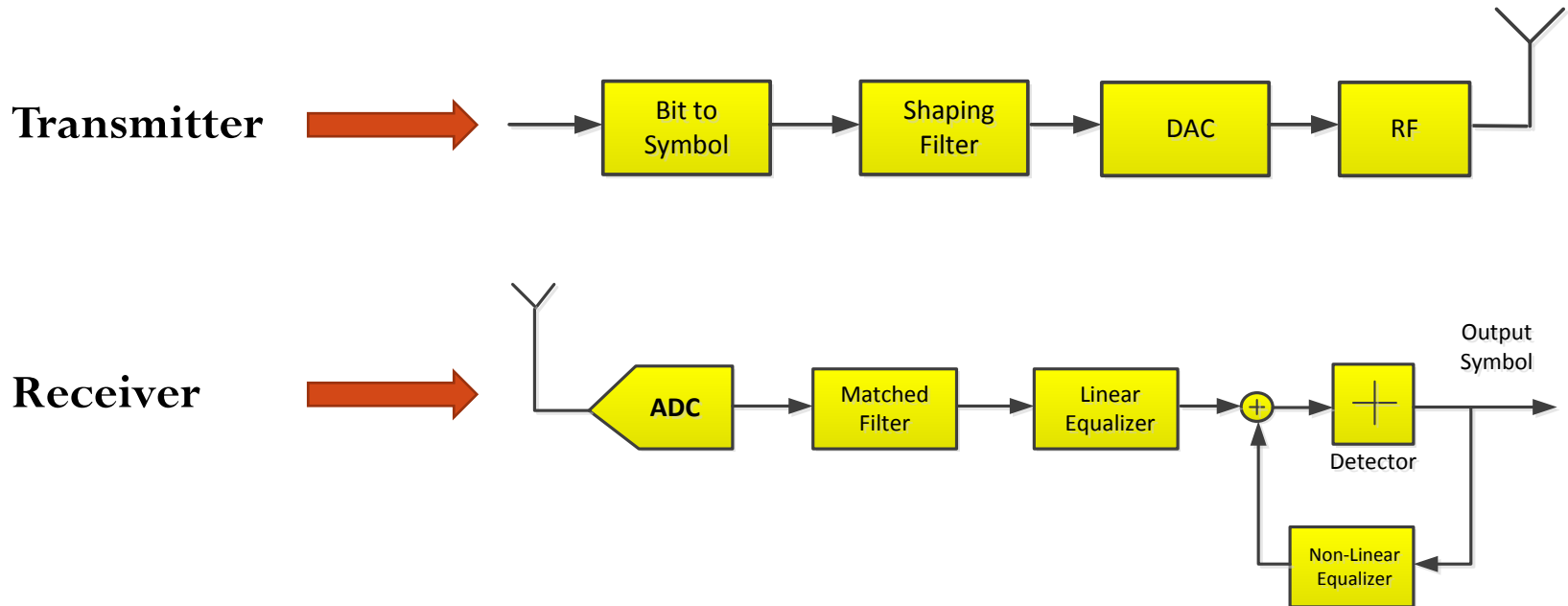
- SC Transmission has Well Controlled Peak-to-Average Power Ratio.
- SC Transmission (Uncoded) Has Better Bit Error Rate (BER) Performance Than OFDM (Uncoded) in Multipath Channel Environment.
- SC Transmission May Have Better Throughput Performance Than OFDM, i.e., No Cyclic Prefix / Guard Interval.
- SC Transmission Has Well Defined Synchronization Property.

Single Carrier (SC) V.S Multi-Carrier (MC)

Cons:

