# OFDM TX Symbol Shaping 802.3bn


**Leo Montreuil, Rich Prodan, Tom Kolze**

Phoenix, January 2013

# Recommendations

- TX window is specified as $N_t$ samples in taper region
  - No need for different set of Alpha for 4K and 8K FFT.
  - Avoid confusion for calculation of $N_t$ with variable Cyclic Prefix.
    Alpha = $N_t/N_{fft}$, $T_p = N_t/204.8e6$
- $N_t$ = {0, 32, 64, 128, 192, 256}
  - $T_p$ = {0, 0.15625, 0.3125, 0.625, 0.9375, 1.25} us
  - Alpha = {0, 0.78125%, 1.5625%, 3.125%, 4.6875%, 6.25% } for 4K FFT
  - Alpha = {0, 0.390625%, 0.78125%, 1.5625%, 2.34375%, 3.125%} for 8K FFT
- A postfix of $N_t$ samples is added, windowing is applied to cyclic prefix and postfix
  - Windowing is absorbed by CP.
  - Symbol time is independent of Window $N_t$.
  - Receiver sampling is independent of TX window.
  - TX window appears to RX as post-cursor multipath, affect only the following symbol, not the previous symbol.

# Windowing Function

# Raised-Cosine Window

- Raised-Cosine window in frequency domain (FD):

$$\mathrm{P}(f) = \left[\frac{\sin(\pi f T)}{\pi f T}\left(\frac{\cos(\pi\alpha f T)}{1-(2\alpha f T)^2}\right)\right], \qquad 0 \le \alpha \le 1$$

- Raised-Cosine window in time domain (TD):

$$p(t) = \begin{cases} \frac{1}{T}, & 0 \le |t| < \frac{T(1-\alpha)}{2} \\ \frac{1}{2T}\left\{1+\cos\left[\frac{\pi}{\alpha T}\left(|t| - \frac{T(1-\alpha)}{2}\right)\right]\right\}, & \frac{T(1-\alpha)}{2} \le |t| \le \frac{T(1+\alpha)}{2} \\ 0, & \text{otherwise} \end{cases}$$

***α = 0 is a rectangular window (no shaping)***

# Examples of Raised-Cosine Window

## MATLAB code for TX window p:

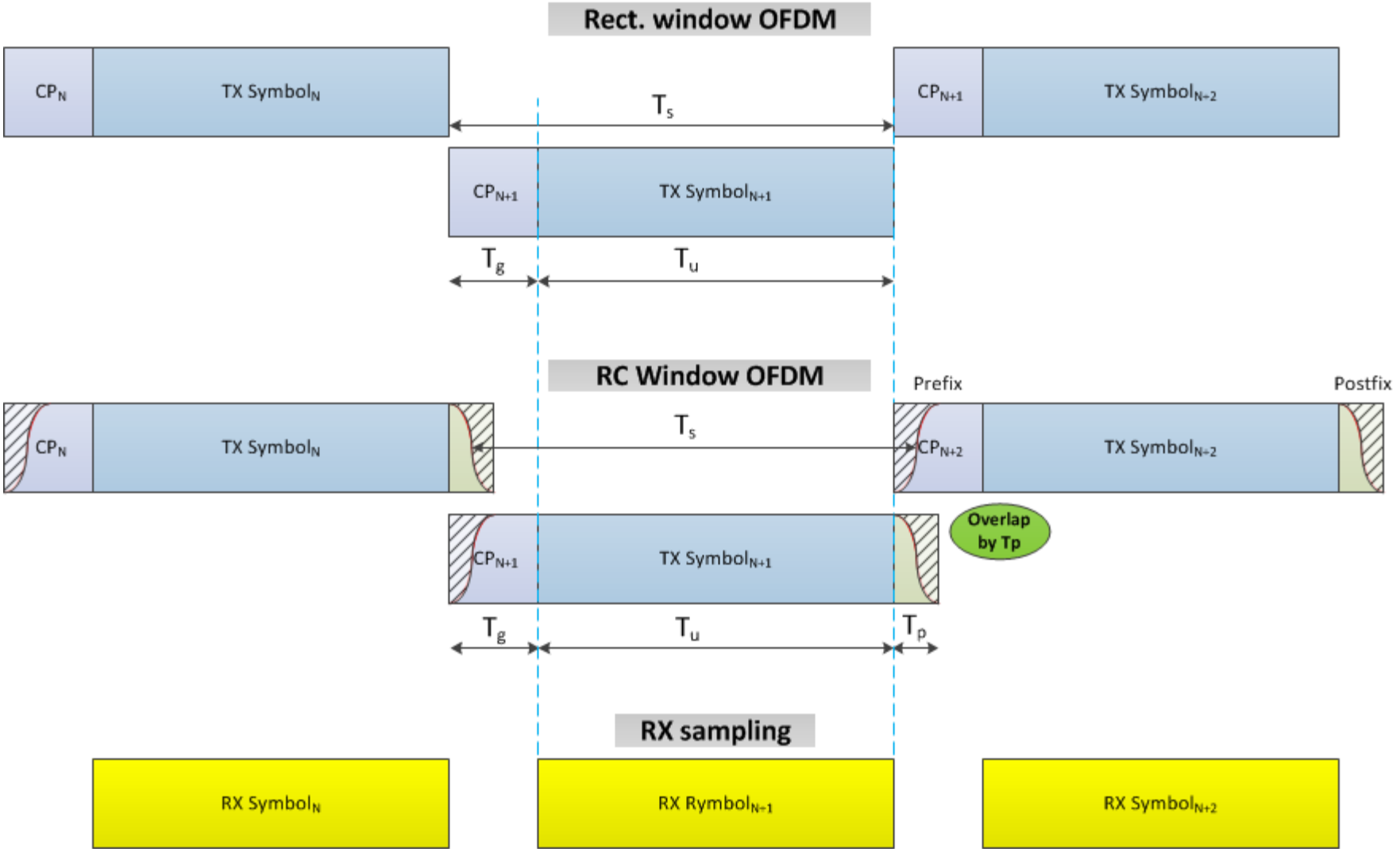
```
Nfft   = 4096;                                          % FFT size
CP     = 256;                                           % Nb. samples in Cyclic Prefix
Alpha  = 1/32;                                          % RX Alpha
Nt     = 2*round(Nfft*Alpha/2);                         % Nb. samples in taper region
p      = 1/2*(1+cos(pi*[-Nt+1/2:Nt-1/2]/Nt));           % Raised-Cosine in TD
p      = [p(1:Nt), ones(1,Nfft+CP-Nt), p(Nt+1:2*Nt)];   % Add ones in middle
```

