Phase Noise and Subcarrier Spacing

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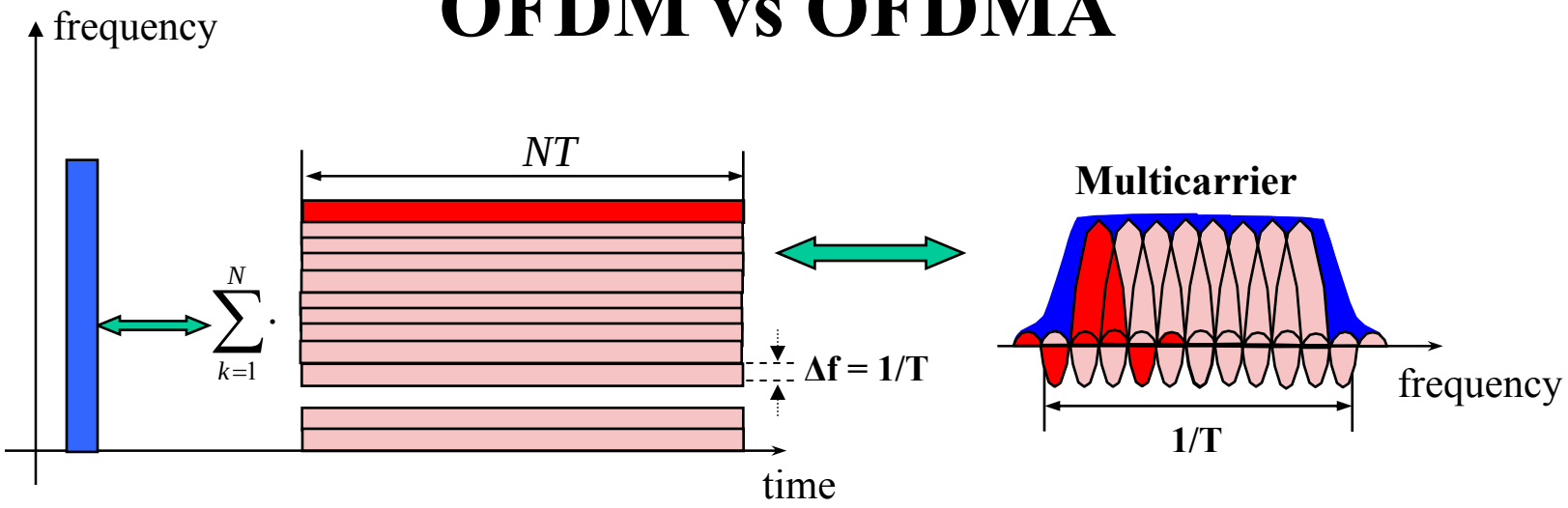
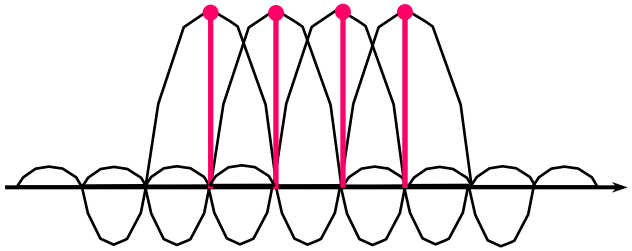
Abstract

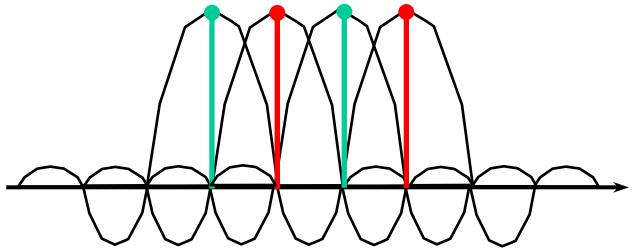
This contribution will discuss the relationship between phase noise and subcarrier spacing for IEEE 802.22. The frequency requirements issues will be discussed as well.

