SYMBOL SIZE CONSIDERATIONS FOR EPOC BASED OFDM PHY

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OFDM Symbol Size Considerations

- Throughput
  - CP overhead reduces with long symbols
  - OFDMA framing with long symbols may create larger framing overheads
- Latency
  - Increases with large symbol sizes
- Burst Event Impact
  - Longer symbols require more FEC latency when a burst event impairs symbols
  - Longer symbol duration can provide more robustness in some burst events
- Phase noise performance
  - Larger symbols more sensitive to phase noise
- Complexity
  - Buffer sizes in FFT implementation increase with symbol size
  - Low frequency phase requirements tougher with larger symbol size

CP size requirements

- Depends on the channel delay spread and the reflection size
  - CP duration does not need to exceed delay spread of the channel to be effective
- Our analysis on simulated and measured loops show that a CP size of 1.0 uSec or shorter is adequate to receive QAM1024 on vast majority of loops
  - Need to verify with established channel model when available
  - Verified on extreme worst case theoretical condition
- CP size can be configured to accommodate larger CP sizes when required (such as broken plant)

CP Overhead

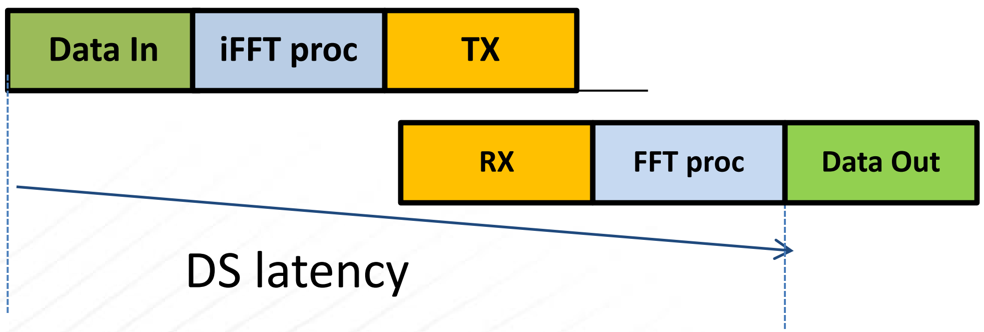
- Assume OFDM sampling frequency of 204.8 MHz, table shows number of subcarriers and CP overheads as a function of symbol size

Subcarrier spacing	100	50	25	12.5
Symbol Size (uSec)	10	20	40	80
Number of subcarriers	2048	4096	8192	16384
CP size = 0 .5 uSec	4.76%	2.44%	1.23%	0.62%
CP size = 1.0 uSec	9.09%	4.76%	2.44%	1.23%
CP size = 1.5 uSec	13.04%	6.98%	3.61%	1.84%
CP size = 2.0 uSec	16.67%	9.09%	4.76%	2.44%

- With CP size of 1.0 – 1.5 uSec, uSec 20 uSec symbol size shows an overhead of less than 5% - 7%, respectively

Latency in the Downstream

- Modulation latency in the downstream with four times the symbol size



FFT Size	Symbol Size (uSEc)	Latency (uSec)
2048	10	40
4096	20	80
8192	40	160
16384	80	320

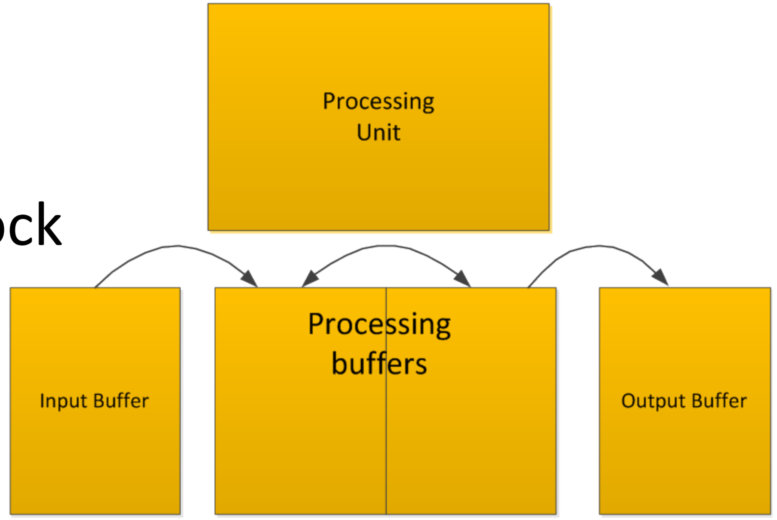
- Modulation latency addition is moderate for 10 - 20uSec long symbols but becomes very large with the larger number of sub-carriers
- In particular 320 uSec latency becomes prohibitive for EPoC taking into account other latency involved

