Introduction

- **Constant Envelope (CE) multicarrier modulations** (CE-OFDM and CE-SCFDMA) represent interesting alternative waveforms for satellite communications;

- Indeed, they would allow to **exploit the benefits of multicarrier modulations** without sacrificing power resources in terms of high input-back off (IBO): **their PAPR is fixed to 0 dB;**

- CE multicarrier modulations are obtained **by applying a non-linear phase modulation to a real-valued OFDM or SC-FDMA signal,** normalized with respect to its amplitude [8-10].

Constant-Envelope Multicarrier Signal Generation

Procedure

$$\{S_1,\ldots,S_N\}$$

Complex symbol sequence (M^2-QAM constellation or DFT-precoded symbols)

$$\underline{\hat{S}} = \left[0, S_1, \ldots, S_N, \underline{Z}, 0, S_N^*, \ldots, S_1^*\right]$$

Conjugate-symmetric zero-padded (oversampled) sequence

I-FFT

$$u(t) = 2\sum_{k=1}^{N} \Re\{S_k\}\cos(2\pi kt/T) - \Im\{S_k\}\sin(2\pi kt/T)$$

Real-valued OFDM (SC-FDMA) signal

PM

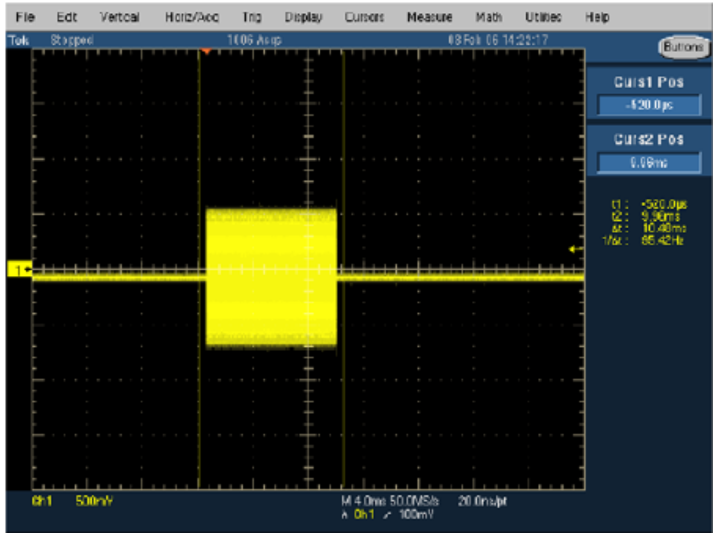
$$x(t) = A_c \,\mathrm{Re}\left\{\exp j\left[2\pi f_c t + 2\pi h \Lambda u(t)\right]\right\} \quad -T_{CP} \le t \le T$$

CE-OFDM (CE-SCFDMA) signal

CE multicarrier signal properties

Time

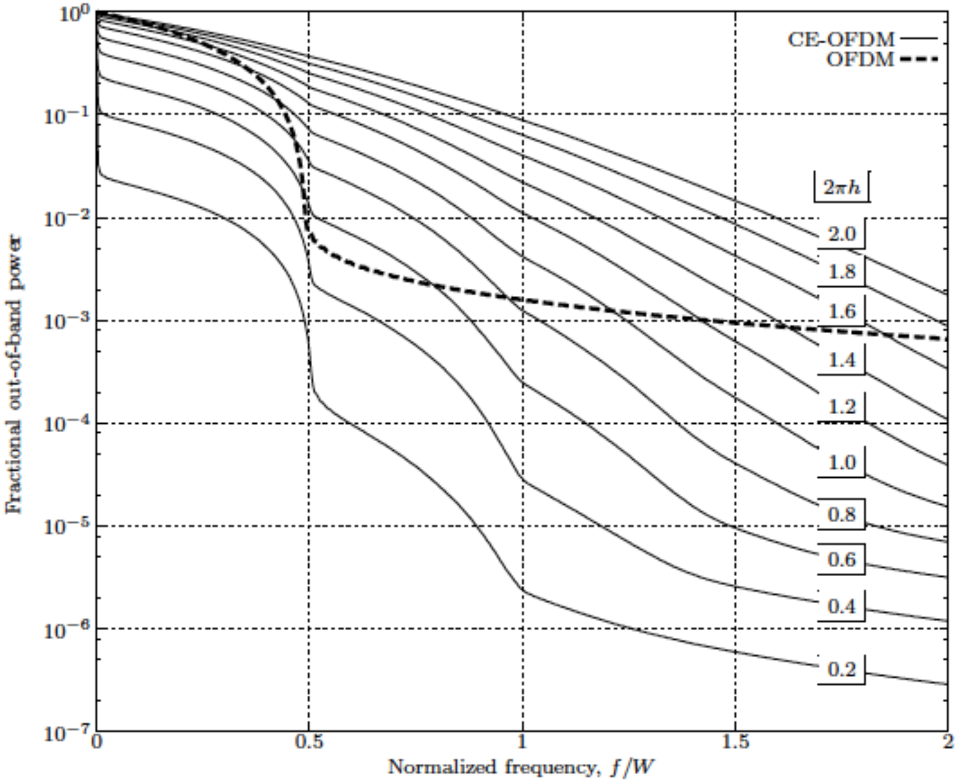
OFDM signal (high PAPR) (courtesy by [8])