OFDM vs OFDMA





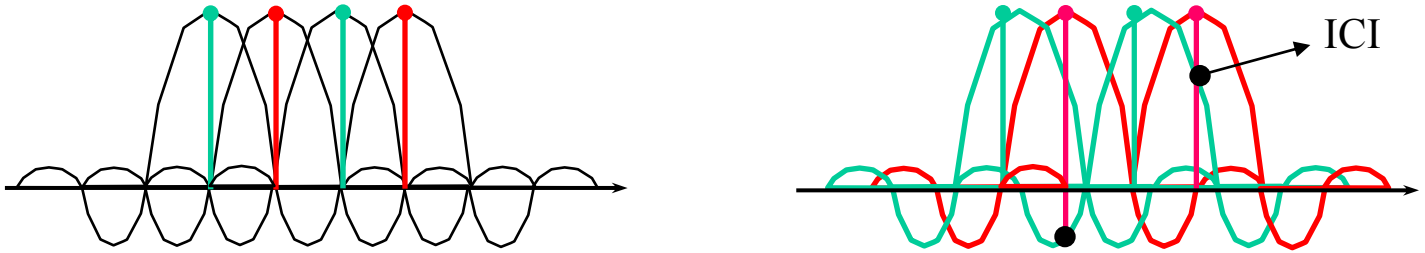
One User uses all the Subcarriers
➔ OFDM



Multiple Users share all the Subcarriers
➔ OFDMA

OFDM vs OFDMA

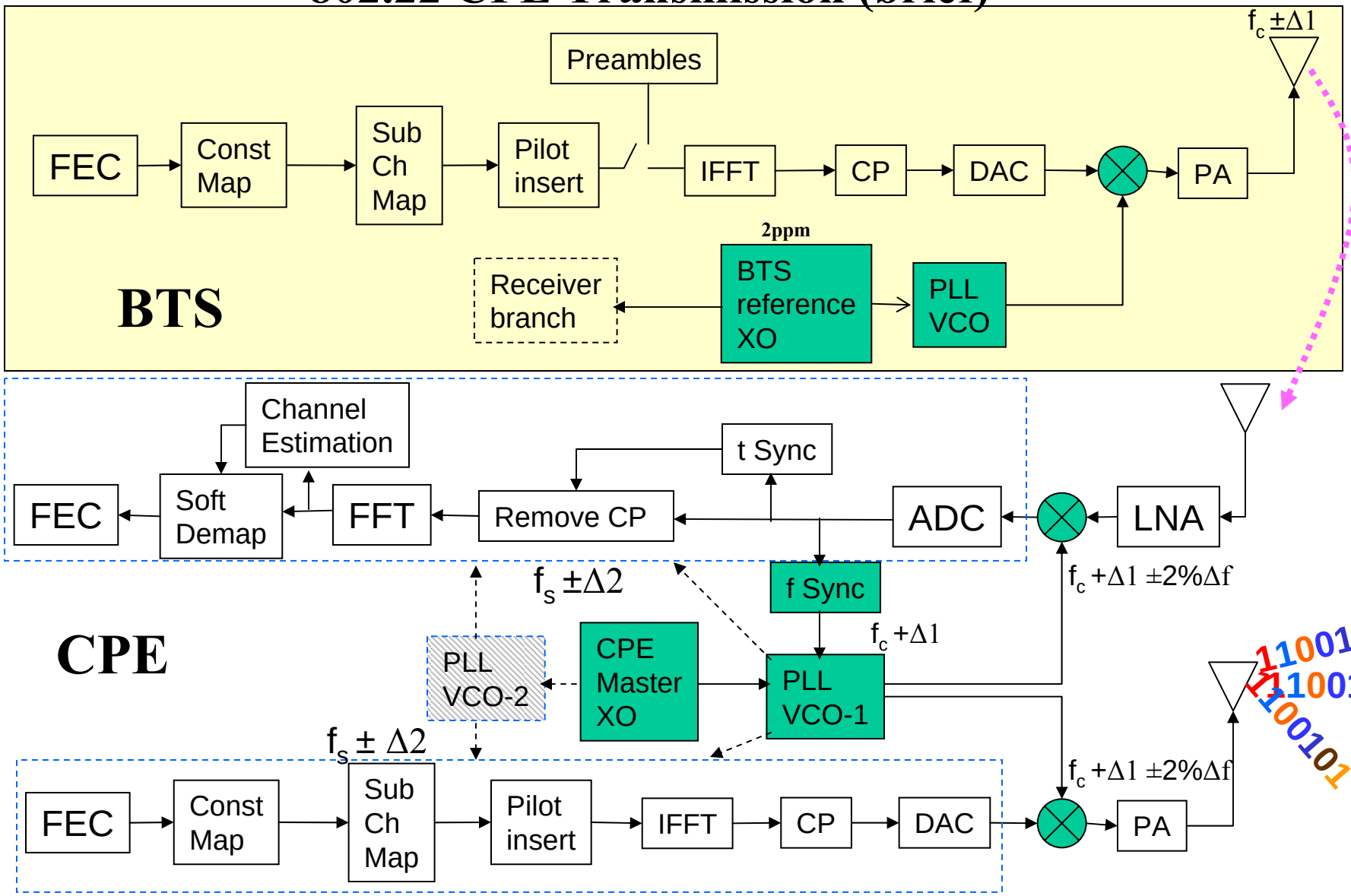
- **Both need tight synchronization**
  - Time synchronization
  - Frequency synchronization
  - Sampling clock accuracy
- **OFDMA for uplink is even tougher due to multiples devices involved**
  - Different oscillators cause Frequency asynchronous therefore non-orthogonality
  - Different oscillator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



