# Symbol Size Considerations for EPoC based OFDM PHY

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OFDM Symbol Size Considerations

- Throughput
  - CP overhead decreases 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 are more sensitive to phase noise at low frequencies
- Complexity
  - Buffer sizes in FFT implementation increase with symbol size
 - Low frequency phase requirements tougher with larger symbol size

CP Size Requirements
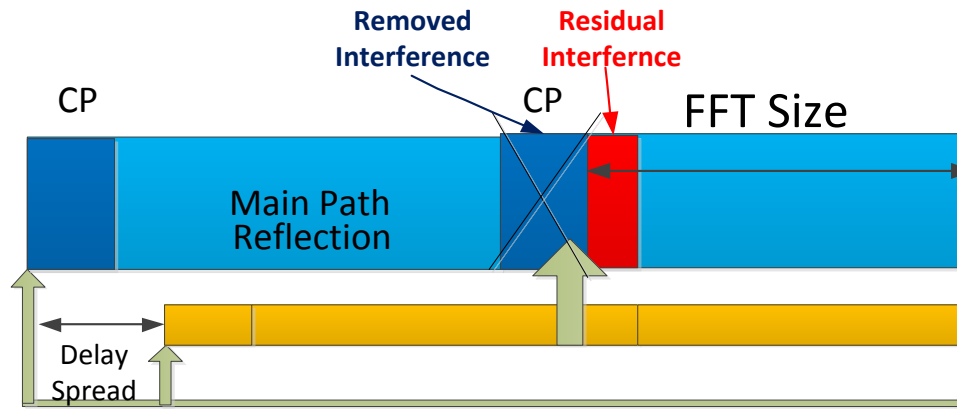
- Depends on the channel delay spread and the reflection size
  - CP size does not need to exceed delay spread of the channel to be effective
  - Interference is relative to residual echo to OFDM symbol size ration

- Analysis on simulated and measured loops show that a CP size not larger than 1.0 uSec is adequate to receive QAM1024 on vast majority of loops in the downstream
  - Need to verify with established channel model when available

- CP size can be configued to accommodate larger CP sizes when required

CP Overhead

- With CP size of 1.0 – 1.5 uSec
  - 20 uSec symbol size shows overhead of 4.5%-7%
  - 40 uSec symbol size shows less overhead of 2.5%-3.5%
- Overhead may increased with window shaping and interleaved legacy signals in the OFDM block

Effective rate with CP overhead
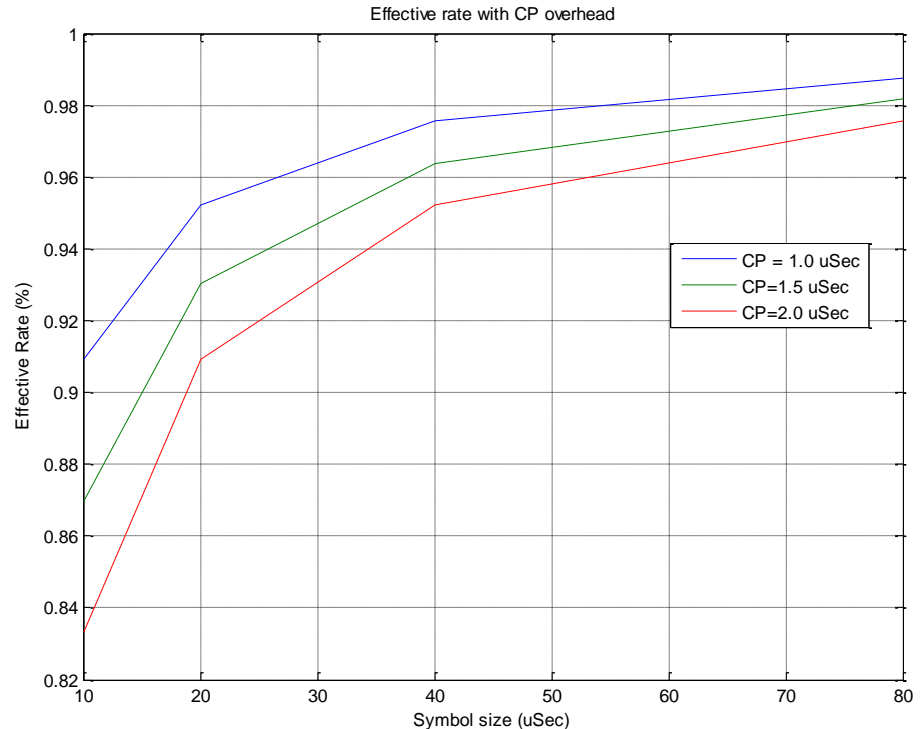
Latency in the Downstream