CE-OFDM signal (0dB PAPR) (courtesy by [8])

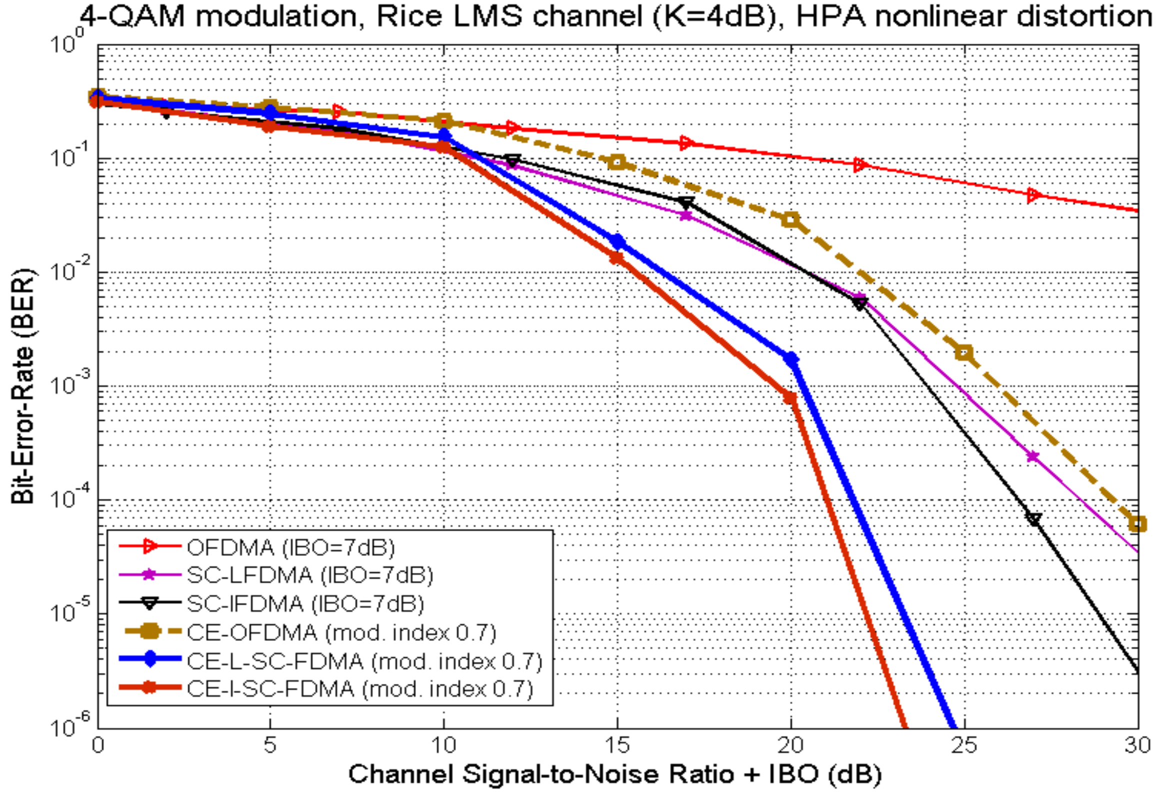
$$B_{CE} = W \max\left\{2\pi h, 1\right\} \quad W = 2N / T$$

