

Phase Noise and Subcarrier Spacing

IEEE P802.22 Wireless RANs

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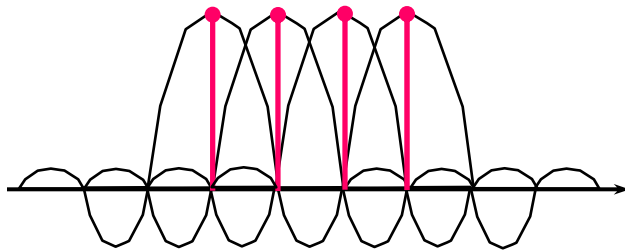
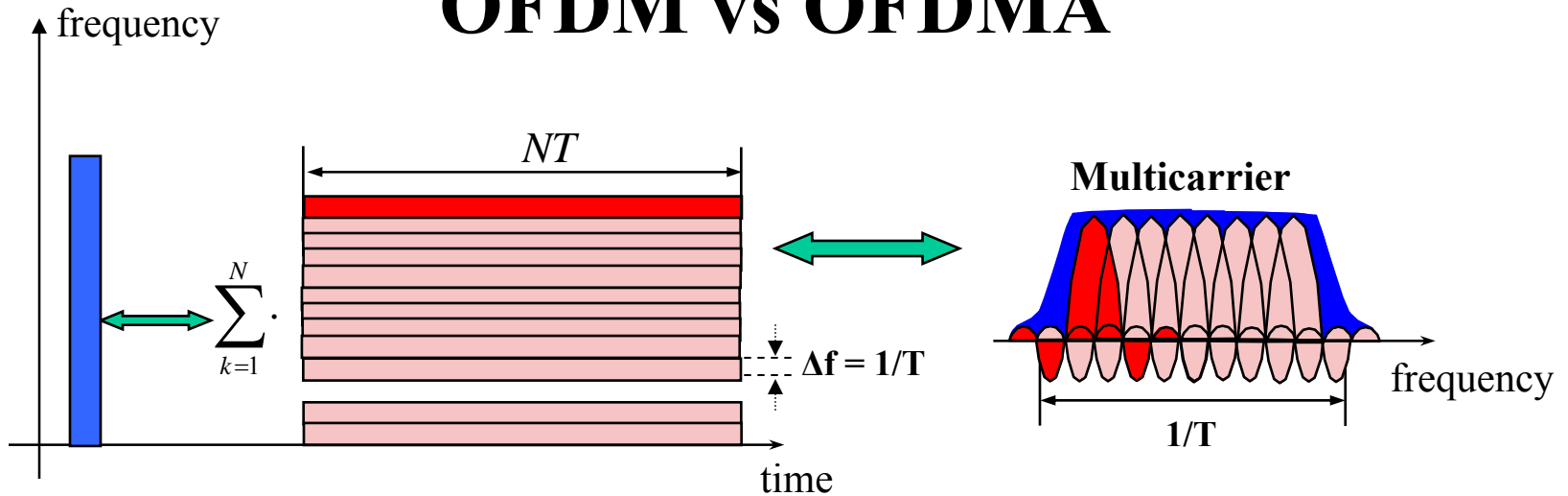
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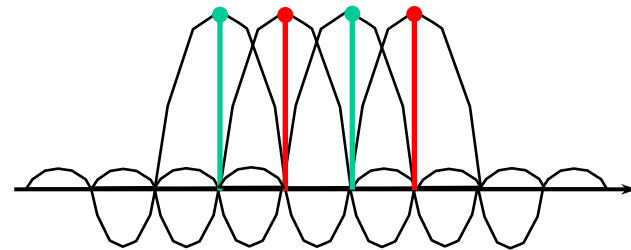
Abstract

This contribution will discuss the relationship between phase noise and subcarrier spacing for IEEE 802.22. The frequency requirements issues will be discussed as well.