## Taper Region weight for Alpha = 1/128 (32 points):

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.0006 | 0.0054 | 0.0150 | 0.0292 | 0.0480 | 0.0711 | 0.0984 | 0.1295 |
| 0.1642 | 0.2022 | 0.2429 | 0.2862 | 0.3316 | 0.3785 | 0.4266 | 0.4755 |
| 0.5245 | 0.5734 | 0.6215 | 0.6684 | 0.7138 | 0.7571 | 0.7978 | 0.8358 |
| 0.8705 | 0.9016 | 0.9289 | 0.9520 | 0.9708 | 0.9850 | 0.9946 | 0.9994 |

***The taper region should not change with different CP → Nt = Alpha*Nfft***

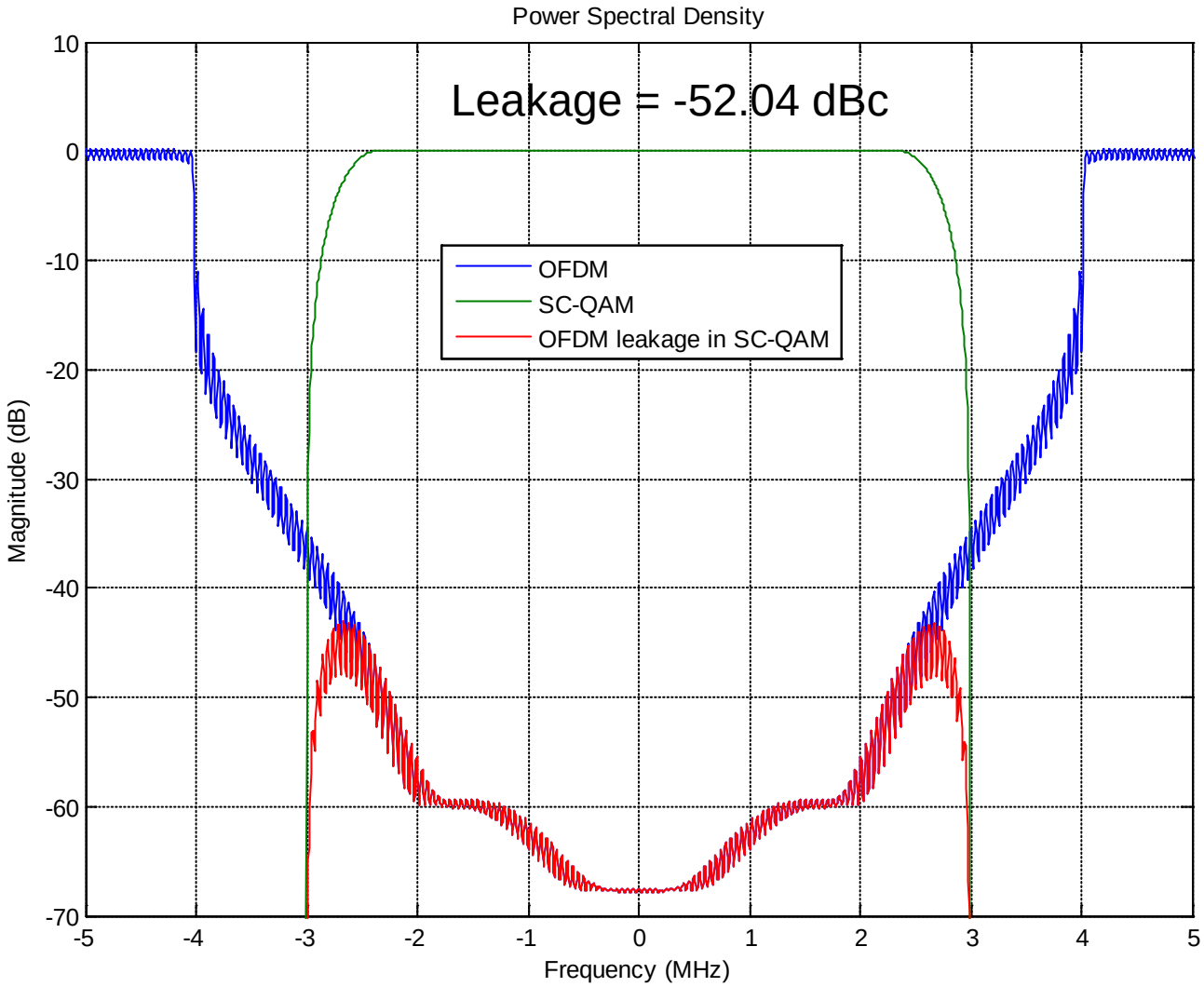
# OFDM TX Windowing, RX sampling offset unaffected by TX Windowing