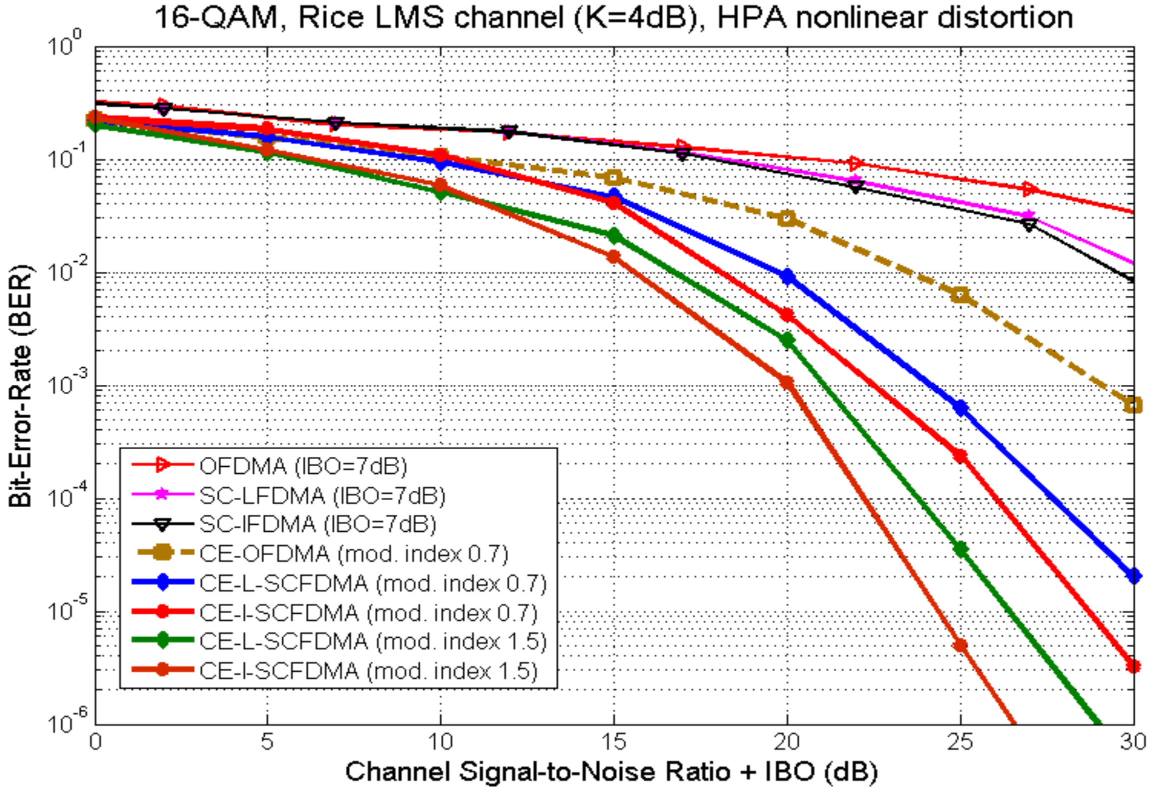
Frequency



Fractional out-of-band power (courtesy by [9])

CE multicarrier performance evaluation (see [10])





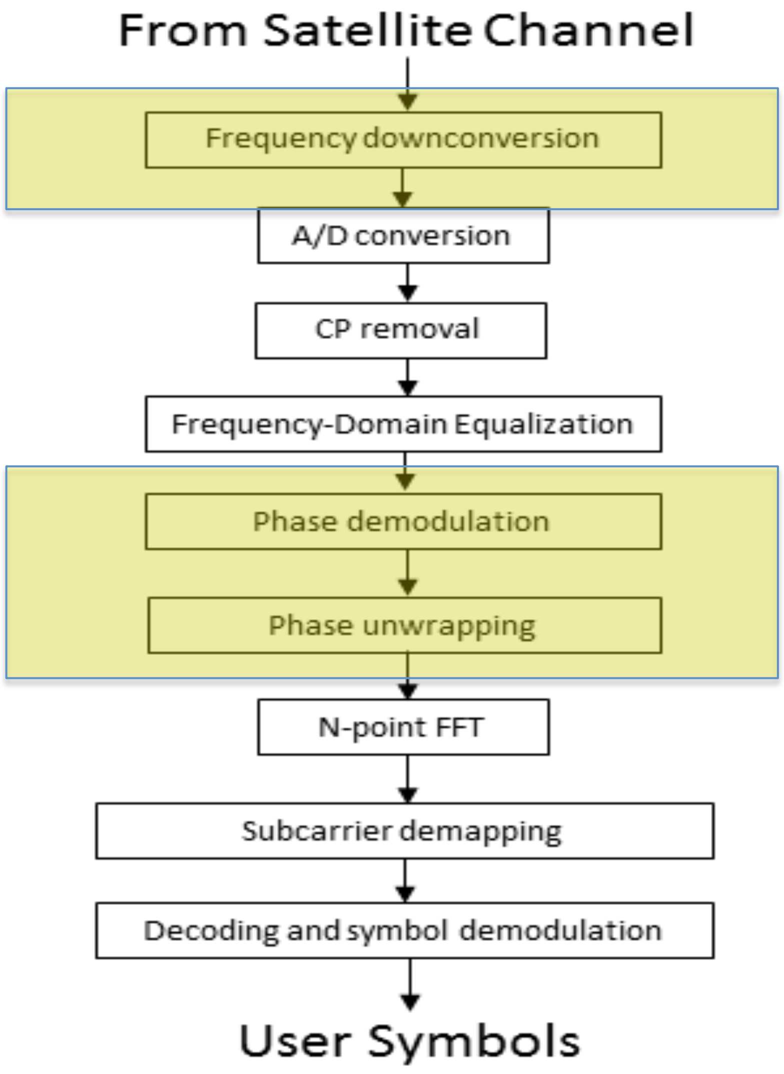
The two plots (taken by [10]) evidence that the increase of bandwidth (more than 3dB) w.r.t. conventional multicarrier techniques turns on a a great improvement of power efficiency -> **higher capacity!!**