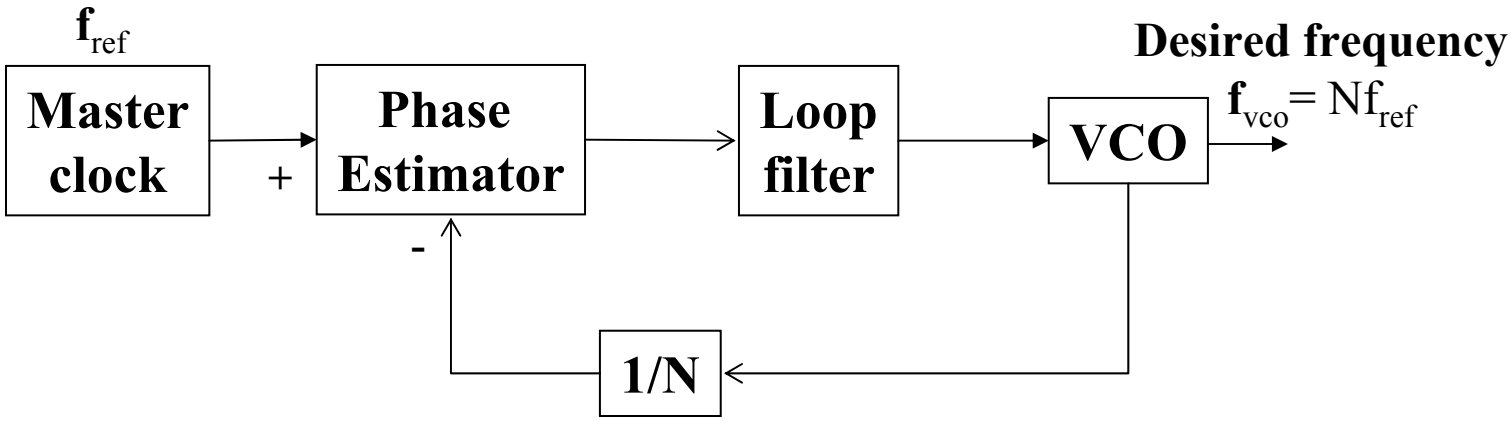
802.22 Frequency requirements and confusions