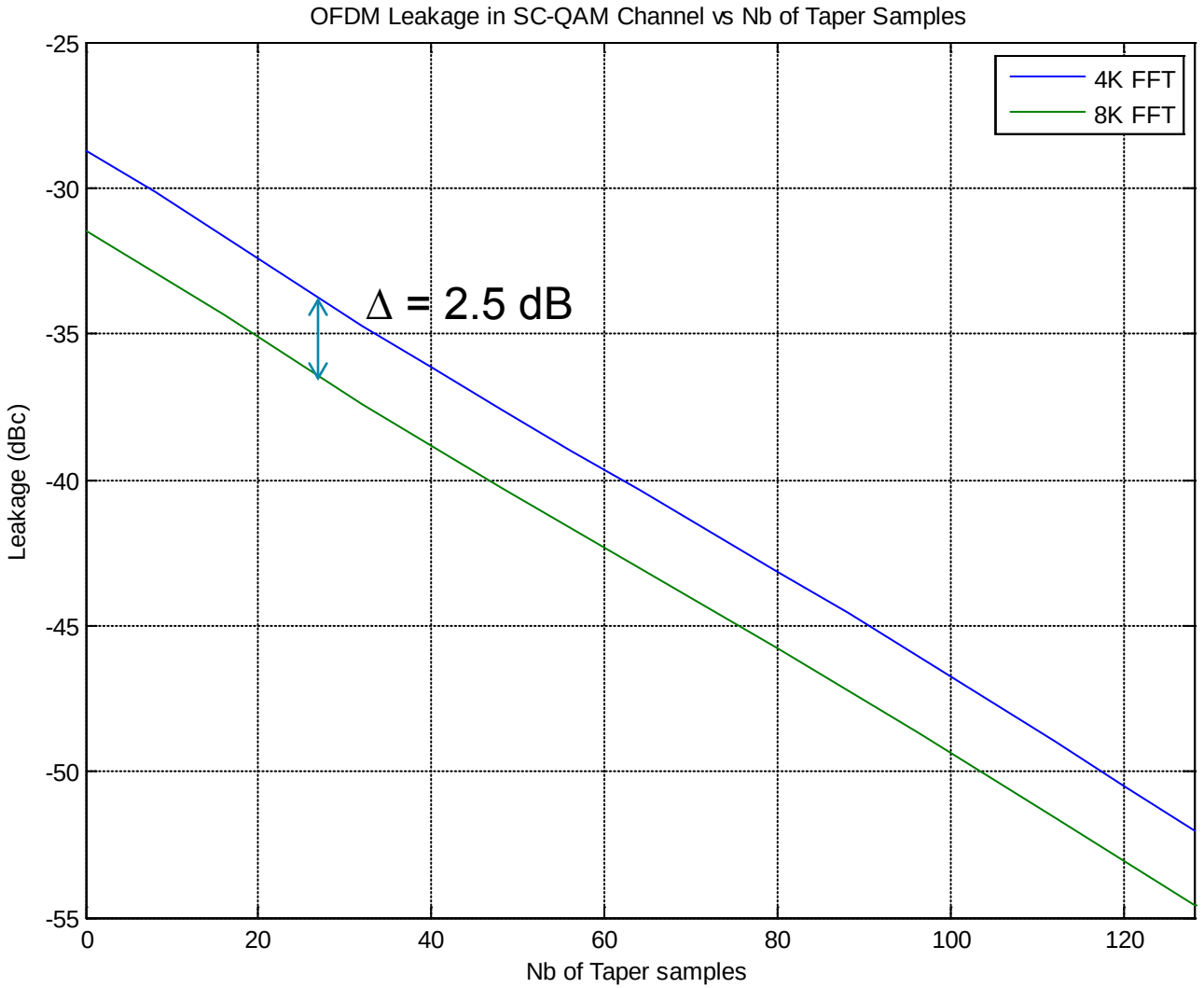

***$T_s$ is independent of RC Window Alpha***

# Leakage in In-Band and Adjacent SC-QAM

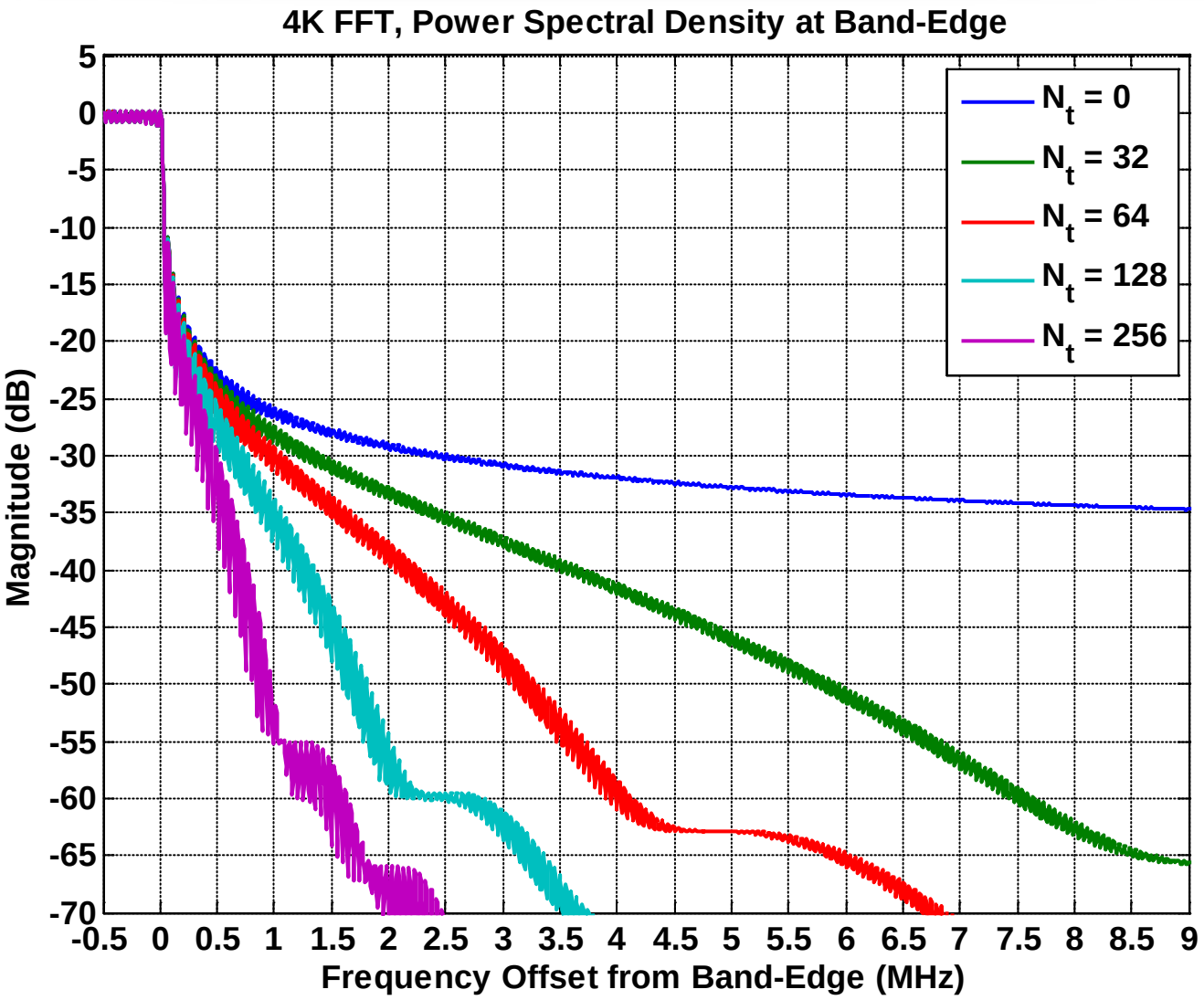
# 4K FFT, $N_t$ = 128, CP = 1.25 us, 8 MHz Spectral Exclusion, SQRT-RC 12% 5.35 MHz Filter