CE multicarrier modulation: phase-noise impact (1)

- In [8-10], the impact of phase-noise on CE multicarrier modulations performance was not investigated;

- This is a big issue, in particular when broadband mm-wave satellite applications are considered!

PHASE NOISE IMPACTS ON THE DETECTION STAGES HIGHLIGTED IN YELLOW



CE multicarrier modulation: phase-noise impact (2)

- Some analytical insights:

$$r(t) = A\exp\left\{j\left(2\pi h\Lambda u(t)+\phi_n(t)\right)\right\}+z(t) \qquad \Lambda=\sqrt{2/N\sigma^2_{M-PAM}}$$

Low-pass equivalent received signal (AWGN channel + phase-noise)

$$\hat{\varphi}(t)=\varphi(t)+\phi_n(t)+\vartheta(t) \qquad \vartheta(t)=arctg\left(\frac{A_z(t)\sin\left(\Phi_z(t)-\varphi(t)-\phi_n(t)\right)}{A+A_z(t)\sin\left(\Phi_z(t)-\varphi(t)-\phi_n(t)\right)}\right)$$

$$\varphi(t)=2\pi h\Lambda u(t)$$

Output of phase-detector

$$\hat{\mathrm{A}}(k)=\left(2\pi h\right)\frac{\Lambda}{2}\mathrm{I}\left(k\right)+\Phi\left(k\right)+\Theta\left(k\right) \qquad \mathrm{var}\left(\Theta\left(k\right)\right)\approx\frac{1}{T}\frac{N_0}{A^2} \qquad \mathrm{var}\left(\Phi\left(k\right)\right)\approx\frac{1}{T}S_\phi\left(\frac{k}{T}\right)$$