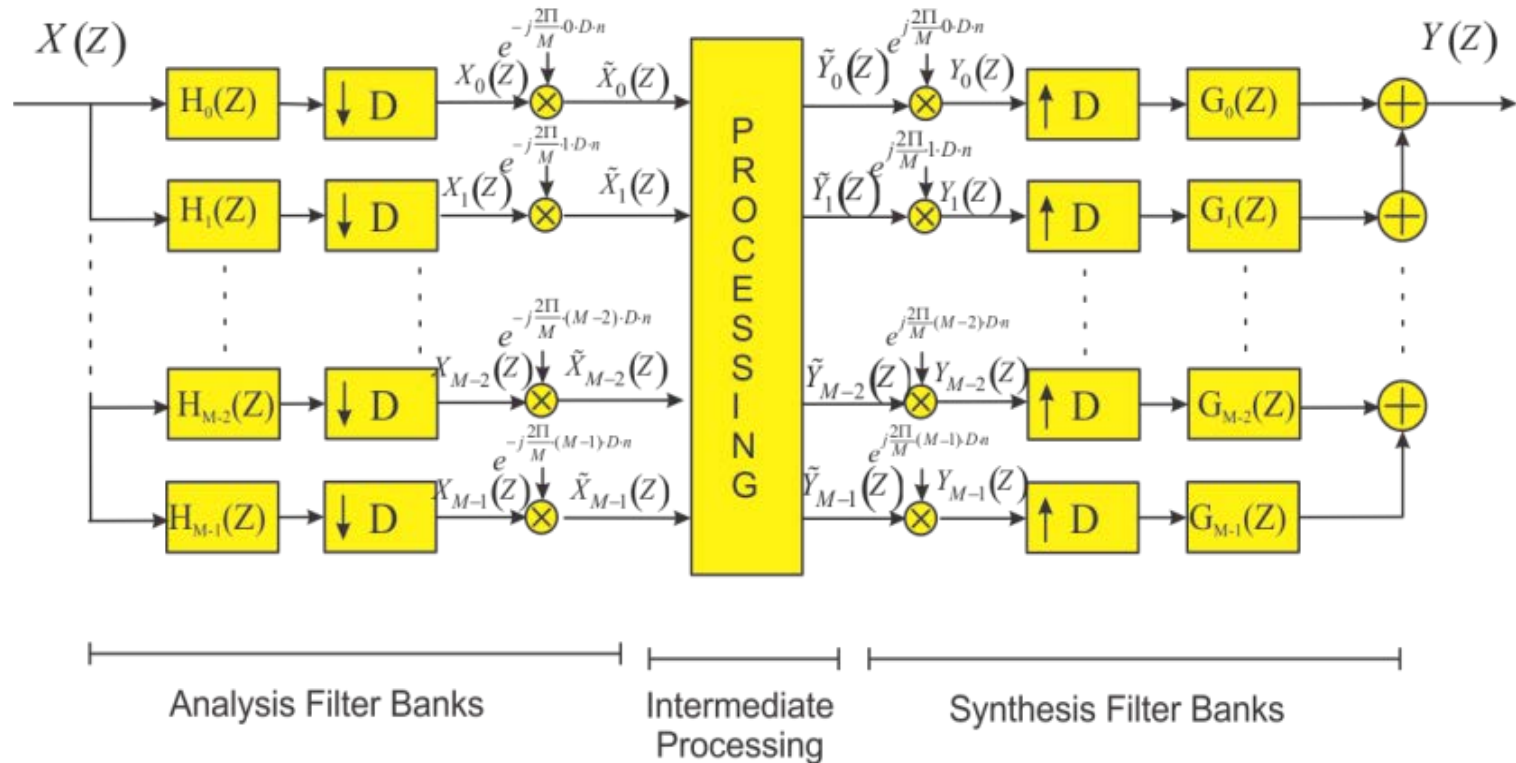
- Requires Building Very *Long Equalizer* Running at High Speed, i.e., Input Sampling Rate, 2 samples / Symbol. The MC Uses Frequency Domain Equalization.
- Requires Significant *Hardware Parallelism*, i.e., Hardware Clock Speed is Comparable to Input Sampling Rate. The MC Relies on Efficient FFT Computation and Built in Parallelism.

Conventional Single Carrier Solution



Many Long High Speed FIR Filters Causing High Power Consumption and Large Silicon Area!