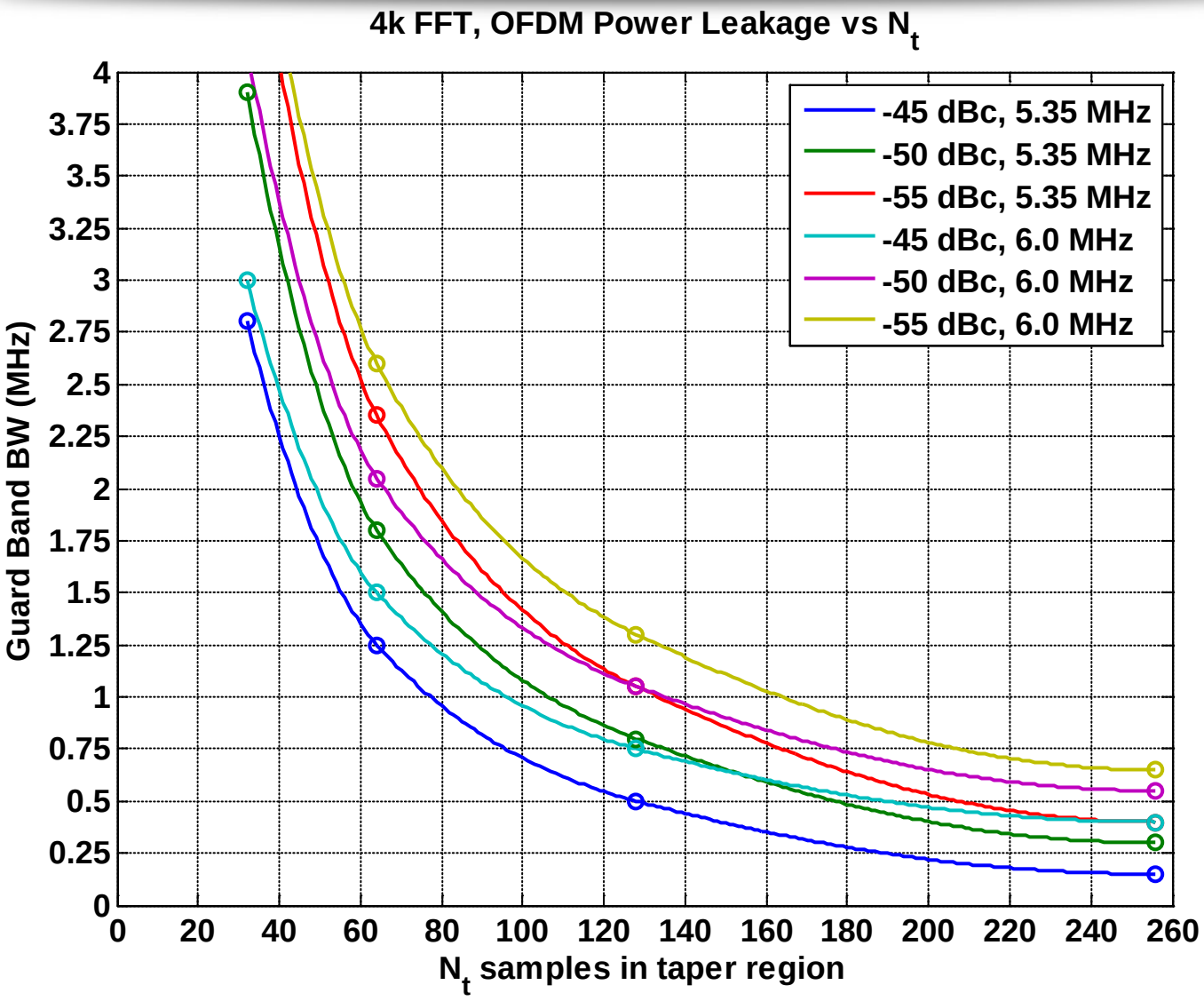
# 4K & 8K FFT, CP = 1.25 us, 8 MHz Spectral Exclusion, SQRT-RC 12% 5.35 MHz Filter