Output of matched filter receiver related to subcarrier *k*

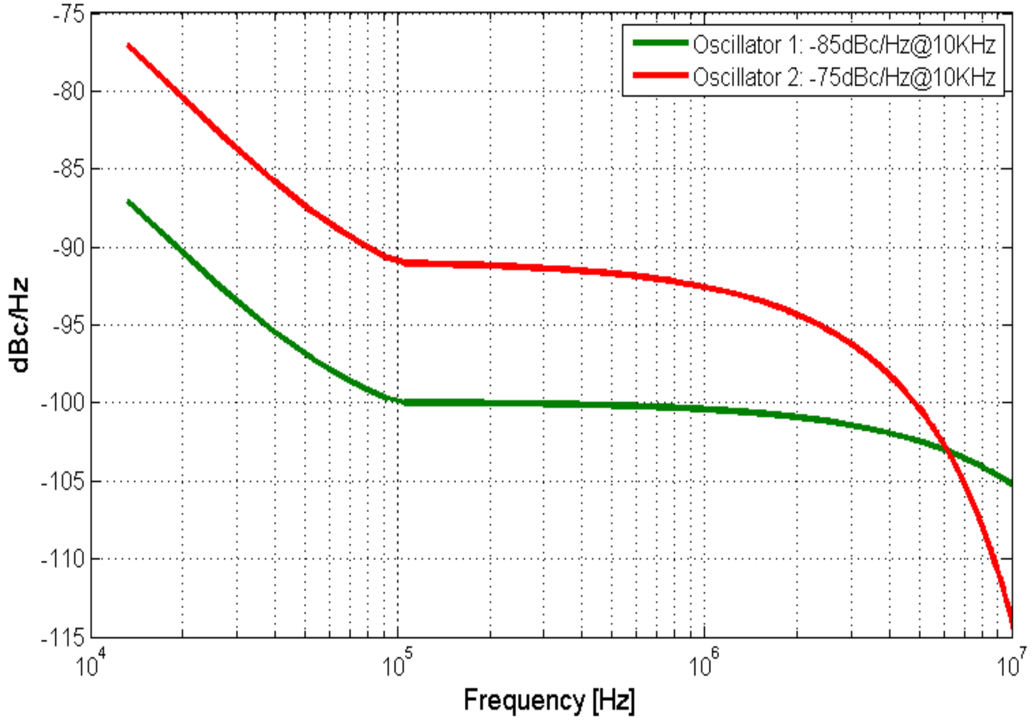
Simulation setup

- DVB-S2 standard configuration

Parameter	Value
Available bandwidth (B_{CE})	33 MHz
Oversampling factor (F_O)	4
Total number of subcarriers (N_S)	512
Symbol vector length (N)	63
Number of users (U)	4
Size of user symbol block (B)	15 symbols

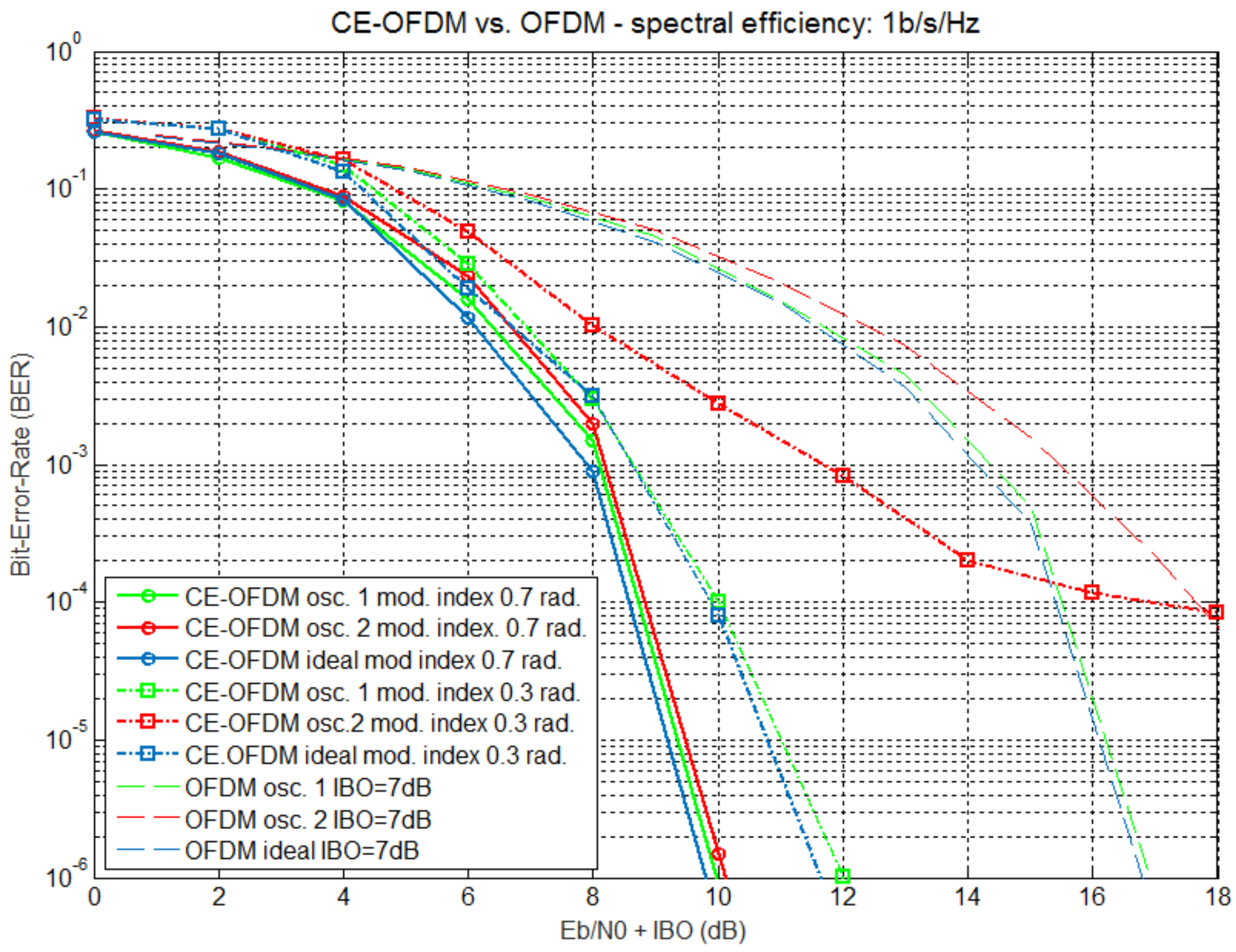
- *Multipath effects neglected*;
- *Nonlinear amplification* (HPA modeled with Saleh's model, IBO>=7dB);
- *Modulation constellations:* 4-QAM and 16-QAM, angular modulation index <=1.0 rad.