Non-Maximally Decimated Filter Bank System



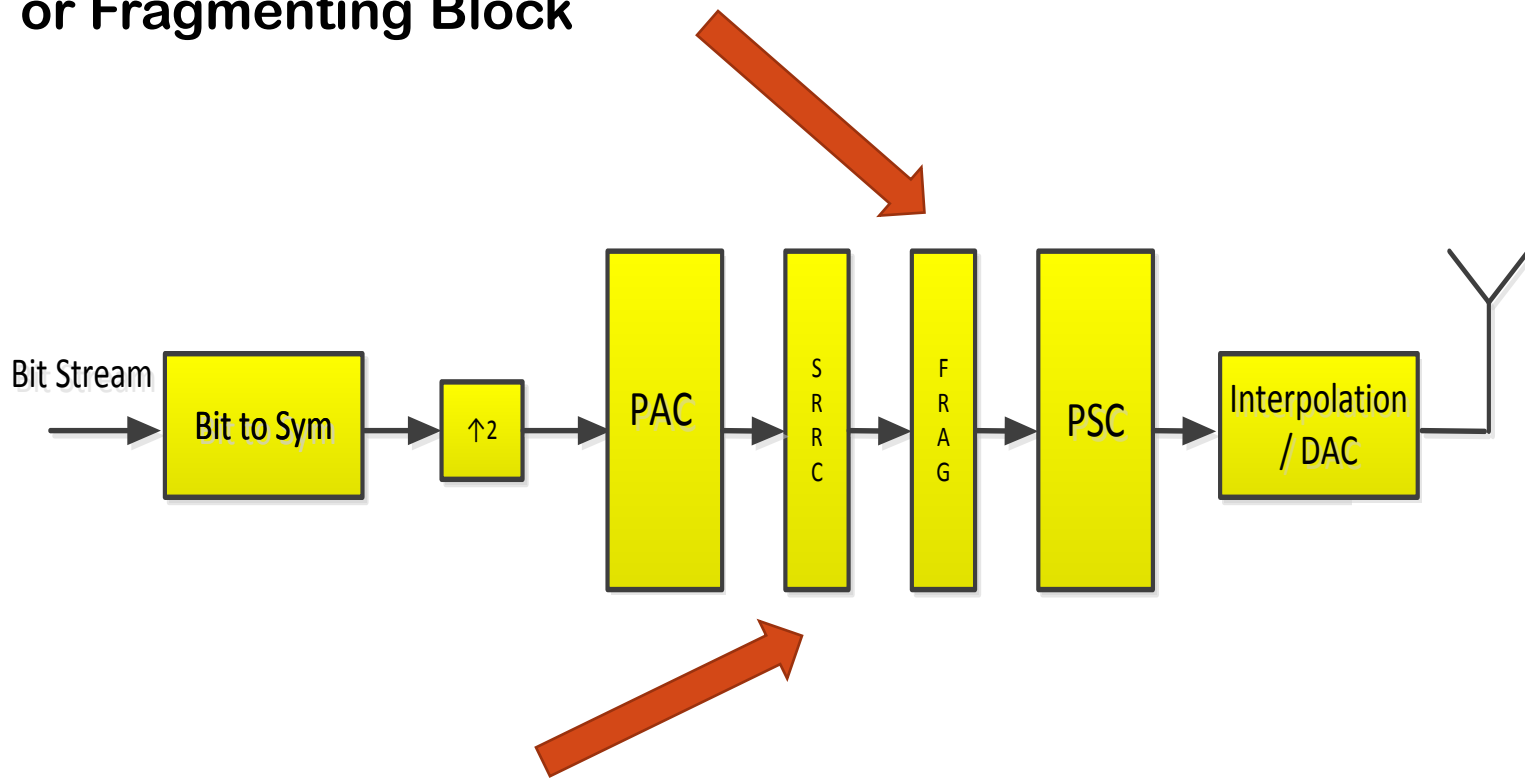
X. Chen , F. J. Harris , E. Venosa and B. D. Rao "Non-maximally decimated analysis/synthesis filter banks: Applications in wideband digital filtering", *IEEE Trans. Signal Process.*, vol. 62, no. 4, pp.852 - 867 2014

Key Advantages of NMDFB

- **Workload Tied to FFT.**
- **Allows Low Speed Processing.**
- **Significant Reduction in Workload When Implementing Long FIR Filters, i.e. Equalizer**

Spectrum Re-Planning Technique (Tx)