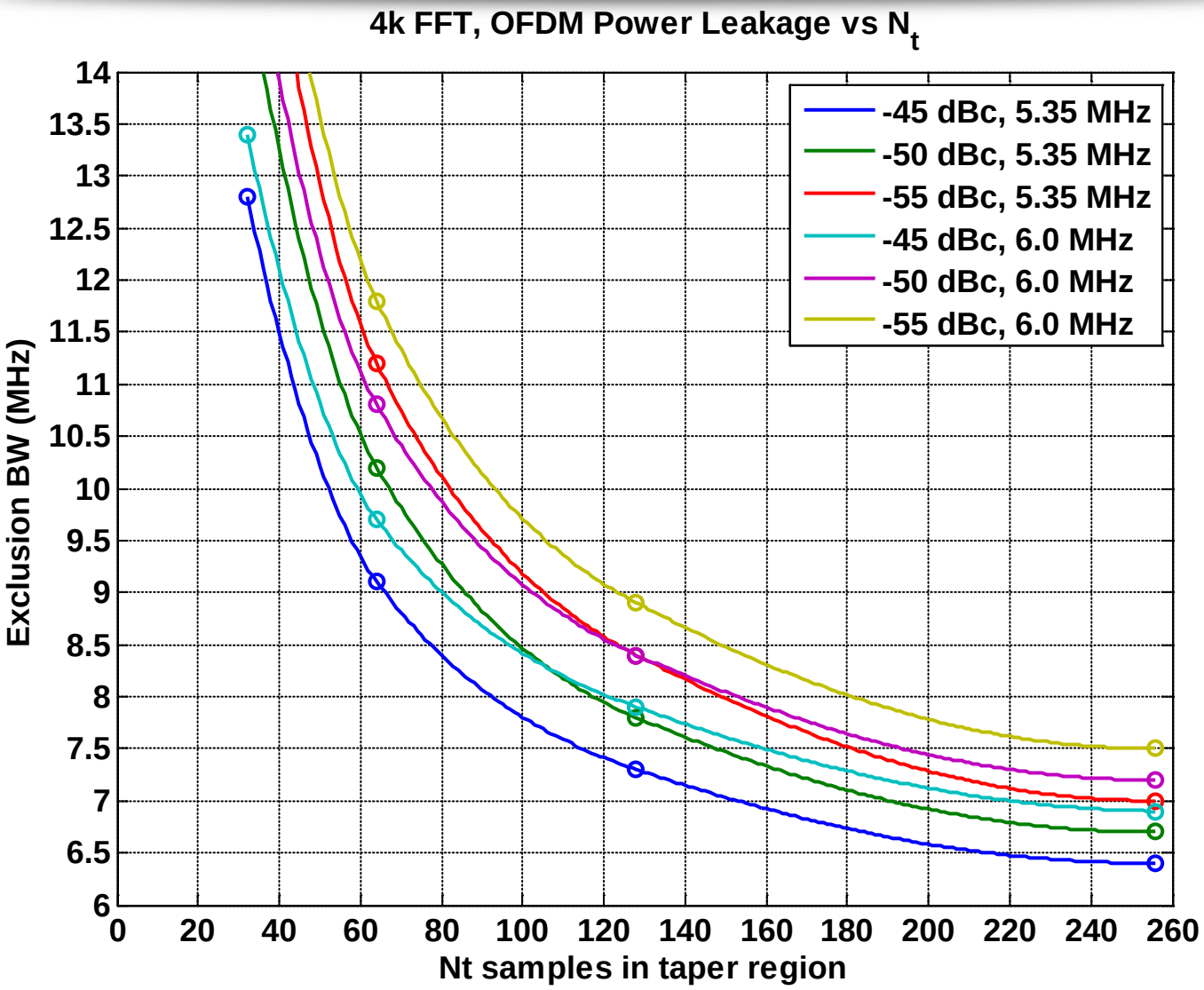
# OFDM TX Power Spectral Density, CP = 1.25 us



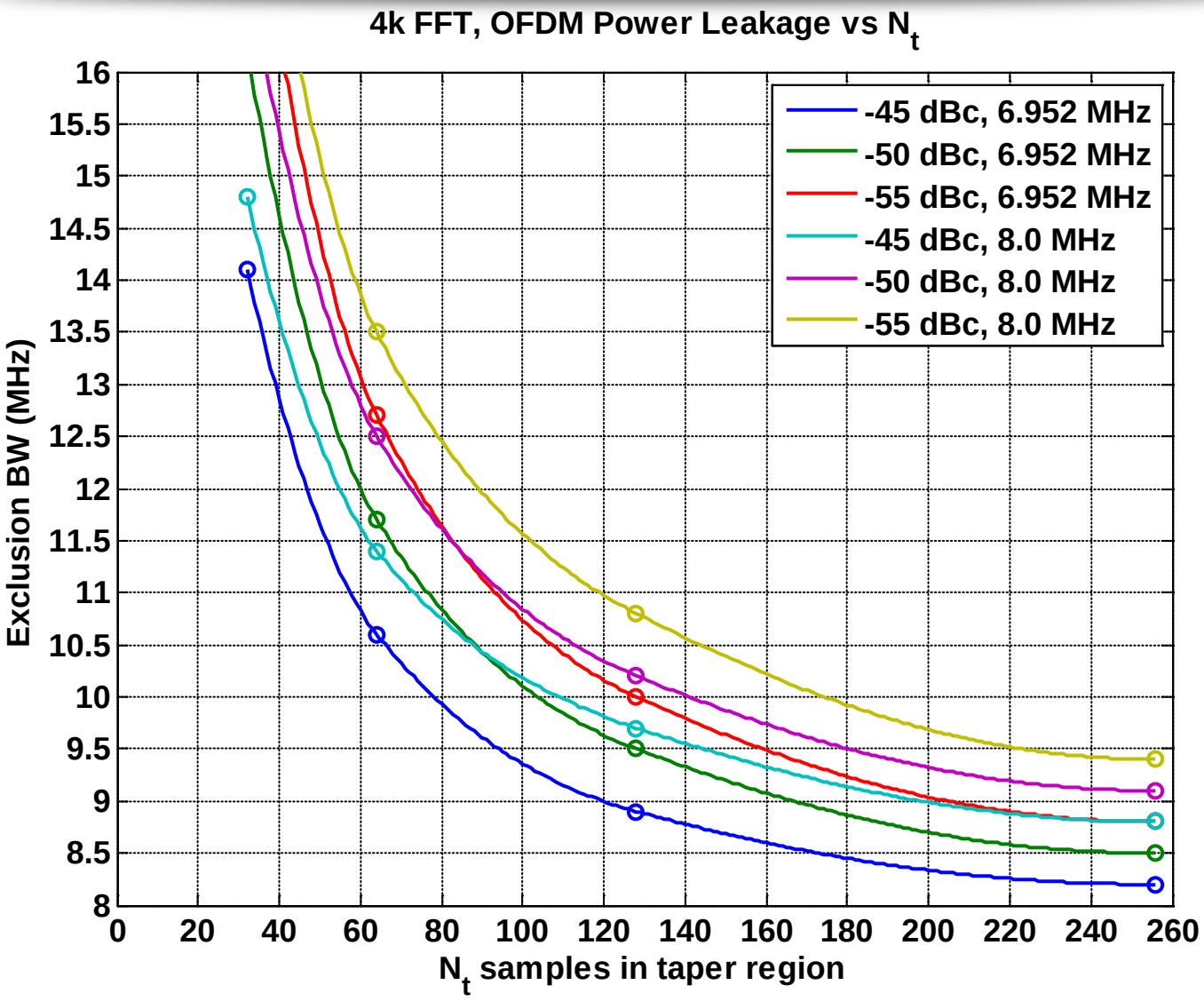
# Adjacent Channel Guard-Band, 6 MHz rectangular and SQRT-RC 12% 5.35 MHz Filter, CP = 1.25 us



