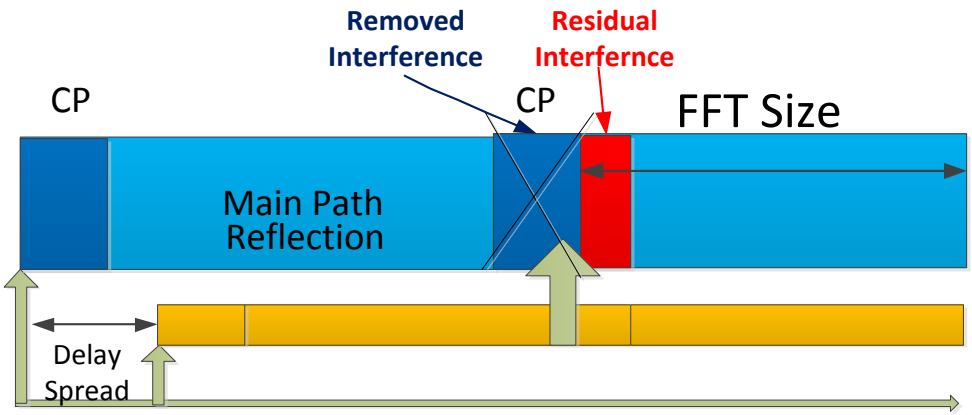
Symbol Size Considerations for EPoC based OFDM PHY

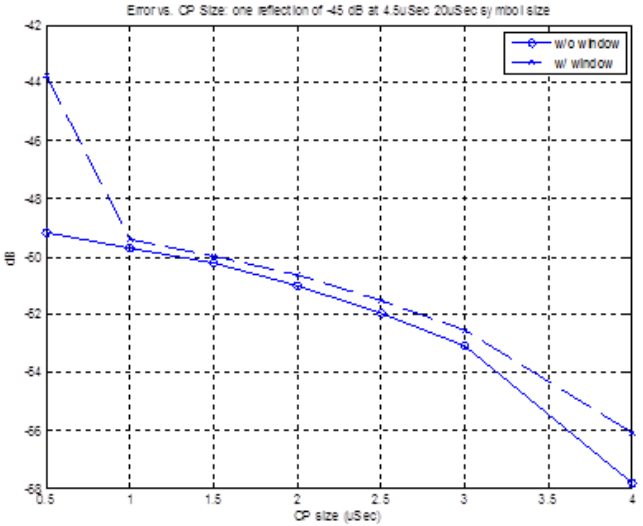
Avi Kliger, Leo Montreuil, Tom Kolze
Broadcom