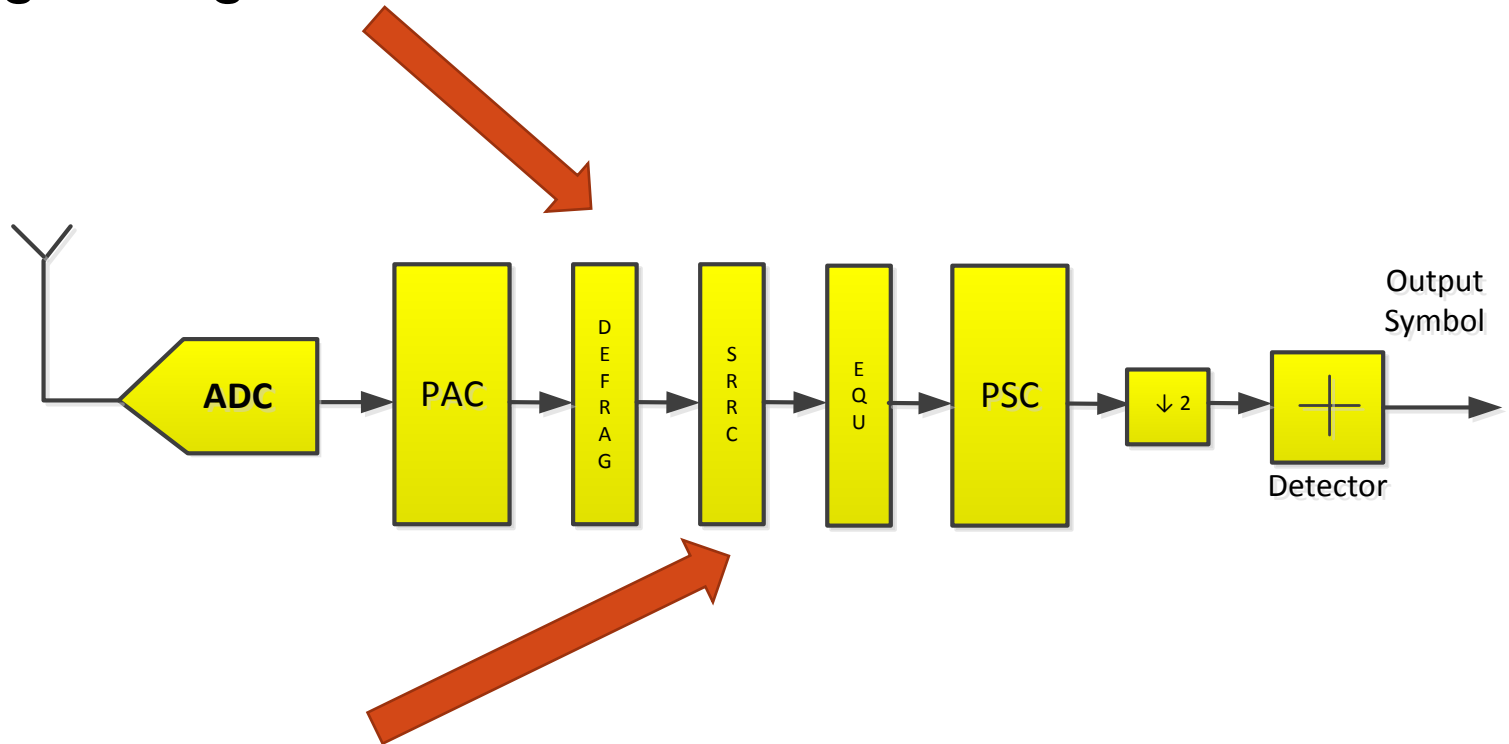
Spectrum Re-Planning or Fragmenting Block



**Square Root Raise Cosine (SRRC) Shaping Filter In
“Frequency Domain” or “Channelizer Domain”**

Spectrum Re-Planning Technique (Rx)

**Spectrum Re-Planning
or Fragmenting Block**



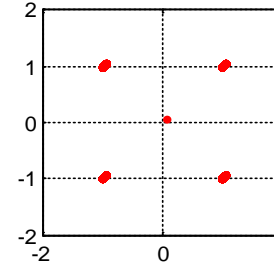
**Square Root Raise Cosine (SRRC) Receiving Filter In
"Frequency Domain" or "Channelizer Domain"**

Example on Spectrum Re-Planning

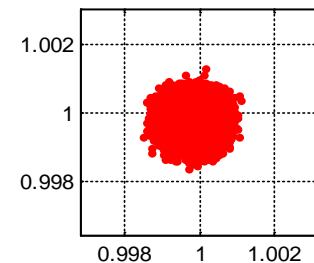
Motivations of Doing Spectrum Re-Planning

- To Improve BER and Simplify the Receiver Design.
- To Collect Underutilized Spectrum
- To Allow Transmitting Wideband Signal Over Multiple Disjoint Frequency Bands .