OFDM vs OFDMA



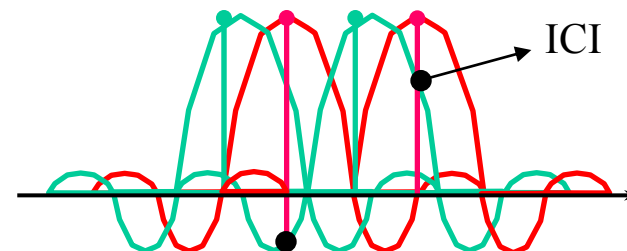
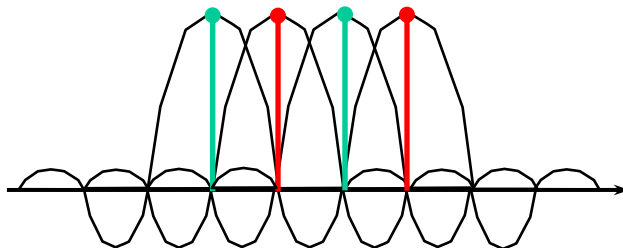
**One User uses all the Subcarriers
→ OFDM**



**Multiple Users share all the Subcarriers
→ OFDMA**

OFDM vs OFDMA

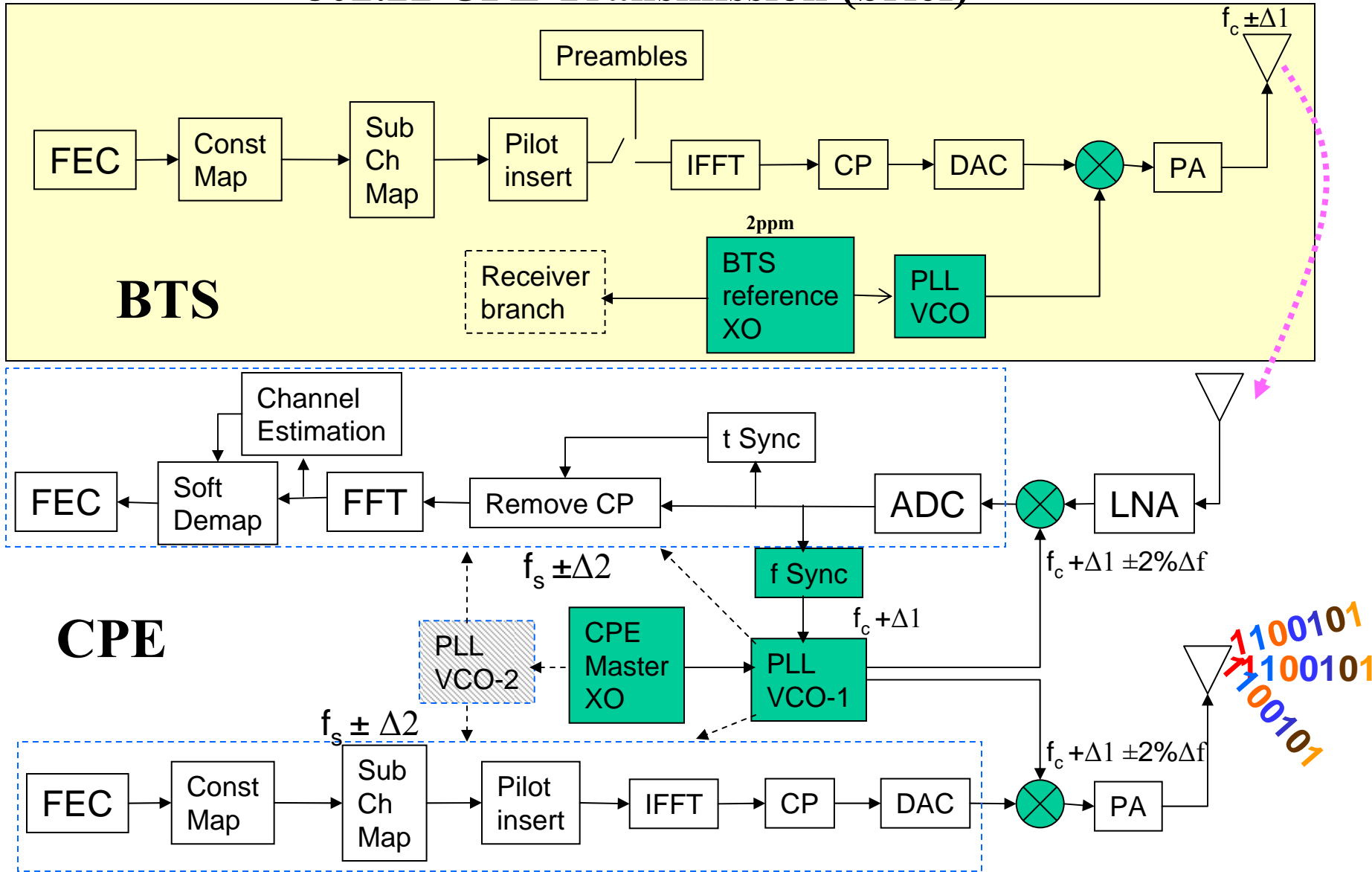
- **Both need tight synchronization**
 - Time synchronization
 - Frequency synchronization
 - Sampling clock accuracy
- **OFDMA for uplink is even tougher due to multiples devices involved**
 - Different oscillators cause Frequency asynchronous therefore non-orthogonality
 - Different oscillator phase noise profiles therefore ICI