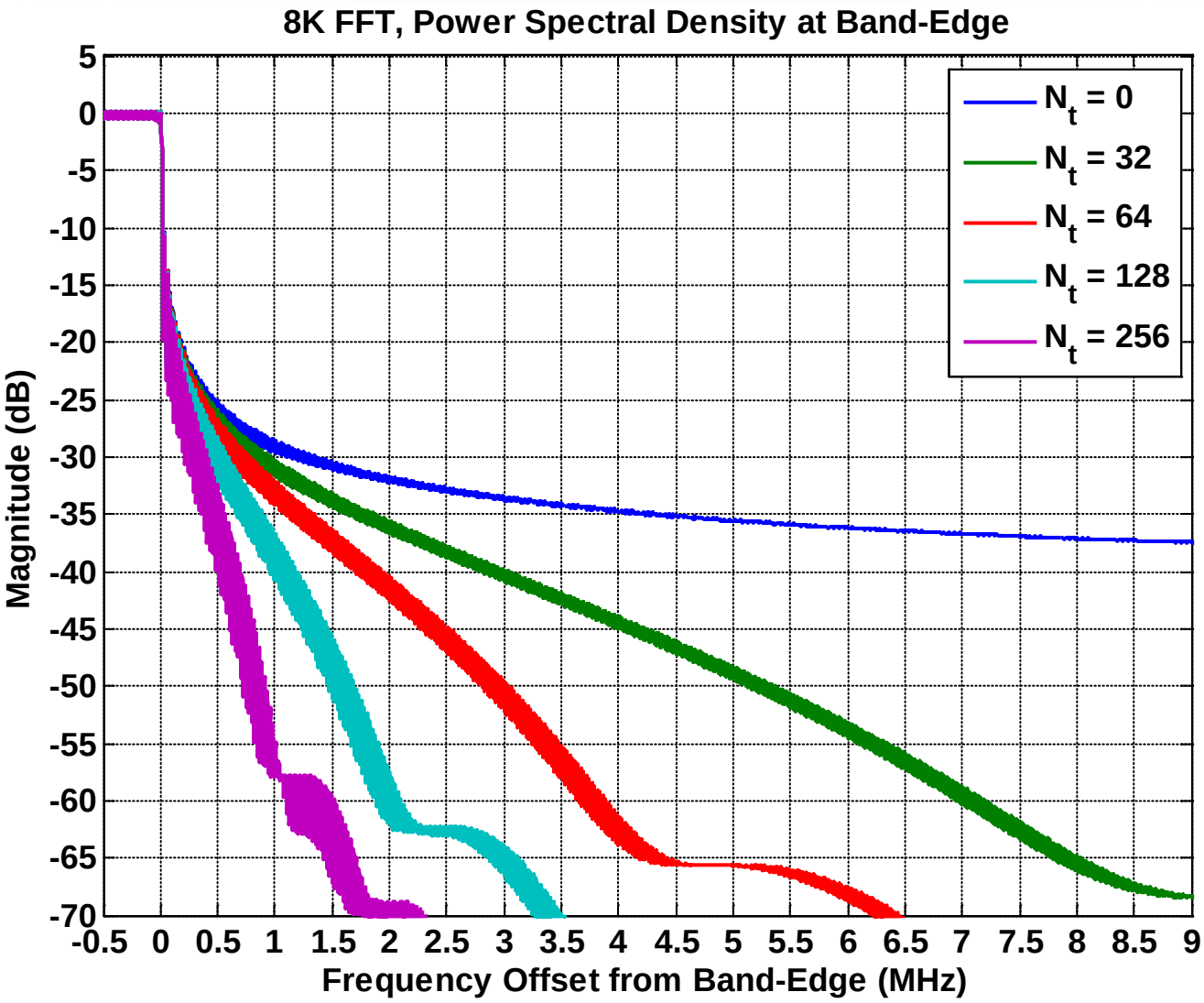
# In-Band Exclusion BW, 6 MHz rectangular and SQRT-RC 12% 5.35 MHz Filter, CP = 1.25 us