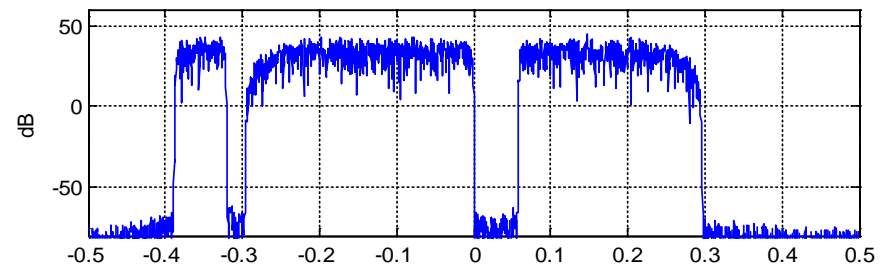
Constellation after De-Fragment / Matched Filtering



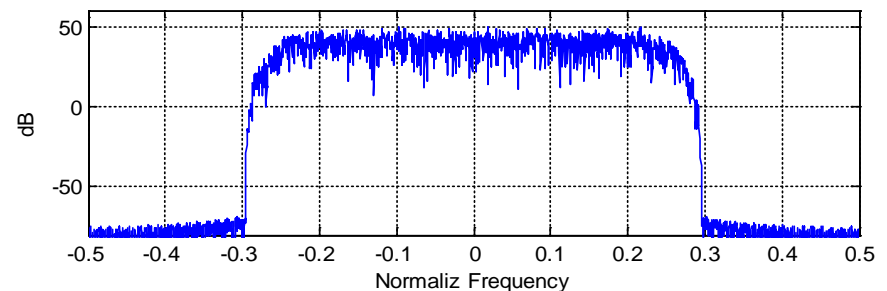
Zoom In



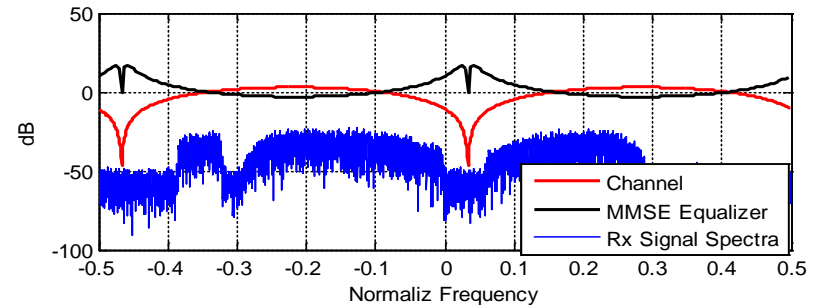
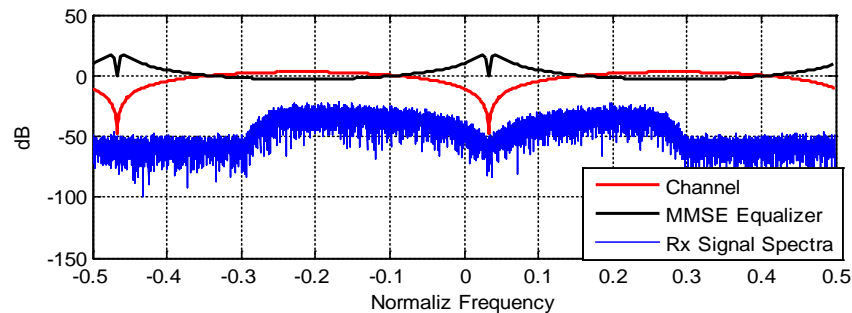
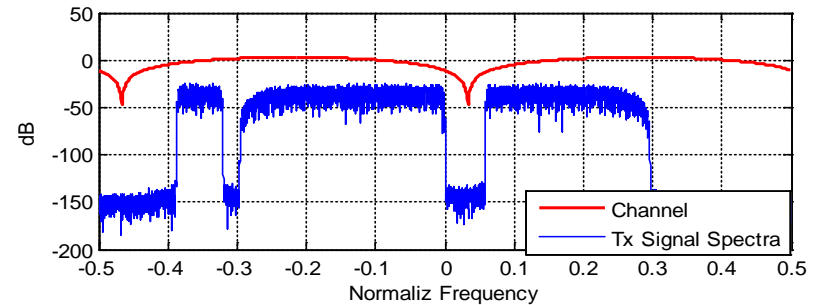
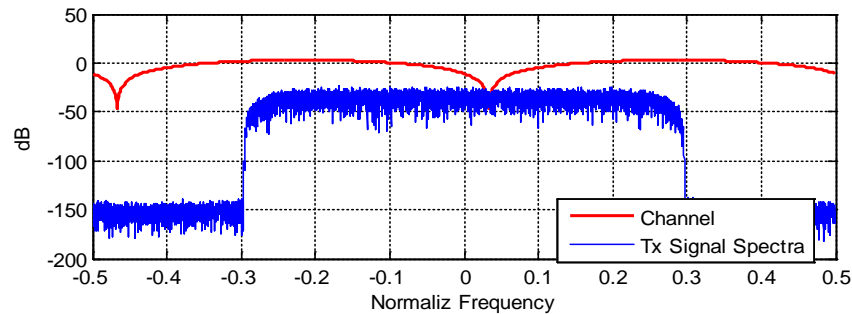
Fragmented Spectrum 2 s/s