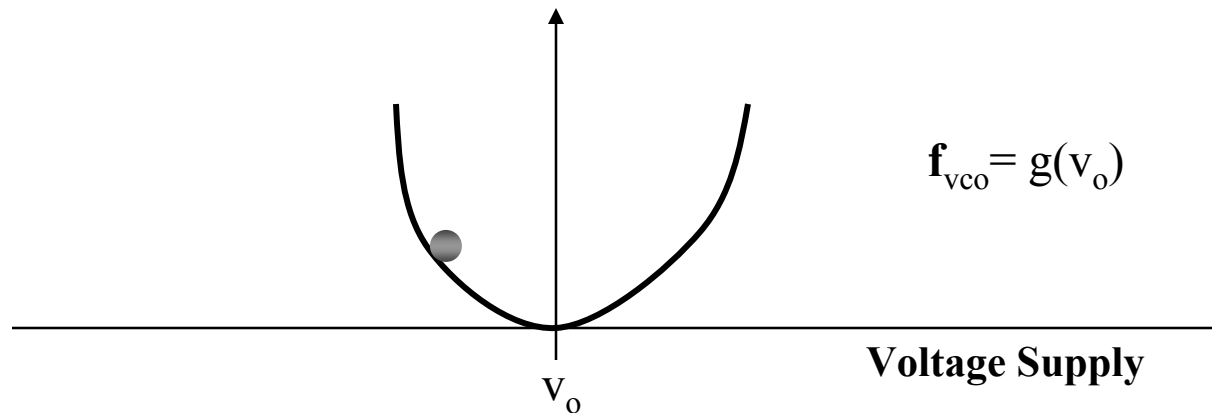
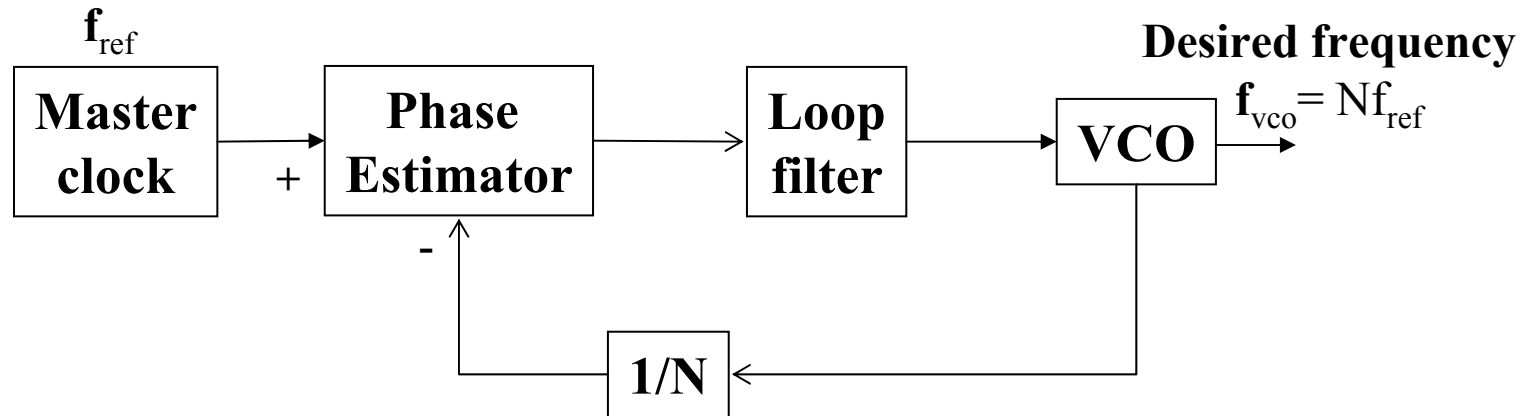
802.22 Frequency requirements and confusions