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

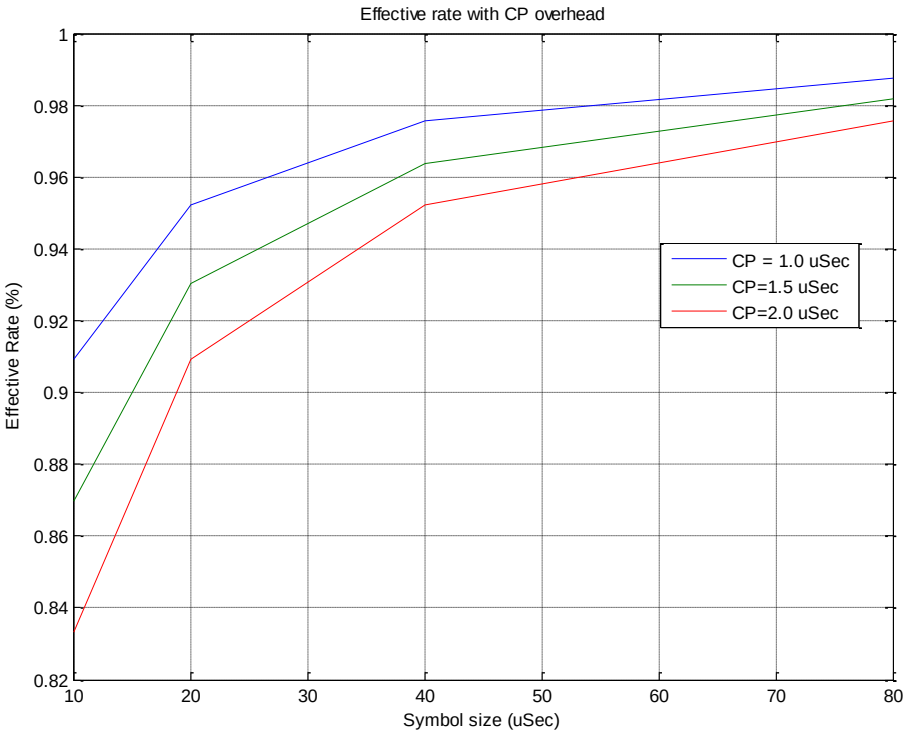




- Depends on the channel delay spread and the reflection size
  - CP size does not need to exceed delay spread of the channel to be effective
  - Interference is relative to residual echo to OFDM symbol size ration
- Analysis on simulated and measured loops show that a CP size not larger than 1.0 uSec 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 configured to accommodate larger CP sizes when required

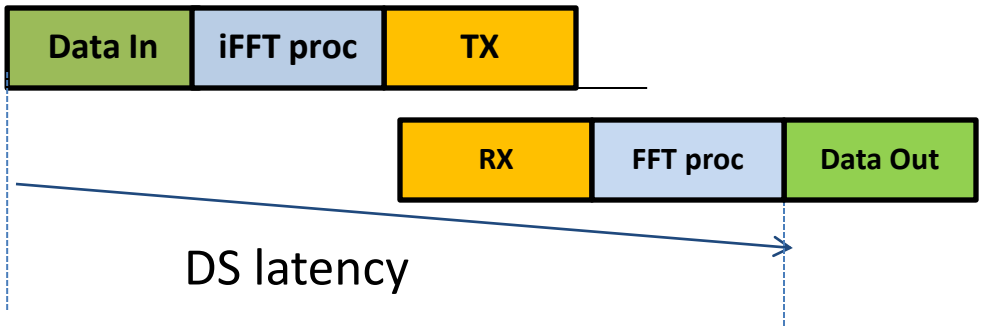
CP Overhead

- 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



Latency in the Downstream

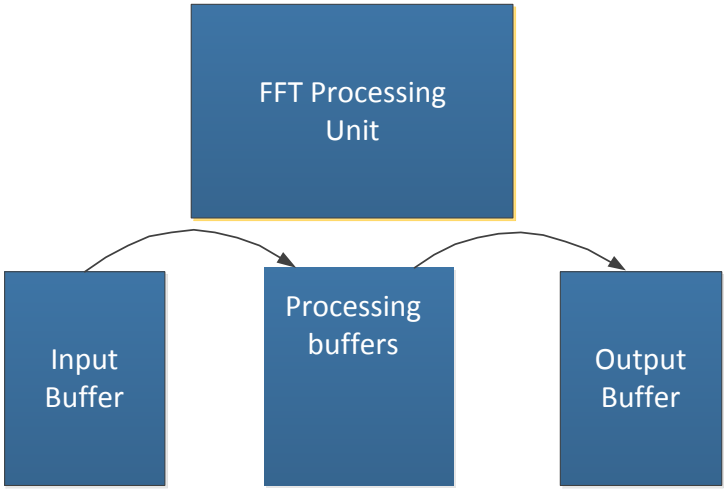
- Modulation latency in the downstream is four times the symbol size