Defragmented Spectrum 2 s/s



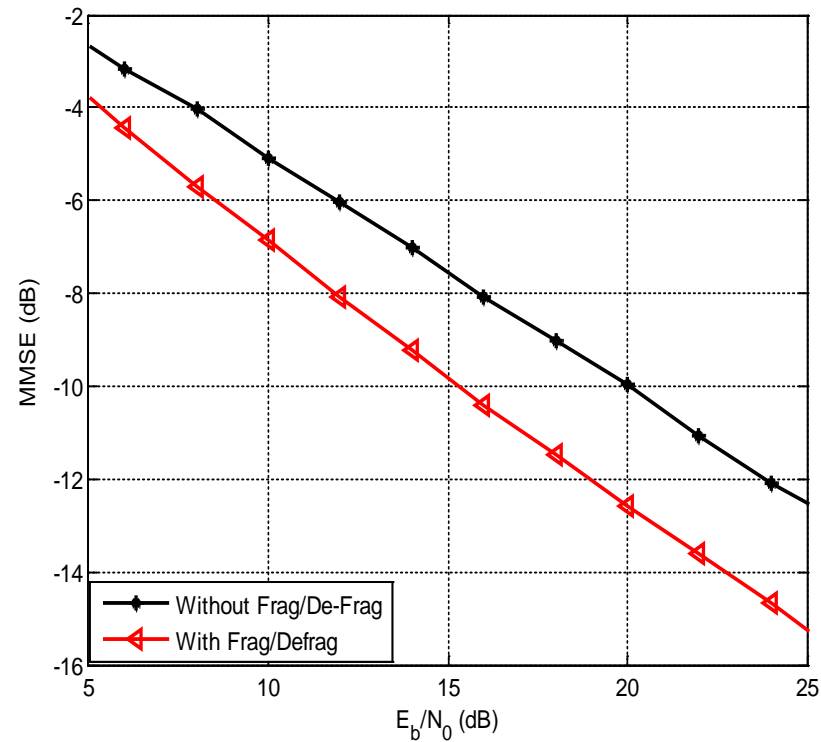
Simulation Example: $H(z) = 1 + (0.9 - j0.45)z^{-2}$, $E_b/N_0 = 20$ dB



Without Re-Planning

With Re-Planning

Simulation Example: MMSE V.S E_b/N_0



Conclusion

- The Spectrum Re-Planning Technique Significantly Improves the Receiver BER in Presence of Severe Fading Channel.
- The Spectrum Re-Planning Technique Simplifies the Receiver Design by Eliminating Decision Feedback Equalizer.
- The Spectrum Re-Planning Technique Allowing Transmitting Wideband Signals Over Discontinued Frequency Bands.
- The Spectrum Re-Planning Technique Does Require More Robust RF Front-end and Higher Speed ADC.
- The Spectrum Re-Planning Technique Does Require Prior Channel Knowledge.

More About NMDFB SC Modem

- **[General Filter Design]** X. Chen , F. J. Harris , E. Venosa and B. D. Rao "Non-maximally decimated analysis/synthesis filter banks: Applications in wideband digital filtering", *IEEE Trans. Signal Process.*, vol. 62, no. 4, pp.852 -867 2014
- **[Single Carrier Diversity Combining]** F. Harris, X. Chen, E. Venosa, B. Rao, "Selection diversity and linear equalization over frequency selective channels for single carrier filter bank-based transmissions," *Acoustics, Speech and Signal Processing (ICASSP), 2014 IEEE International Conference on* , vol., no., pp.5779,5783, 4-9 May 2014
- **[Spectrum Fragmenting / Defragmenting]** F. J. Harris, E. Venosa, X. Chen, and B. D. Rao, "Polyphase analysis filter bank downconverts unequal channel bandwidths and arbitrary center frequencies," *Analog Integrated Circuits and Signal Processing*, vol. 71, no. 3, pp. 481–494, 2012.
- **[General Receiver Design]** X. Chen, F. Harris, E. Venosa, B. Rao, "Non-Maximally Decimated Filter Bank Based Single Carrier Receiver: A Pathway to Next Generation Wideband Communication", *Eurasip Journal on Advances in Signal Processing*, 2014, Vol. 62.