HW Complexity - FFT

- FFT complexity comprised of
  - DSP processing
  - Memory buffers
- DSP processing
  - Small difference between FFT sizes
- Buffer complexity
  - Increase linearly with number of sub-carriers and become substantial with large FFT size
- Adds significantly to the total PHY complexity

HW Complexity Memories

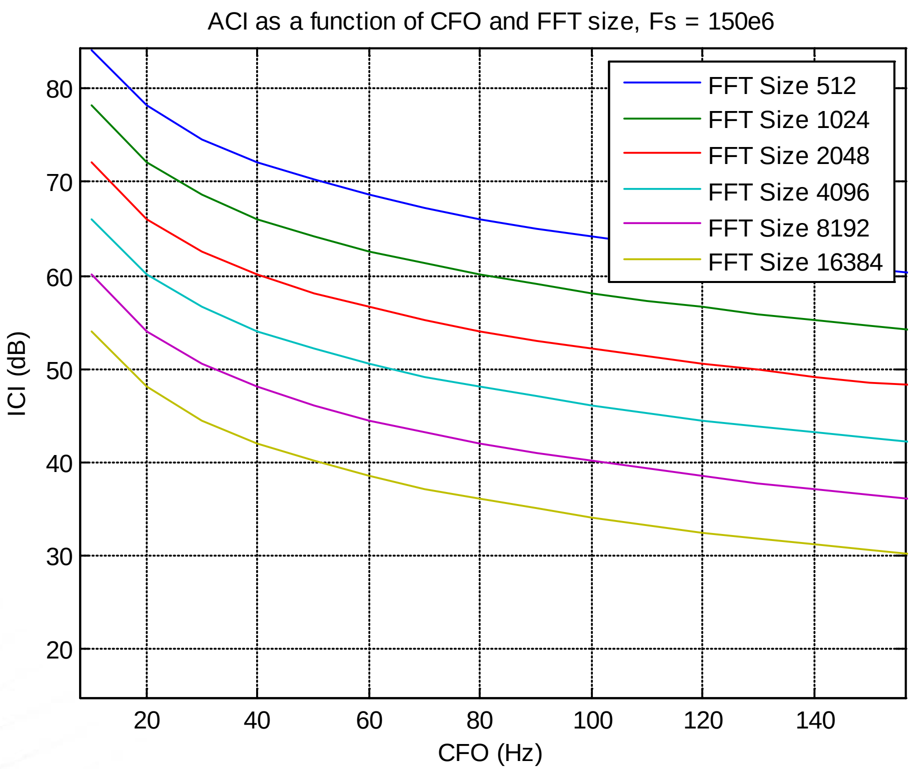
- FFT implementations require 3-4 FFT-size long buffers per FFT processor (depending on implementations)
- Additional FFT-size buffer is required for equalization



- Memory size for 4K
  - 4*(2*16bits)*4K = 32KB per block
- Memory size for 16K
  - 4*(2*16 bits)*16K = 128KB per block
- Significant addition to PHY complexity

HW Complexity – Frequency Offset and Phase Noise

- Carrier offset
  - Curves depict ideal ICI calculations
  - Shows larger sensitivity to large number of sub-carriers
  - Make it harder to achieve target SNR with large symbol
- Phase noise and frequency drift
  - Smaller subcarrier spacing (larger symbols) imposes more difficult requirements for the XTAL phase noise