- Modulation latency in the downstream is four times the symbol size
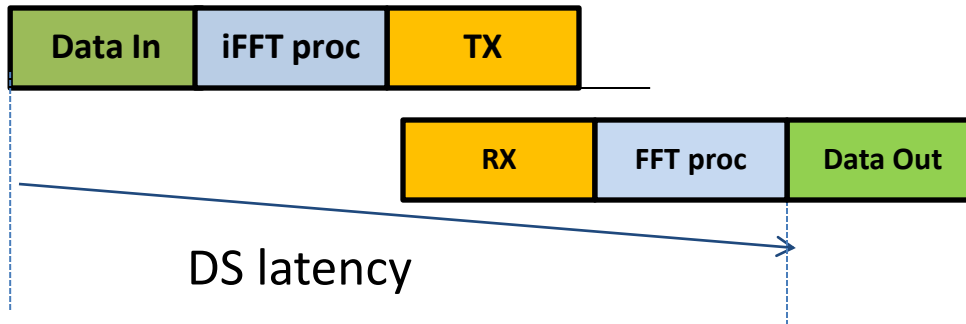
DS latency

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 latencies involved
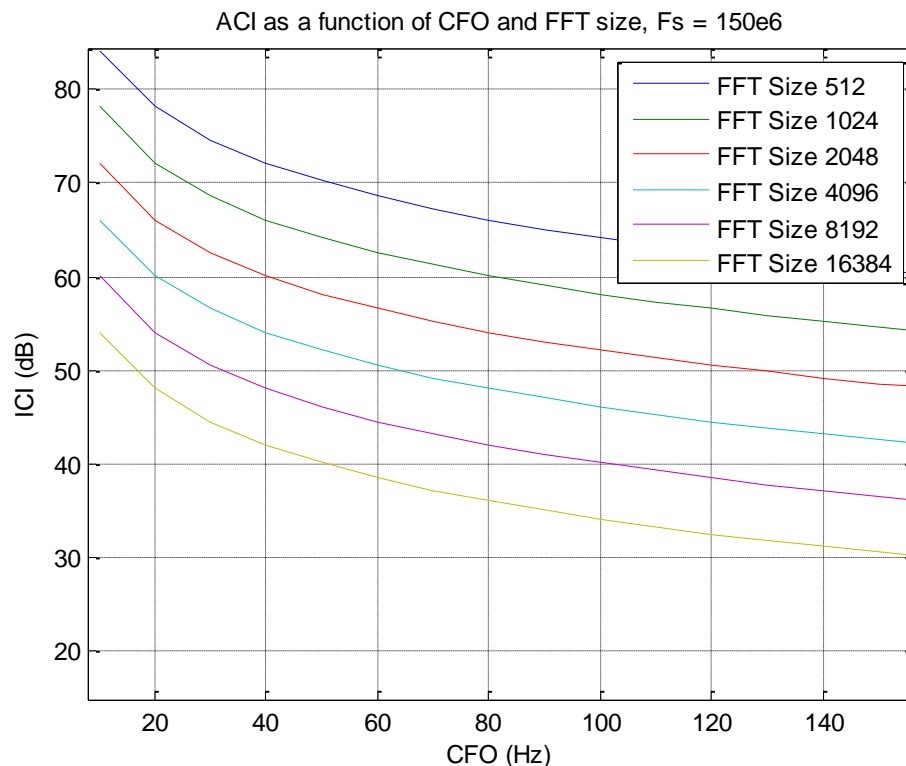
HW Complexity
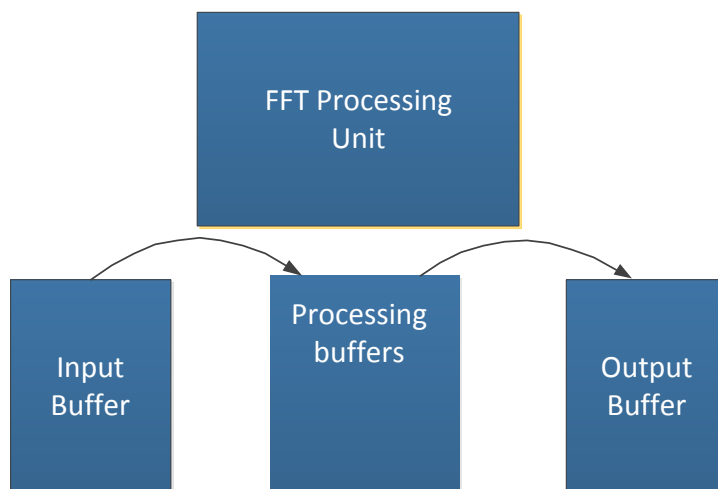
- FFT processing unit processing
  - Small and difference between FFT sizes are small
- Buffer Sizes
  - Increase linearly with number of sub-carriers and become substantial with large FFT size
- FFT implementations require 3-4 FFT-size long buffers per FFT processor (depending on implementations)