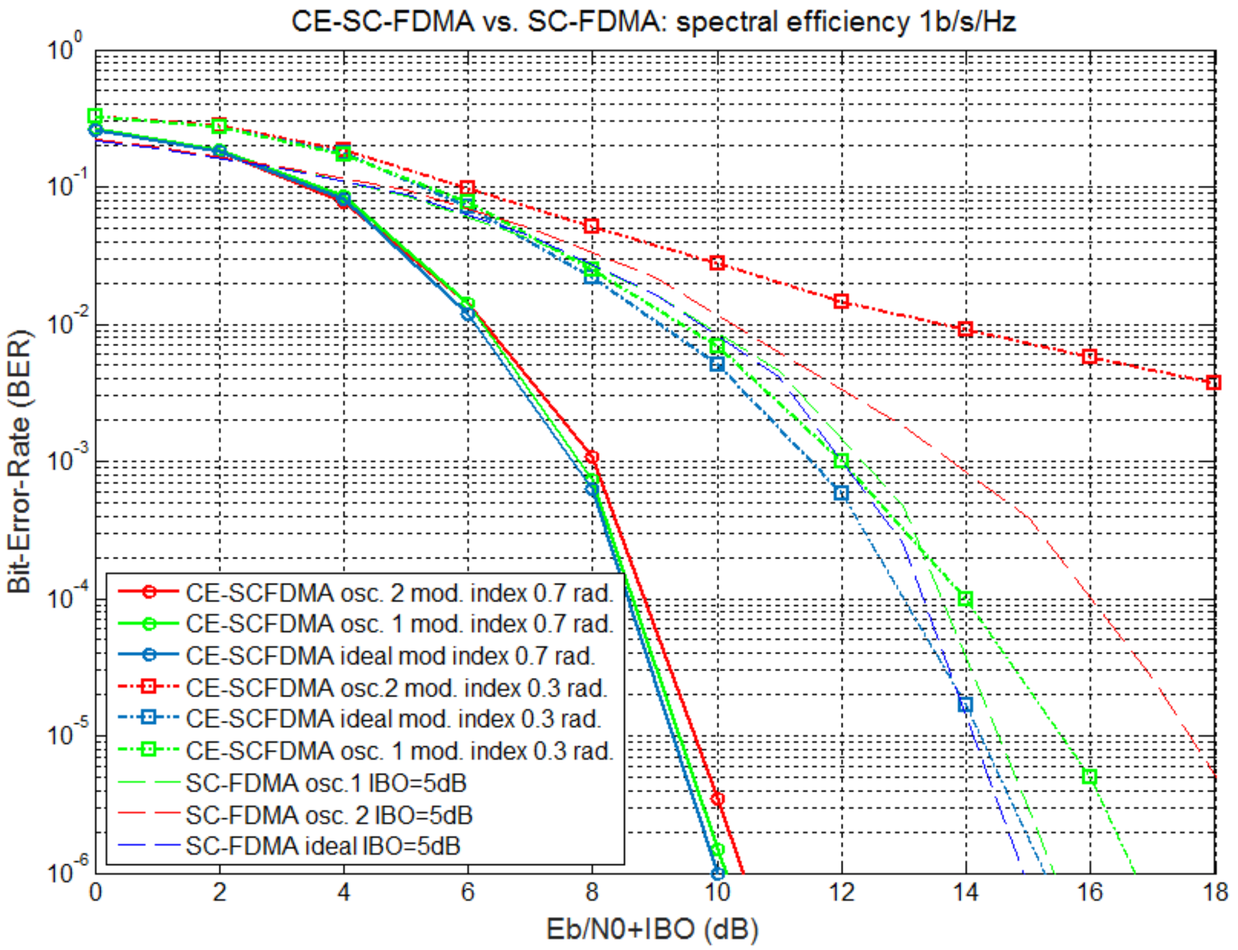
MATLAB simulations



Phase noise masks