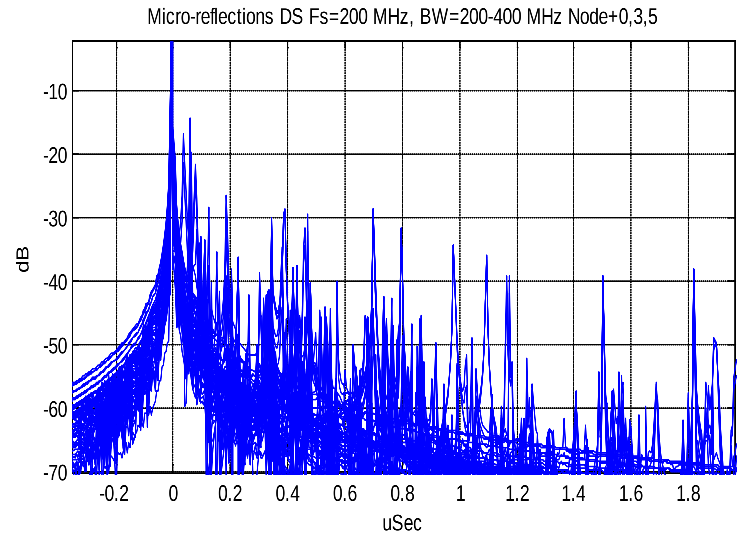


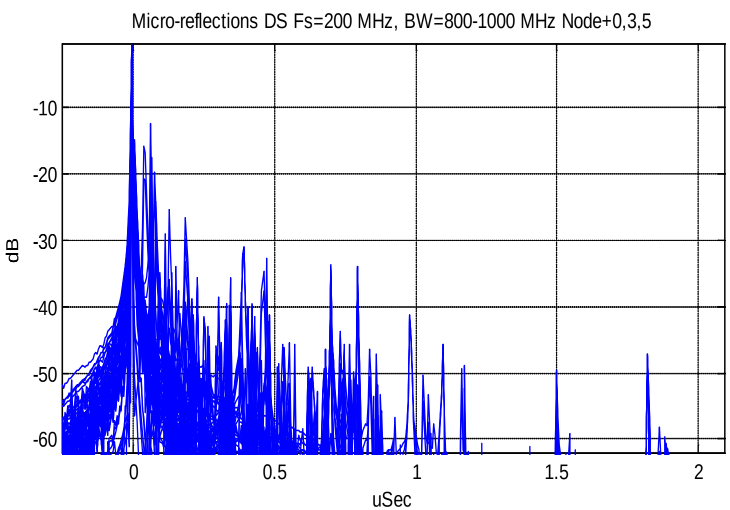
Conclusions

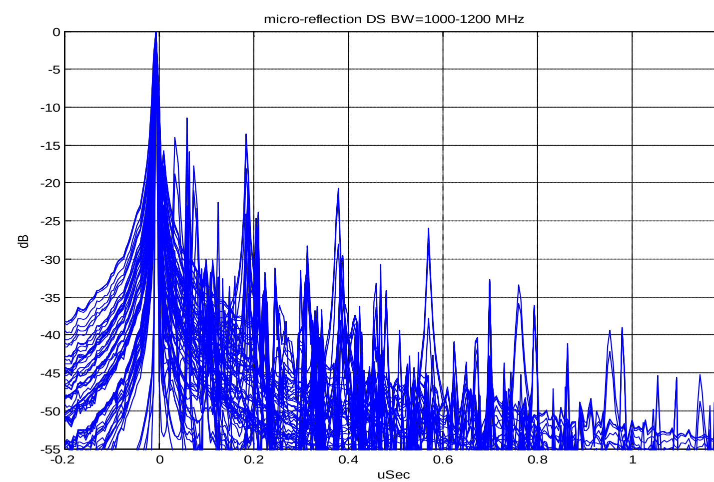
- With OFDM sampling frequency of 204.8 MHz:
- 4K sub-carriers provide a good trade-off between throughput loss due to CO overhead vs. complexity and latency
- 16K sub-carriers impose significant complexity and latency issues
- Configure CP to handle worst case networks if needed
  – Avoid incrementing complexity and latency to support extreme (rare) corner cases
- The analysis is based on in-house data and simulations and should be verified once a channel model with micro-reflection is available

Loop Impulse responses - Downstream

- Aggregated impulse responses over about 70 simulated channels
- Node+0, Node+3 and Node+5 topologies
- Examples: 200 MHz bands at 200-400 and 1000-1200 MHz
- Simulated loops to be used to assess required guard interval







Simulated CP size and ISI- Downstream

- The simulated loops were used to assess required CP size per loop and with different window sizes
  - Require ISI of ≤ -40 dBc
    - To support QAM1024
  - Tukey window is used, sizes are relative to 4096 FFT size
- CP sizes per loop are depicted, sorted by size
  - (X-axis is a loop index, y-axis the CP in uSec)
- Based on results we propose the following CP sizes:
  - ~0.5 uSec for most loops with short windows
  - ~1.0 uSec for most loops with larger window sizes
  - ~1.5 uSec for worst loops with larger window sizes
  - ~2.0 uSec (or higher?) for extreme cases
- CP size is configurable
  - CP size is set according to loop conditions and shaping requirements