- Additional FFT-size buffer is required for equalization
- Memory size for 4K FFT size
  - 4*(2*16bits)*4K = 32KB per block
- Memory size for 16K FFT size
  - 4*(2*16 bits)*16K = 128KB per block
- Significant addition to PHY complexity and power consumption

Frequency Offset and Phase Noise

- Carrier frequency 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 is more harmful with longer symbols

    - Smaller subcarrier spacing (larger symbols) imposes more difficult requirements for the XTAL phase noise

ACI as a function of CFO and FFT size, Fs = 150e6

Legend:
- FFT Size 512
- FFT Size 1024
- FFT Size 2048
- FFT Size 4096
- FFT Size 8192
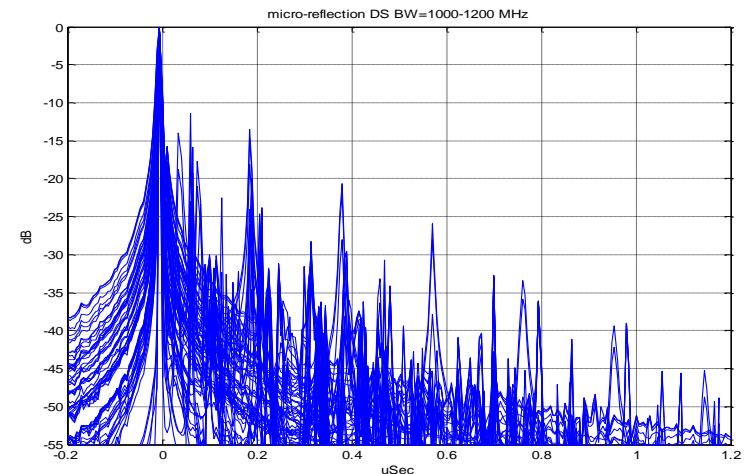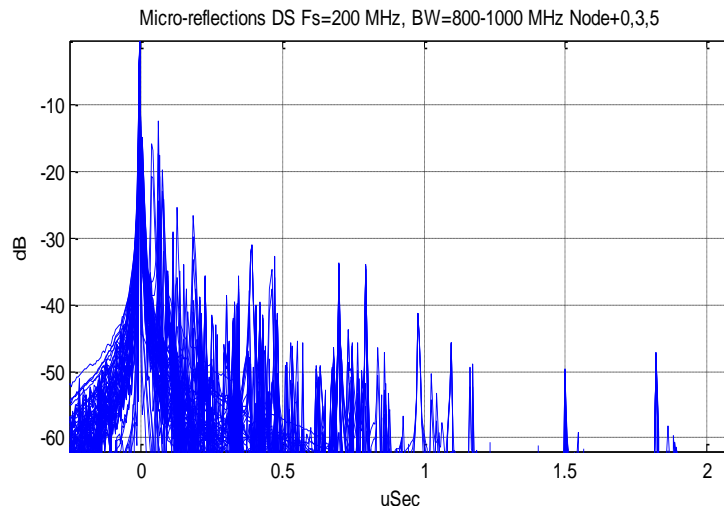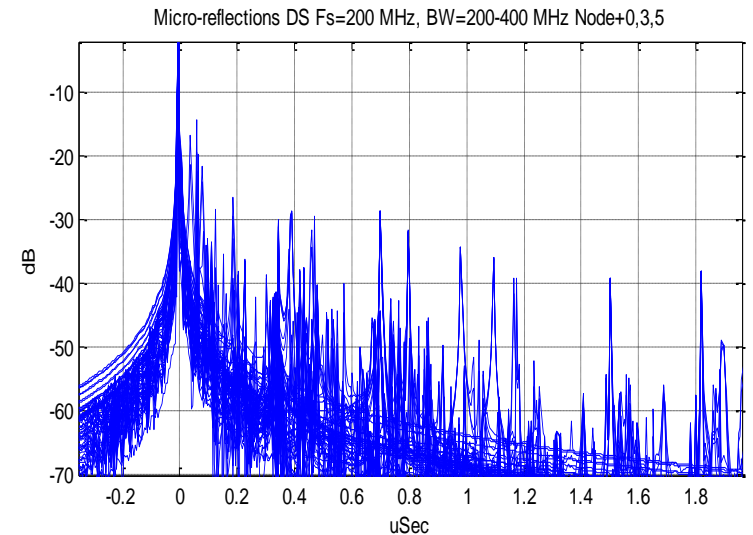- FFT Size 16384