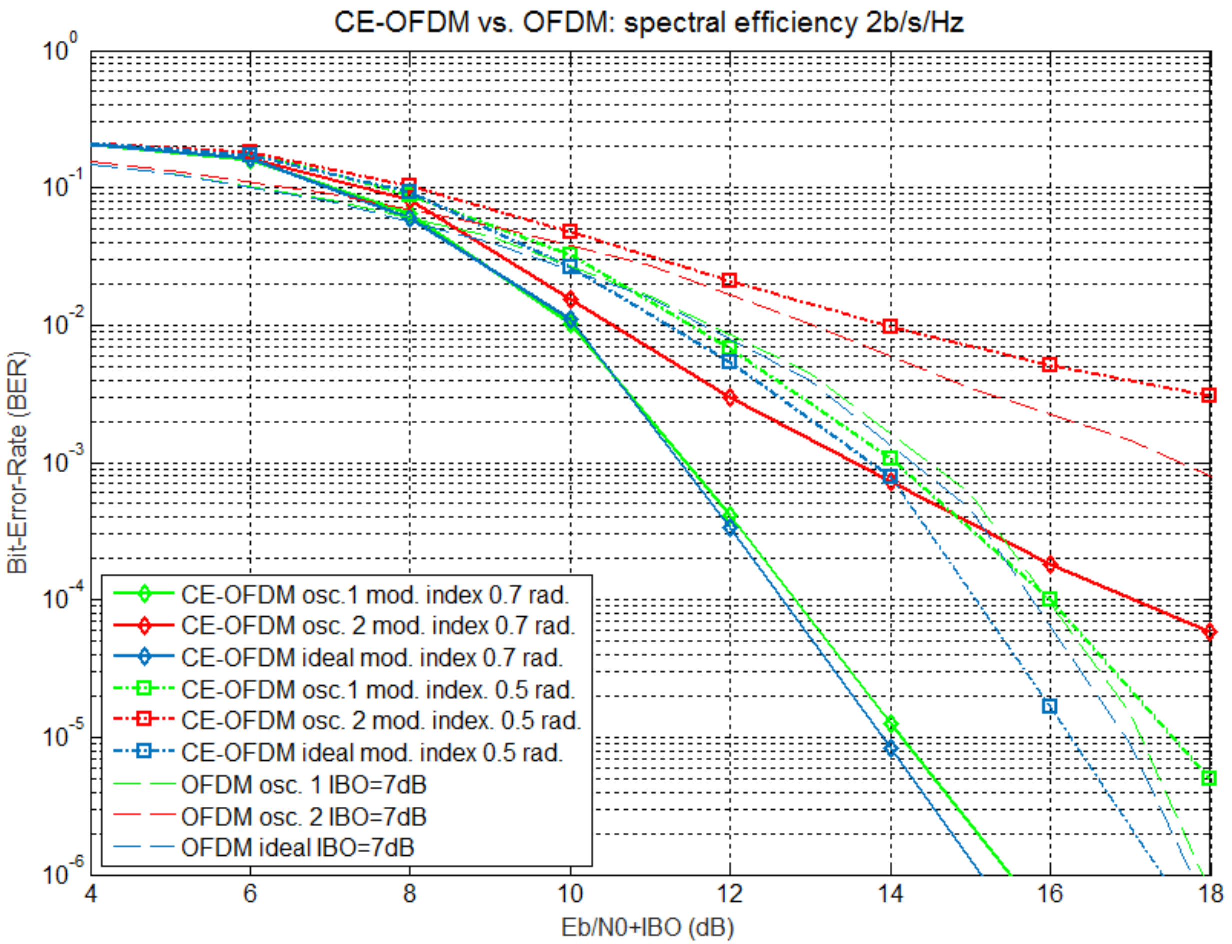
Simulation results (4-QAM, eff. 1b/s/Hz)