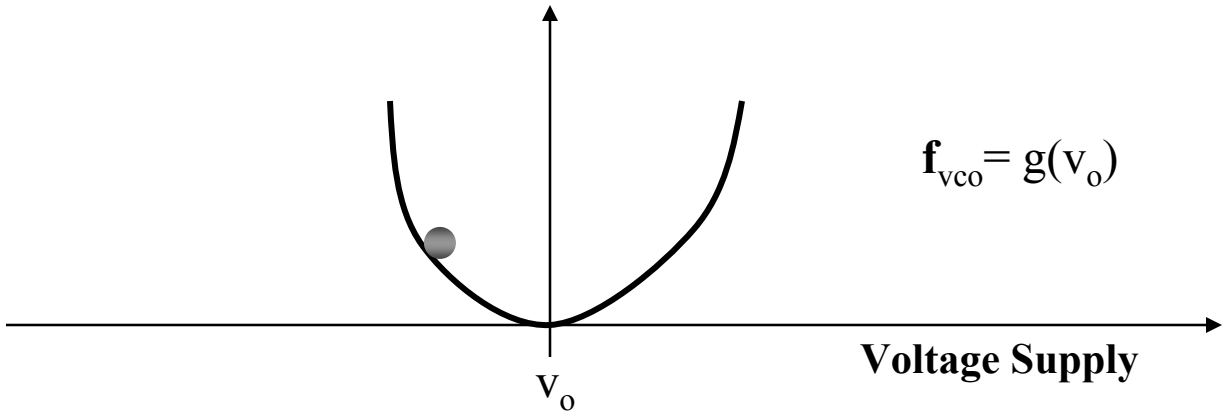
- **Center frequency and symbol clock frequency tolerance (refer 802.22 draft 2.0, clause 8.12.1)**
  - At the BS, transmitted center frequency, receive center frequency and symbol clock frequency shall be derived from the same reference oscillator
  - At BS, reference frequency tolerance shall be better 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 +/- Δ1 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)



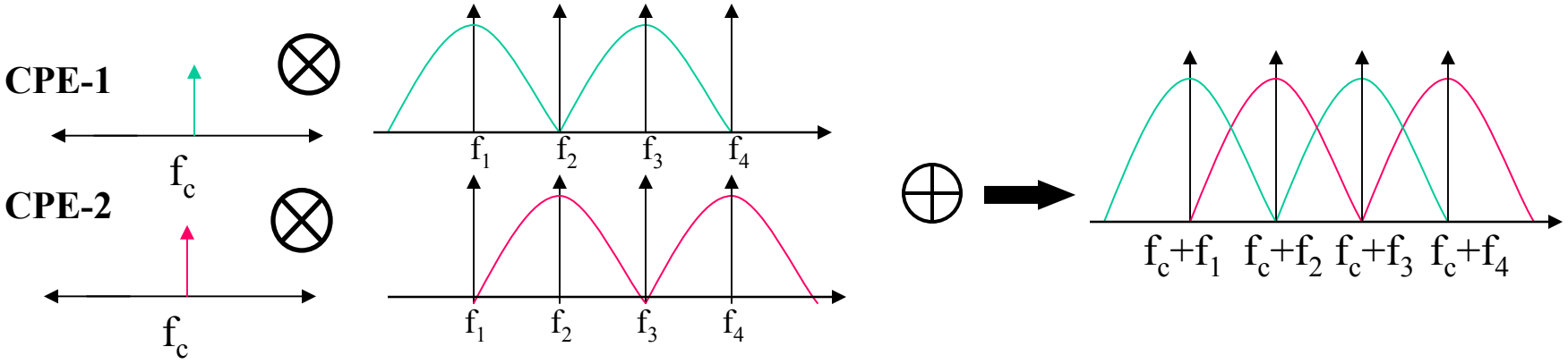
Basic PLL


f_{ref}
Master clock
+
Phase Estimator
-
Loop filter
VCO
Desired frequency
$f_{vco} = Nf_{ref}$
1/N