- **Center frequency and symbol clock frequency tolerance (refer 802.22 draft 2.0, clause 8.12.1)**
 - At the BS, transmitted center frequency, receive center frequency and symbol clock frequency shall be derived from the same reference oscillator
 - At BS, **reference frequency** tolerance shall be better than +/- 2 ppm
 - Note this seemed not limiting the frequency out of the transmitter?
 - If 10 MHz → ferror = fref x accuracy = 10 x 2 = +/- 20 Hz!
 - Suggested wording change: **At BS, reference frequency tolerance shall be better than +/- 2 ppm (?), the the modulated carrier frequency shall be accurate to within +/- Δf Hz.**
 - At the CPE, both the transmitted center frequency and the symbol clock frequency shall be synchronized and locked to the BS with a maximum tolerance of 2% of the subcarrier space denoted as Δf (refer: ETRI contribution doc# 204 in mentors)
 - Note that transmitted center frequency and symbol clock frequency are quite different in terms of implementation. Therefore they should be separately specified. So far we have agreed that: **At CPE, the transmitted center frequency shall be synchronized and locked to the BS with a maximum tolerance of 2% the subcarrier spacing; and the frequency of symbol clock shall be synchronized and locked to the BS (symbol clock frequency?) with a maximum tolerance of 2% the subcarrier spacing.** Refer **WiMAX Forum™ Mobile System Profile, 4 Release 1.0 Approved Specification, 5 (Revision 1.7.0: 2008-09-18)**, the 2 parameters are separately specified!
 - Is this 2% of subcarrier spacing for symbol clock accuracy good enough will be a separate issue! 66.96/6.68 MHz > 10 ppm!
 - Provide a separate number for clock frequency accuracy such as **(2% Δf)/carrier frequency.**