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 latencies involved

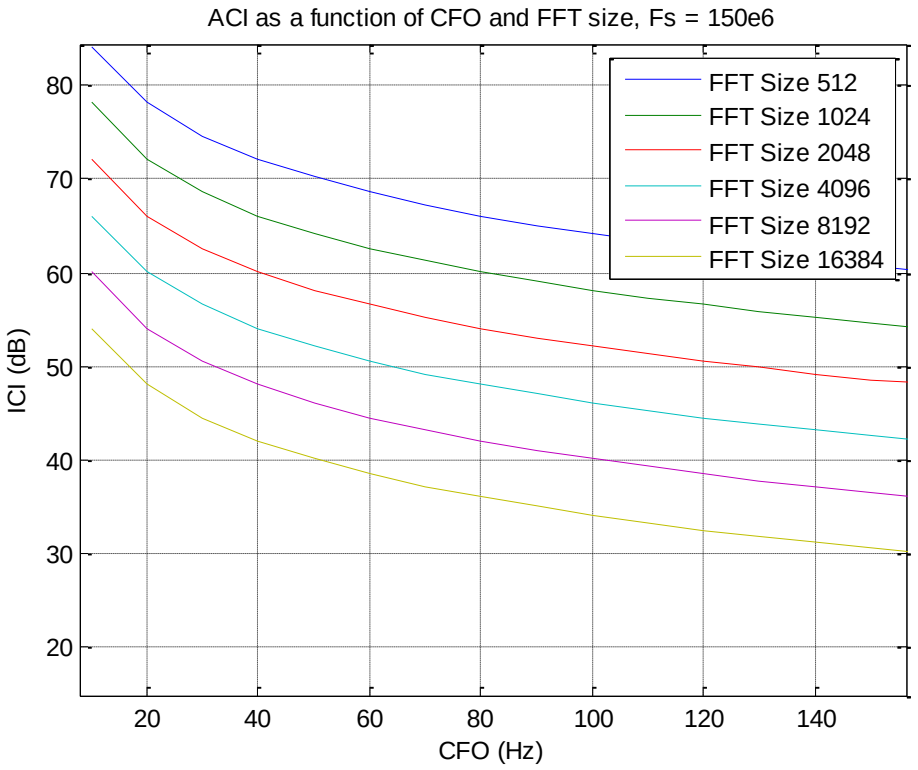
HW Complexity



- 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



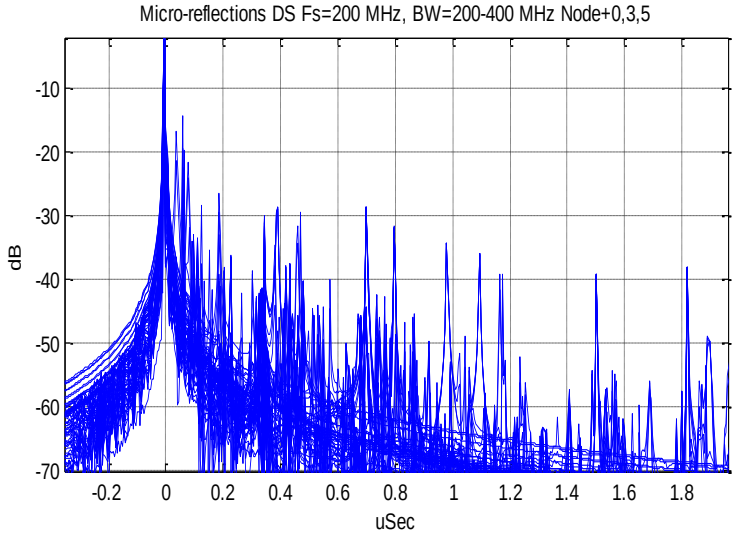
Conclusions

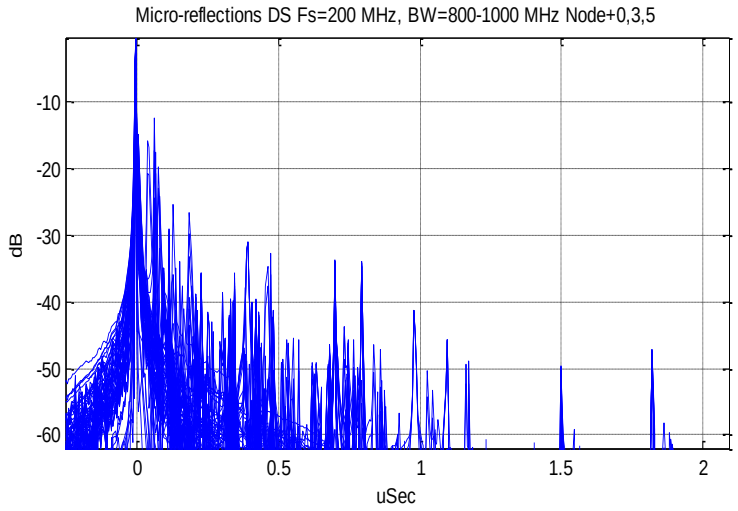
- With OFDM sampling frequency of 204.8 MHz:
- 4K sub-carriers provide a good trade-off between CP overhead vs. complexity and latency
- 16K sub-carriers impose significant complexity and latency issues
- Configure CP to handle worst case networks if needed
  - Avoid incrementing complexity and latency 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