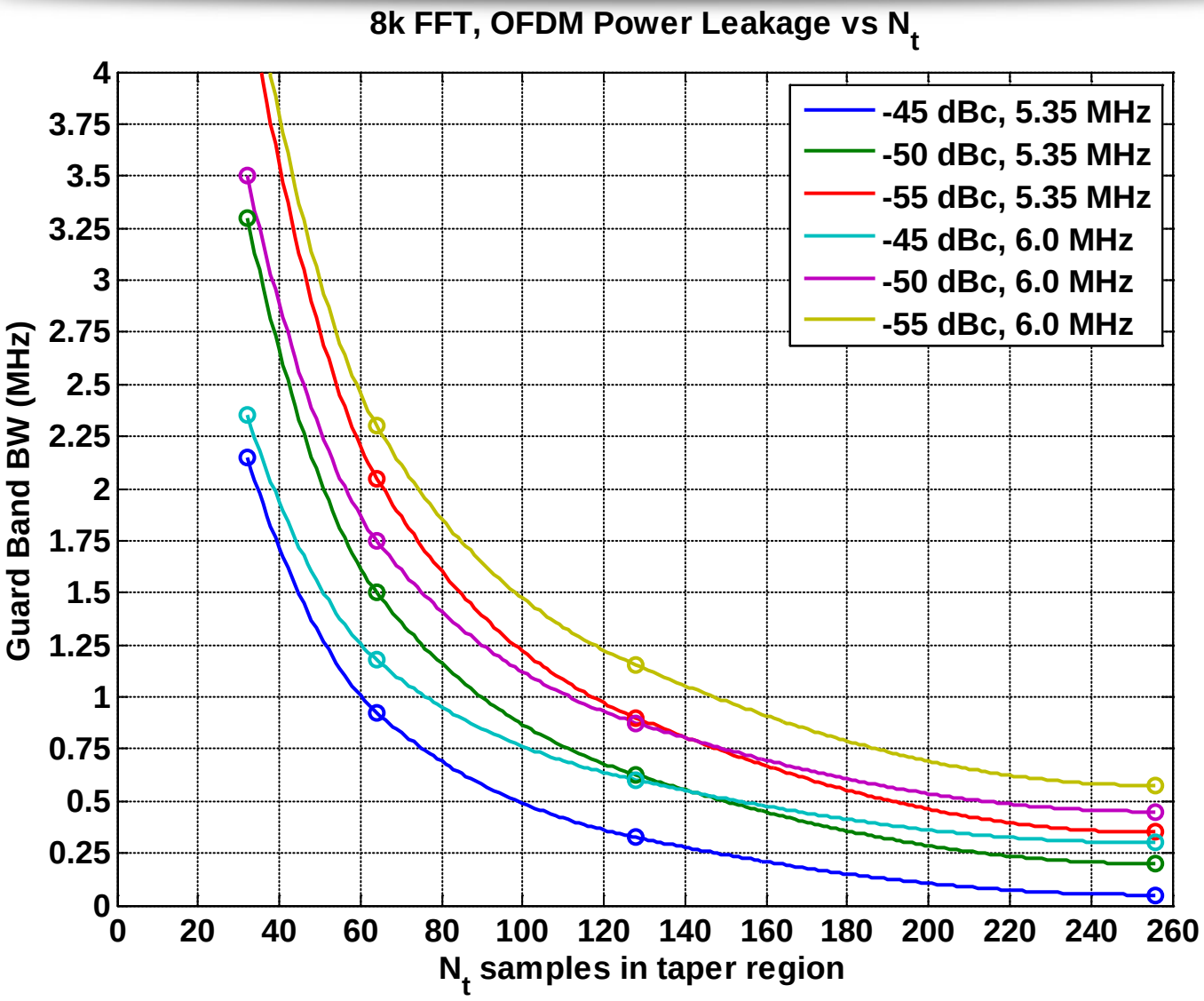
# In-Band Exclusion BW, 8 MHz rectangular and SQRT-RC 15% 6.952 MHz Filter, CP = 1.25 us



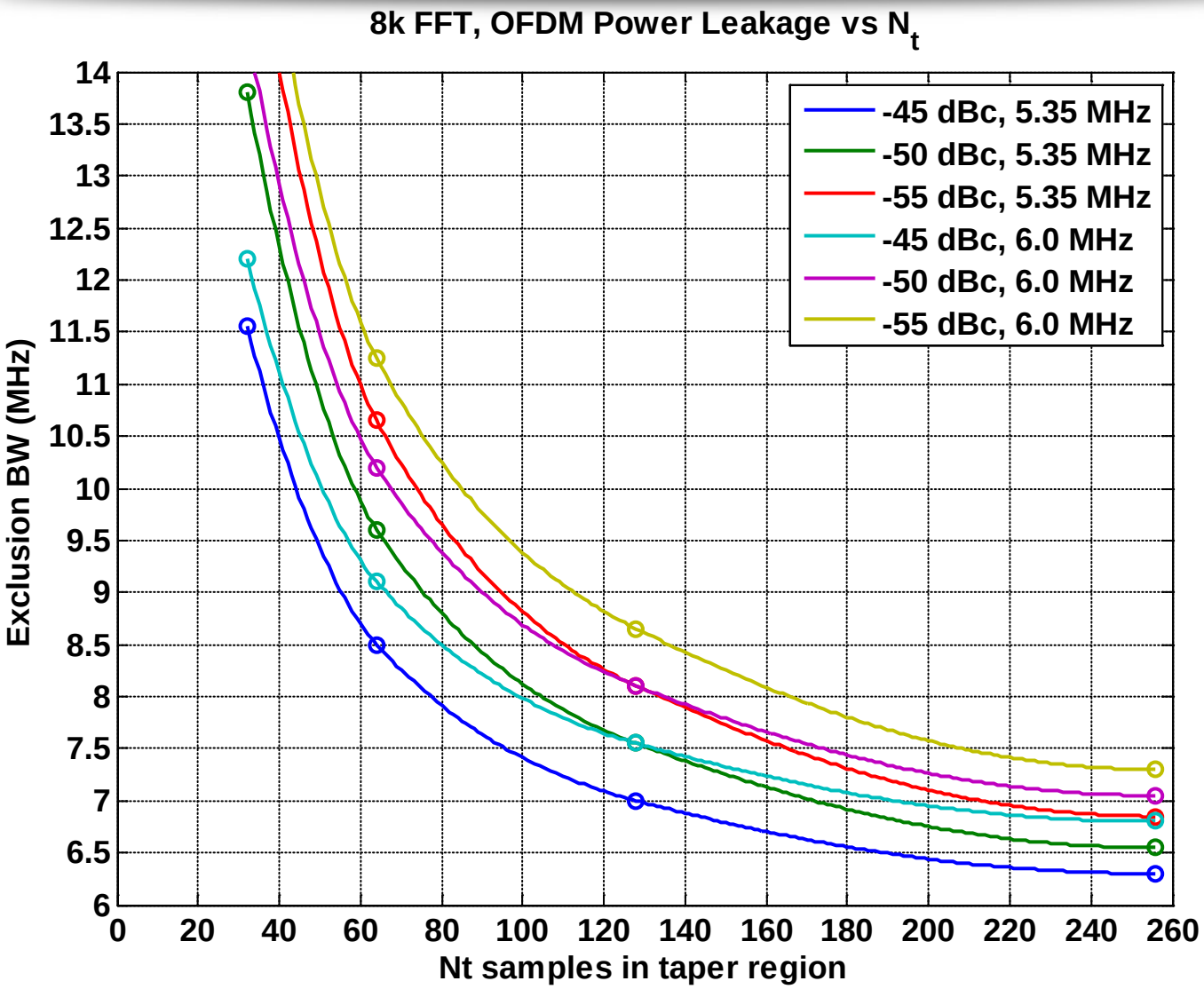
# OFDM TX Power Spectral Density, CP = 1.25 us