802.22 CPE Transmission (brief)

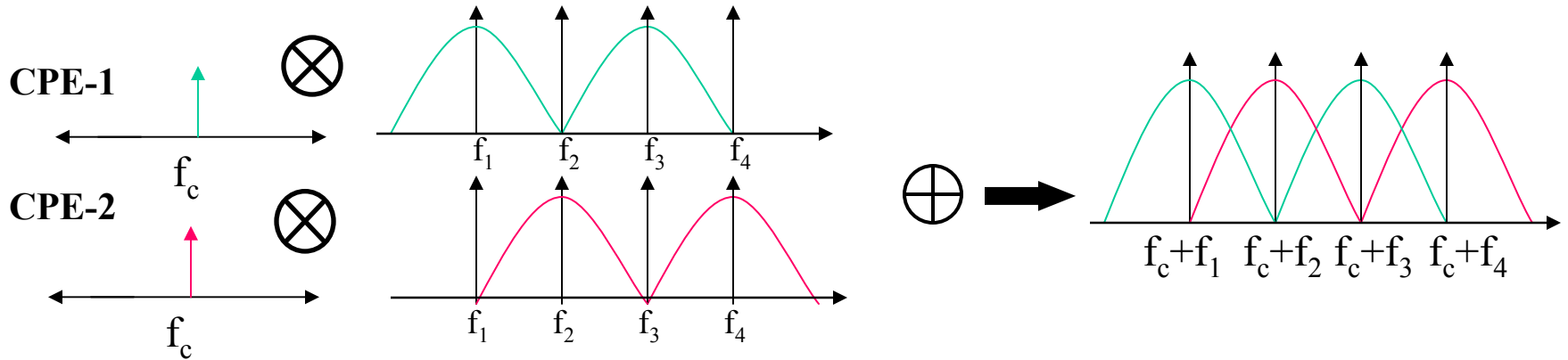


Basic PLL

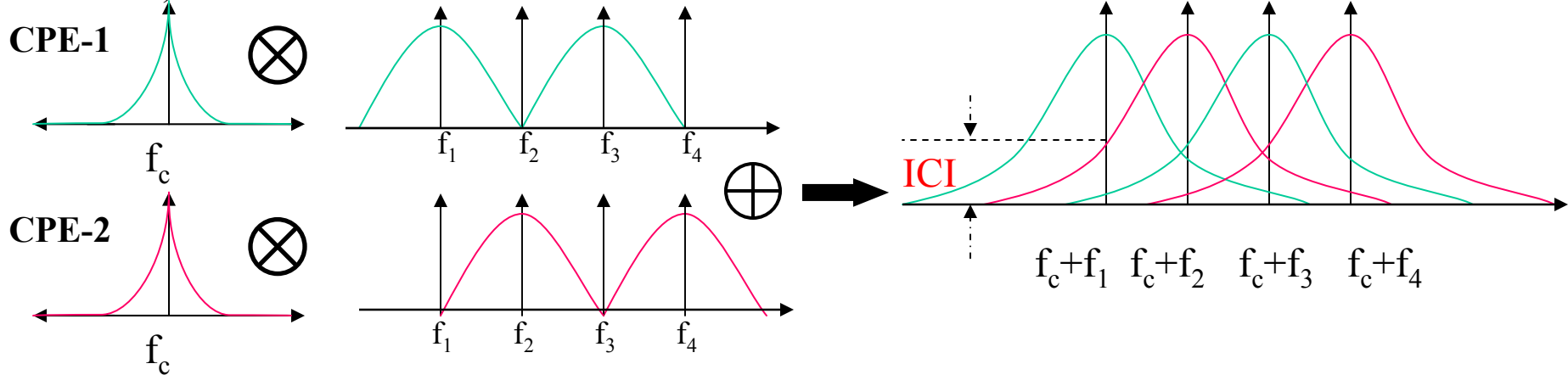


802.22 CPE Phase Noise

A) Ideal local oscillators

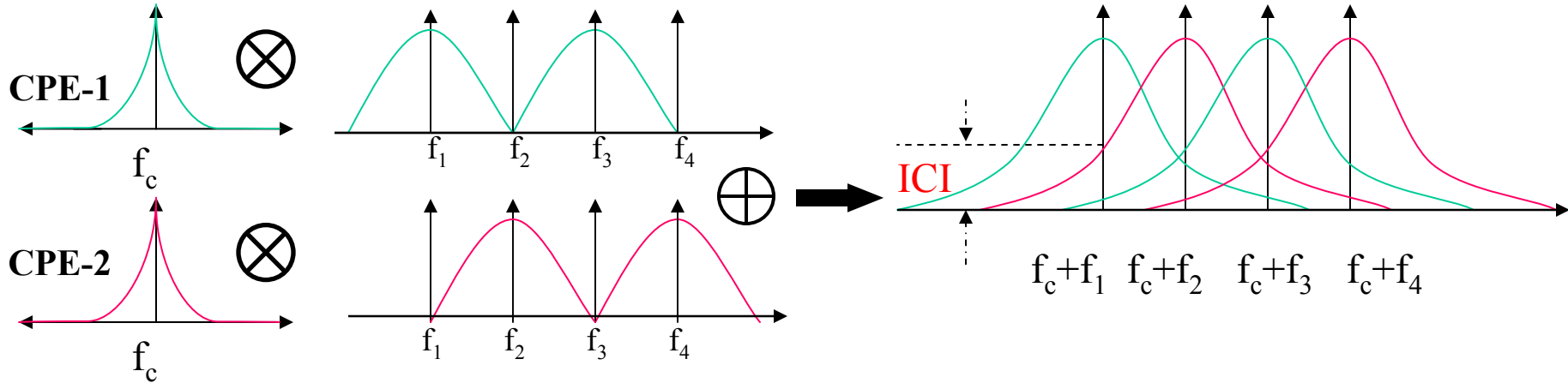


B) In Practice

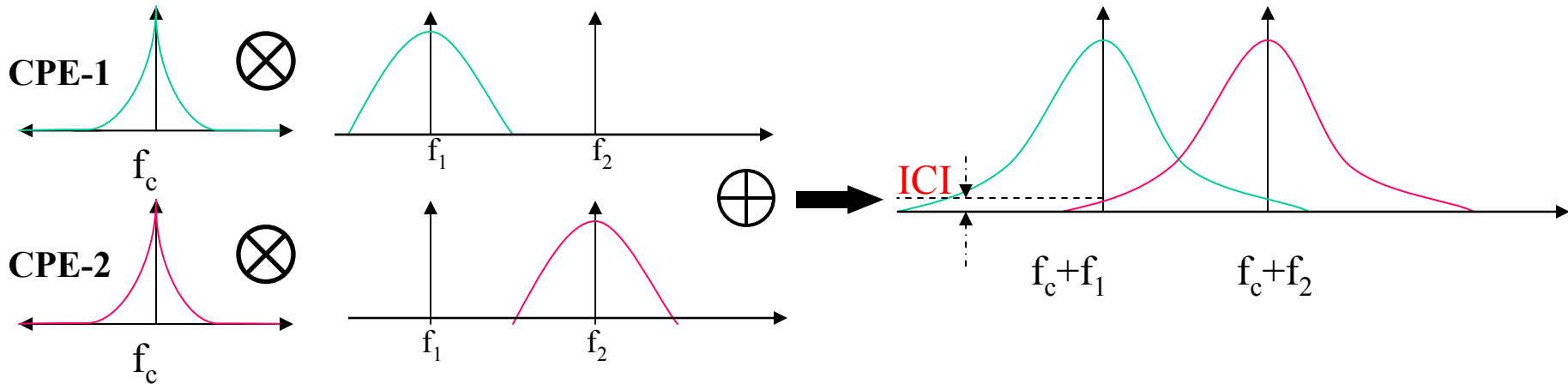


802.22 CPE Phase noise effect reduced when Δf larger

A) When using 4 subcarriers



B) Same bandwidth but only use 2 subcarriers



Phase Noise Model-I

- **Lorentian: phase noise spectrum density can be described as**

$$L(\delta f) = \frac{\pi f_{xo}^2 \gamma}{\pi (\pi f_{xo}^2 \gamma)^2 + \Delta f^2}$$

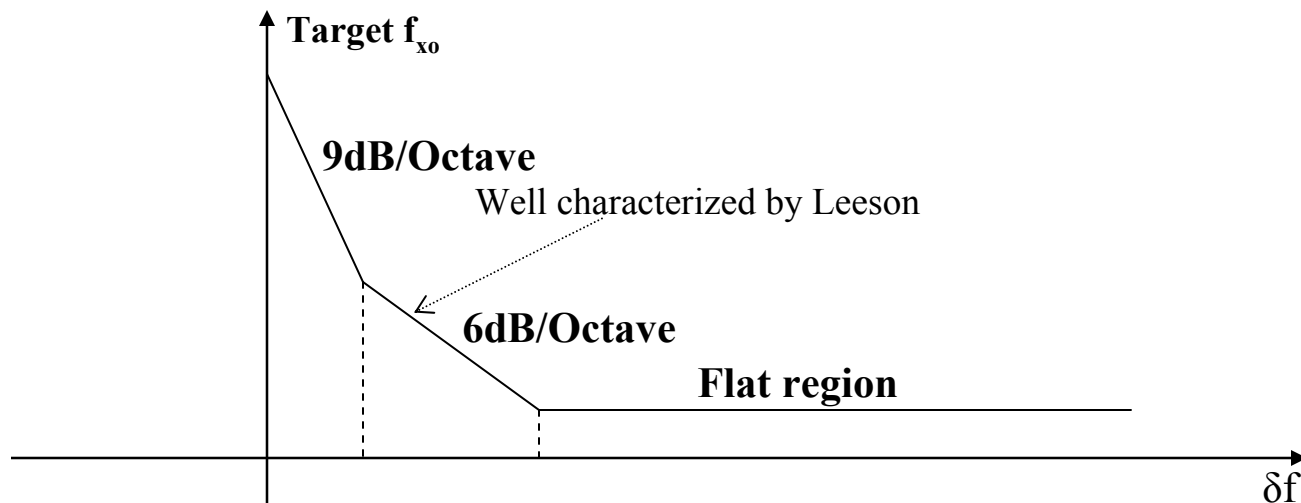
- Where $\delta f = f - f_{xo}$, f_{xo} is the desired frequency to generate, γ is the oscillator phase noise factor characterizing the oscillator
- **Line Width is defined the full bandwidth of the -3dB**
 - Which can be calculated as $BW_{3dB} = 2\sqrt{\pi \pi f_{xo}^2 \gamma}$

Phase Noise Model-II

- **Leeson's Model: Phase noise spectrum density**

$$L(\delta f) = \frac{F \kappa T}{A} \frac{1}{8 Q_L^2} \left(\frac{f_{x0}}{\delta f} \right)^2$$

- Where F is the device noise factor, κ is Boltzmann constant, T is the temperature, A is the oscillator output power, Q_L is a loaded Q and $\delta f = f - f_{x0}$.