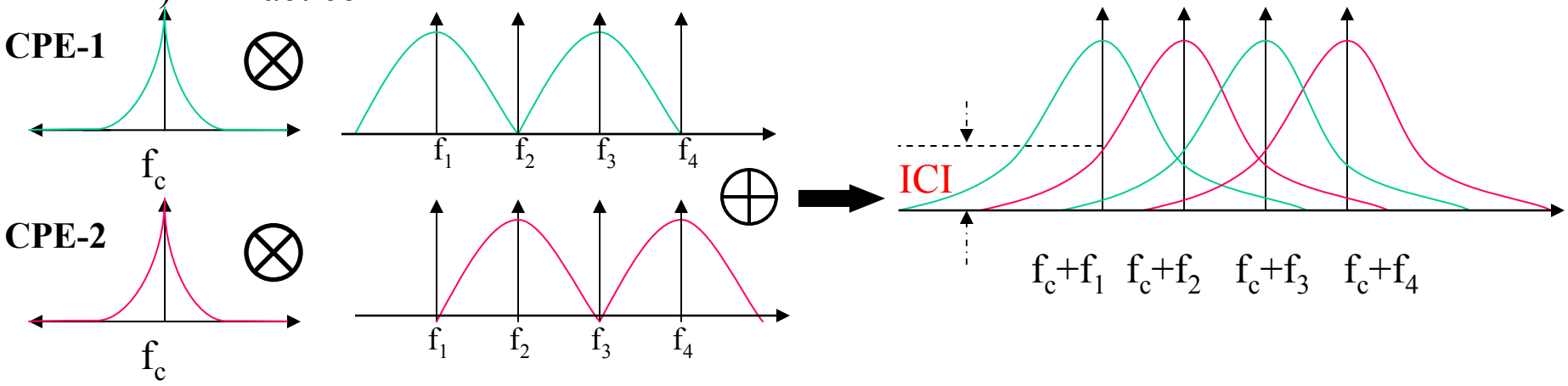

$f_{vco} = g(v_o)$
Voltage Supply
v_o

802.22 CPE Phase Noise

A) Ideal local oscillators

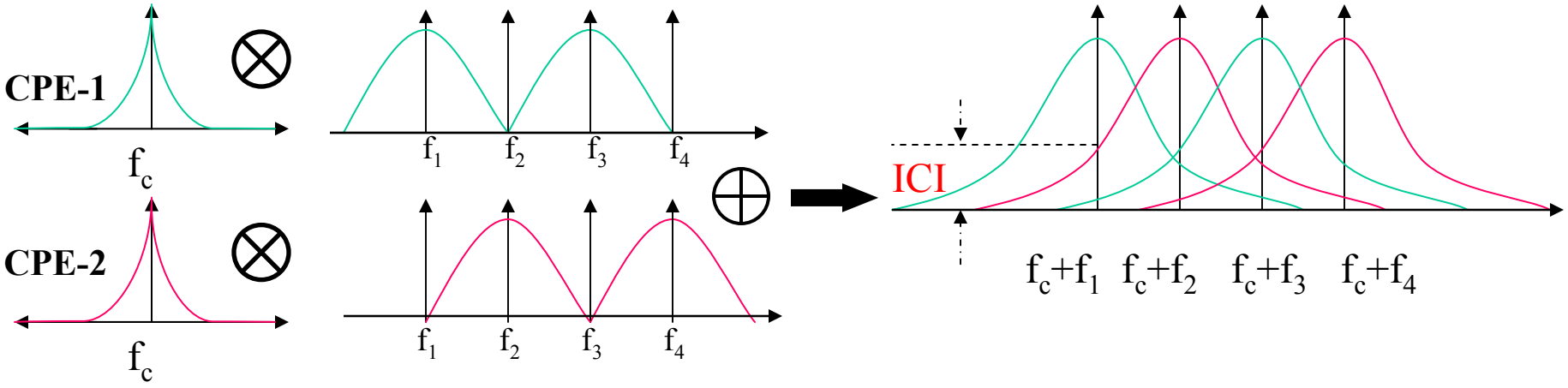


B) In Practice

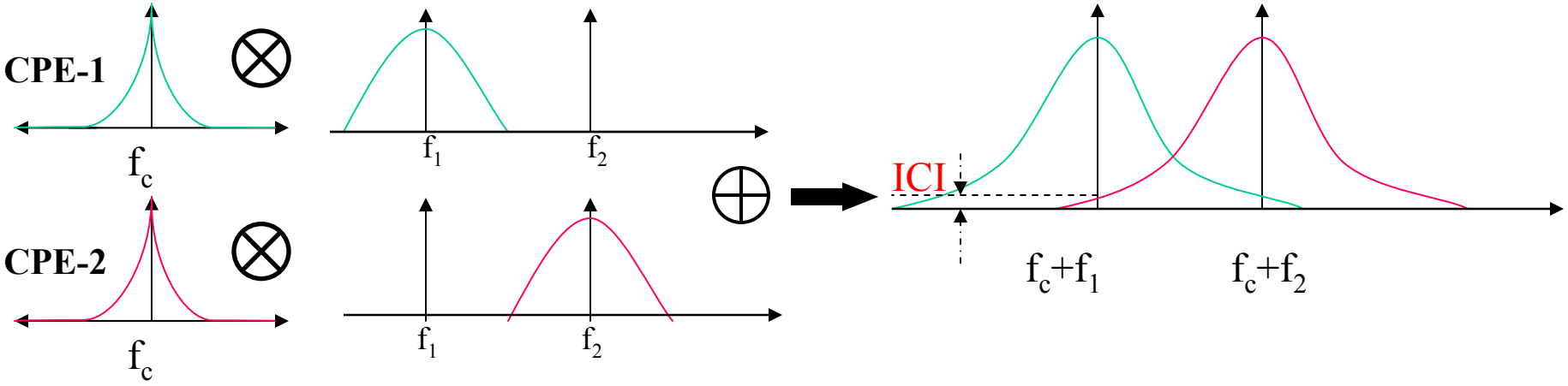


802.22 CPE Phase noise effect reduced when Δf larger

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**

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

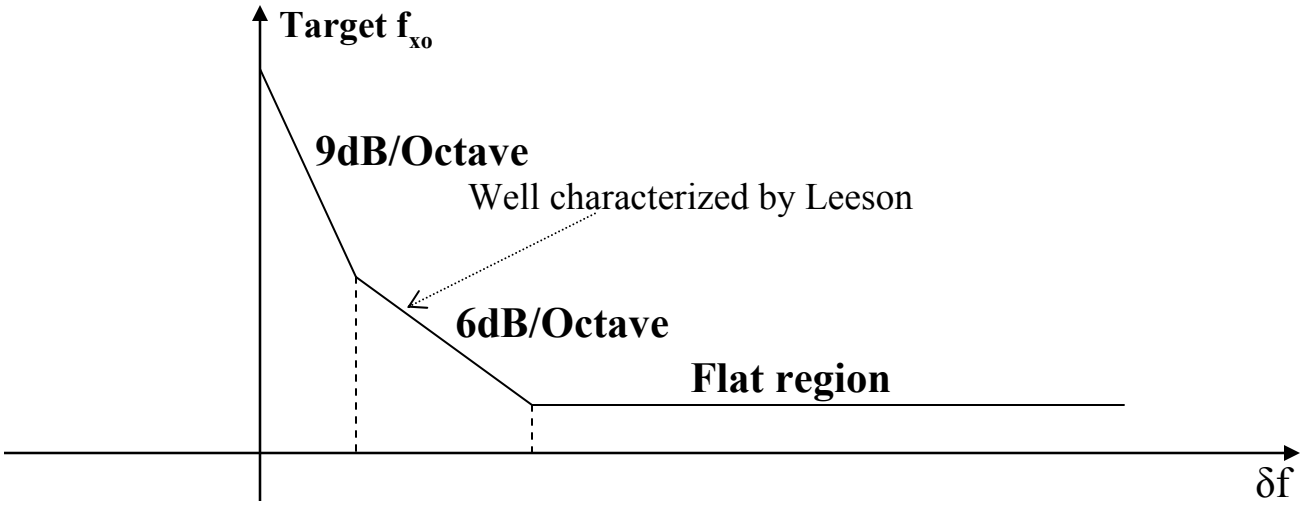