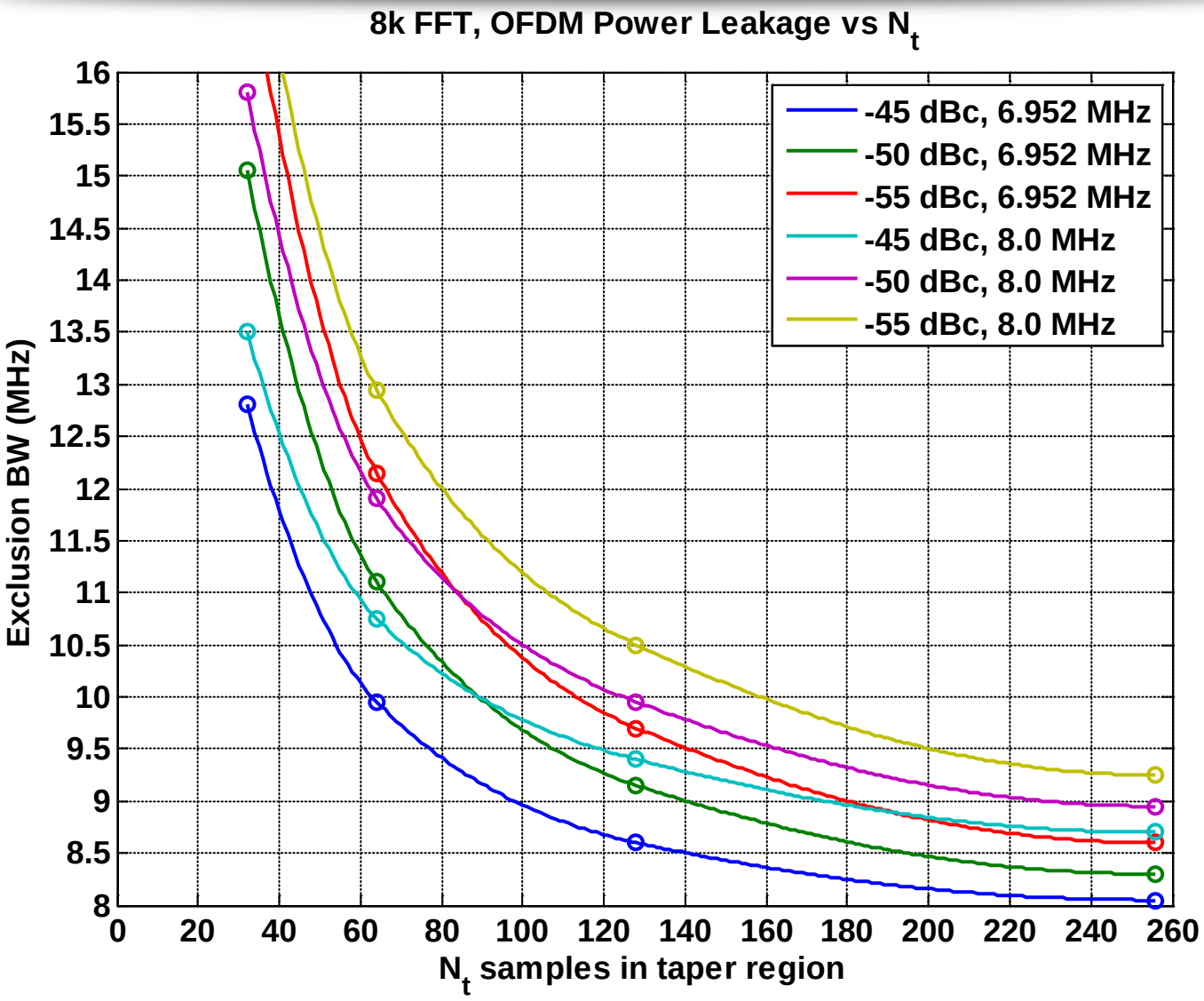
# Adjacent Channel Guard-Band, 6 MHz rectangular and SQRT-RC 12% 5.35 MHz Filter, CP = 1.25 us



# In-Band Exclusion BW, 6 MHz rectangular and SQRT-RC 12% 5.35 MHz Filter, CP = 1.25 us



# In-Band Exclusion BW, 8 MHz rectangular and SQRT-RC 15% 6.952 MHz Filter, CP = 1.25 us



# Thank You