802.22 Subcarrier Spacing Options

- Refer Gerald 22-06-0264-10-000-ofdma-parameters.xls and Robert 22-09-0137-01-0000-unification-of-sampling-rates-for-the-three-tv-bandwidths.doc
- Now they are all integer cycles!

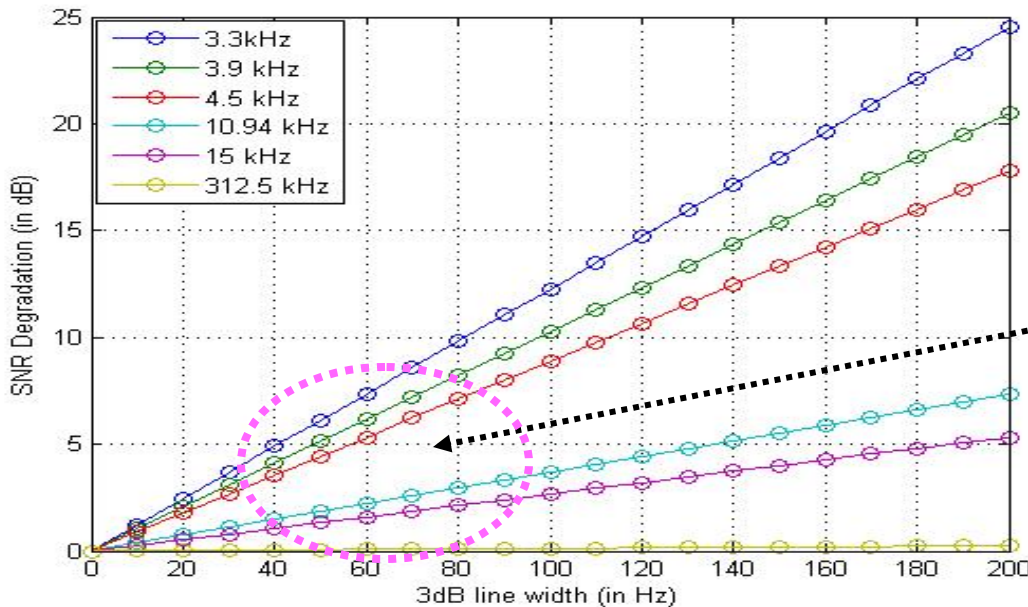
TV band	6 MHz	7 MHz	8 MHz
Subcarrier	6.68/2048 =	8/2048 =	9.22/2048 =
Space Δf	3.310546875 kHz	3.90625 kHz	4.501953125 kHz

SNR reduction due to phase noise

- OFDM/OFDMA SNR loss due to phase noise

$$L_{SNR} = -10 \log \left(\frac{SNR_{withici}}{SNR_{withoutici}} \right) \approx \left(\frac{10}{\ln 10} \frac{11}{60} \left(4\pi \frac{BW_{3dB}}{\Delta f} \right) \right) SNR_{withoutici}$$

- Suppose $SNR_{withoutici} = 40$ dB



Interested region?

Conclusions and recommendations

- **Use Sampling clock 8 MHz to unify all sampling clocks for 6 MHz, 7 MHz and 8 MHz channels**
- **Provide the following 3 physical-layer configuration Options for US**
 - 1k FFT mode
 - OFDM + round Robin for US
 - Consecutive subcarrier allocation with 6 band $1680/8 = 210$ subcarriers per band!

References

- Denis Petrovic, Wolfgang Rave, Gerhard Fettweis, Performance Degradation of Coded-OFDM due to Phase Noise, VTC Spring 2003
- Pollet et al, BER Sensitivity of OFDM Systems to Carrier Frequency Offset and Wiener Phase Noise, *IEEE TRANSACTIONS ON COMMUNICATIONS*, VOL. 43, NO. 2/3/4, FEBRUARY/MARCH/APRIL 1995
- IEEE 802.22 draft version 2.0
- IEEE 802.16, Part 16: Air Interface for Broadband Wireless Access Systems, P802.16Rev2/D5 (June 2008)
- WiMAX Forum™ Mobile System Profile, 4 Release 1.0 Approved Specification, 5 (Revision 1.7.0: 2008-09-18)