  - Where $\delta f = f - f_{xo}$, f_{xo} is the desired frequency to generate, γ is the oscillator phase noise factor characterizing the oscillator
- **Line Width is defined the full bandwidth of the -3dB**
  - Which can be calculated as $BW_{3dB} = 2\sqrt{\pi}\pi f_{xo}^2 \gamma$

Phase Noise Model-II

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

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

  - 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 $\delta f = f - f_{xo}$.



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!**

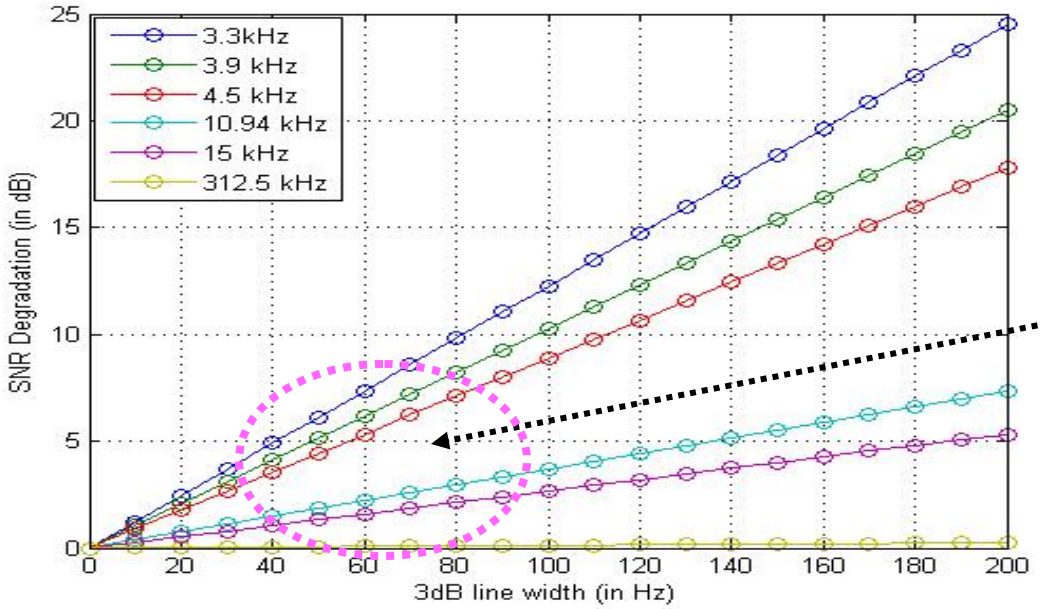
TV band	6 MHz	7 MHz	8 MHz
Subcarrier Space Δf	6.68/2048 = 3.310546875 kHz	8/2048 = 3.90625 kHz	9.22/2048 = 4.501953125 kHz

SNR reduction due to phase noise

- **OFDM/OFDMA SNR loss due to phase noise**

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

- **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)