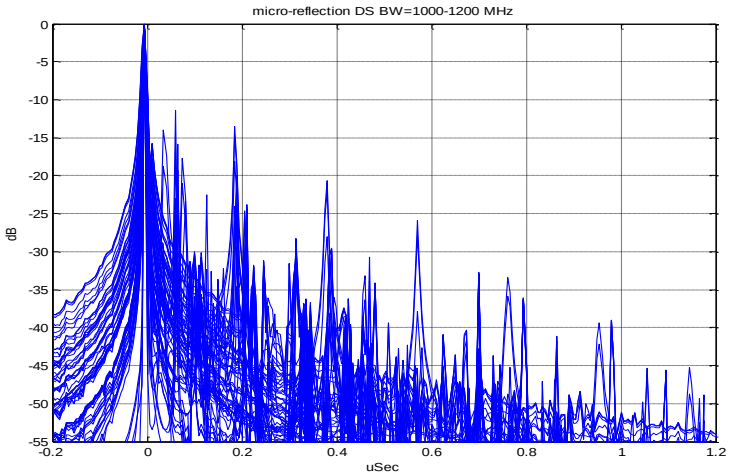
Back Up Slides

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

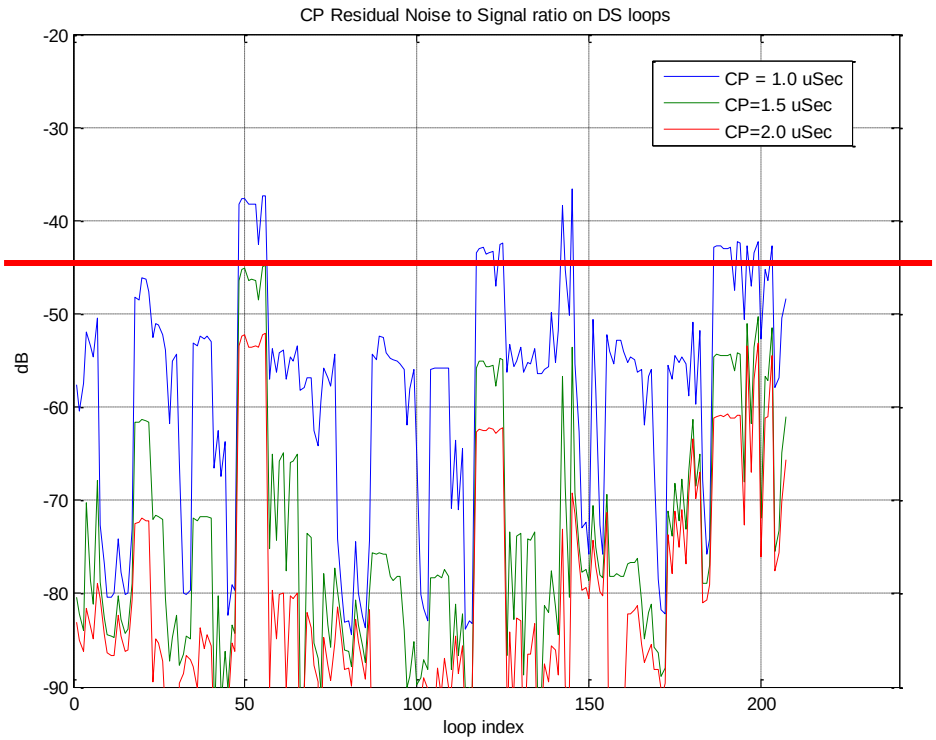






Simulated CP size and ISI- Downstream

-45 dB



- 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