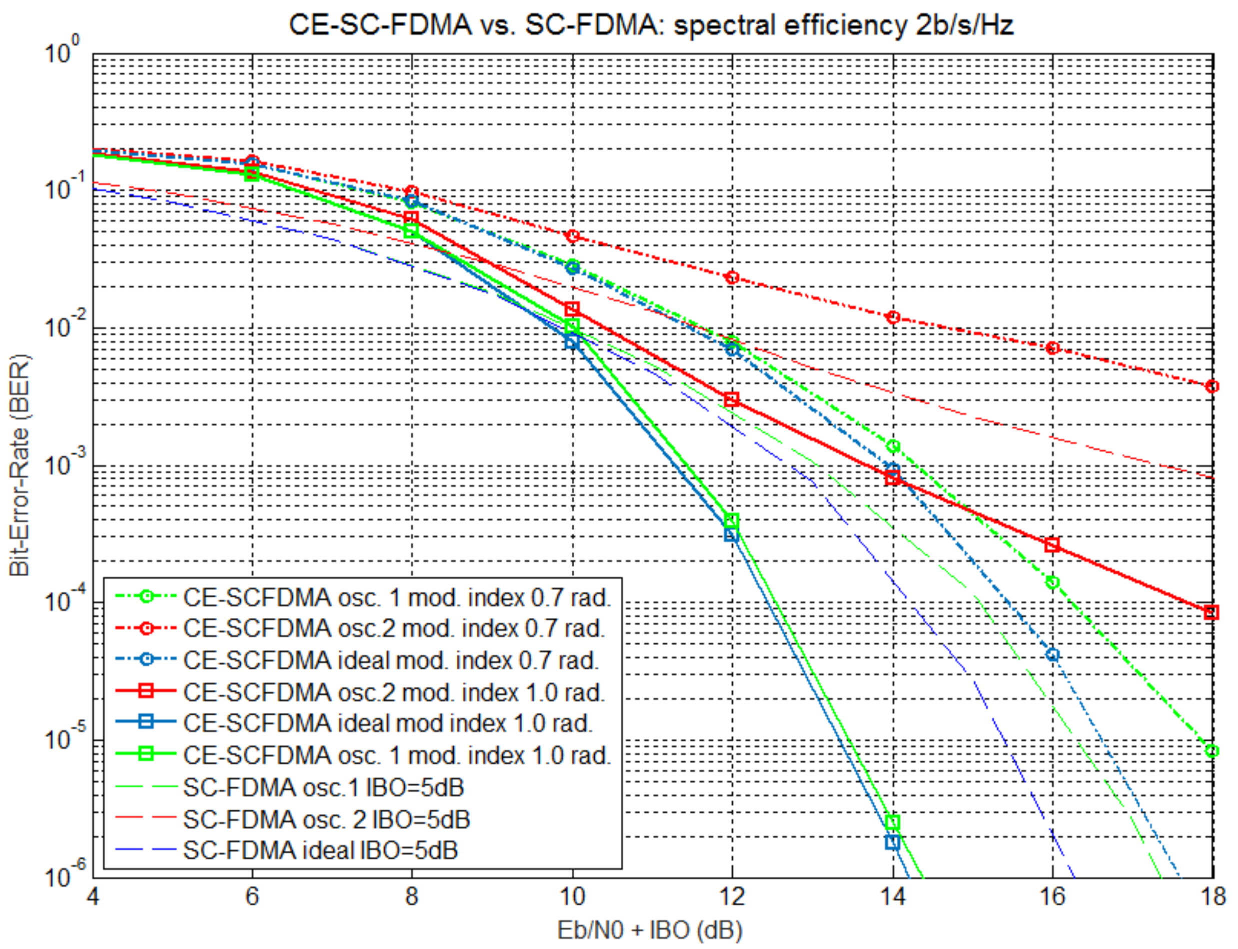




NOTICE: OFDM and SC-FDMA have used a **BPSK** modulation

Simulation results (16-QAM, eff. 2b/s/Hz)





NOTICE: OFDM and SC-FDMA have used a **4-QAM** modulation

Conclusion

- The impact of phase noise on constant envelope multicarrier transmission techniques has been analyzed by means of simulations;
- Simulation results evidenced that CE-OFDM and CE-SC-FDMA are quite robust against moderate levels of phase noise, provided that the modulation index is properly chosen;
- High level of phase noise can involve an irreducible error-floor also on CE multicarrier waveforms, in particular for higher order modulations;
- The comparison with regular OFDM and SC-FDMA is globally in favor to CE techniques, due to their inherent resilience to nonlinear distortions.