ICI (dB) vs CFO (Hz)

Conclusions

- With OFDM sampling frequency of 204.8 MHz:

- 4K sub-carriers provide a good trade-off between CP 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

- Analysis was based on in-house data and simulations and should be verified once a channel model with u-reflection is available
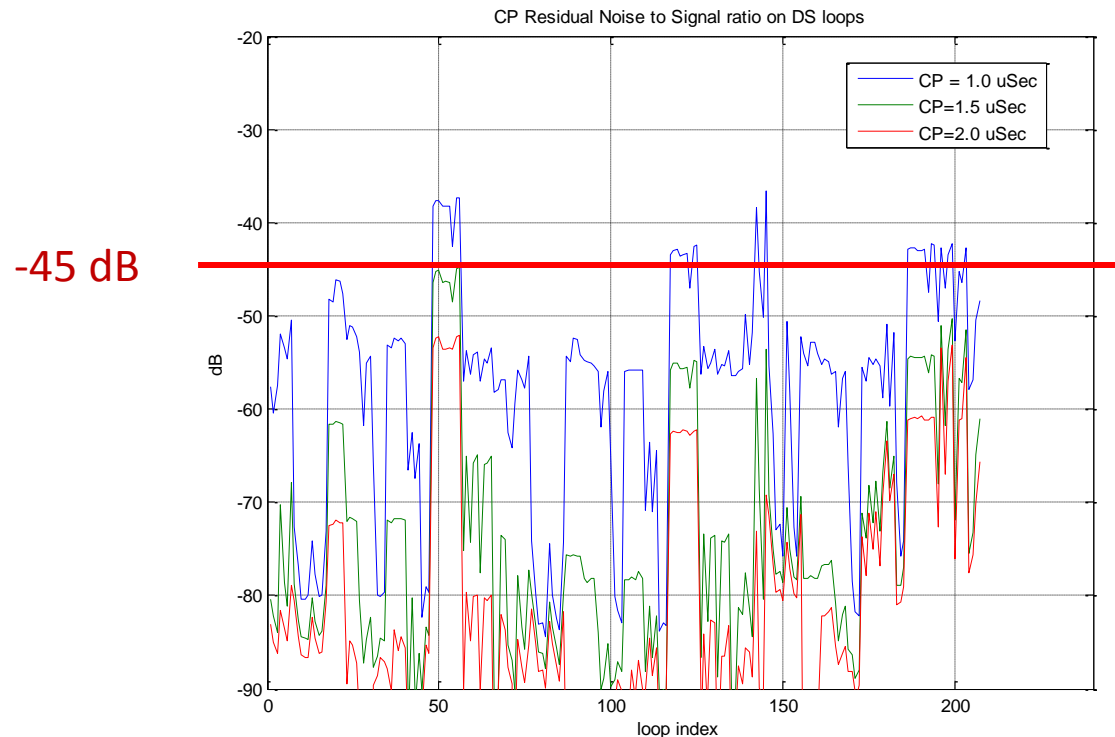
Back Up Slides

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, 800-1000 MHz and 1000-1200 MHz
- Simulated loops were used to assess required CP size

Micro-reflections DS Fs=200 MHz, BW=200-400 MHz Node+0,3,5

Micro-reflections DS Fs=200 MHz, BW=800-1000 MHz Node+0,3,5

micro-reflection DS BW=1000-1200 MHz

Simulated CP size and ISI- Downstream

- Noise due to residual was used to assess required CP size per loop
  - Require ISI of ≤ -45 dBc (to be "low enough compared to 37 dB signal to background noise ratio)
  - Sufficient to support QAM1024
- CP sizes 1.0 uSec , 1.5 uSec and 2.0 uSec
- For most loops CP size of 1.0 uSec is adequate, 1.5 uSec was enough for all loops

Thank You