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Waveforms comparison results on a generic LDPC chain with Non Linearities

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Introduction

- Optimization of the satellite payload regarding system constraints is an important point
  - A trade off has to be done between Back off of the amplifier(s) and wanted intermodulation products power

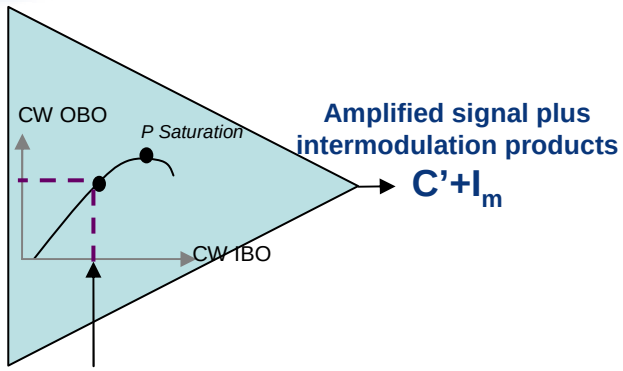
- A comparison is done in this presentation between several waveforms considered for the NGH satellite component in term of non linearity robustness
  - OFDM,
  - single Carrier OFDM,
  - Extended and Weighted single Carrier OFDM
  - TDM waveform (reference case)

Presentation Plan

- Non linearity problem
- Waveform Comparison Criteria
- Waveforms quick summary
- Simulation hypothesis
- Waveform comparisons
- Conclusions

Non linearity problem

Non linear amplifier with gain **G** depending from IBO

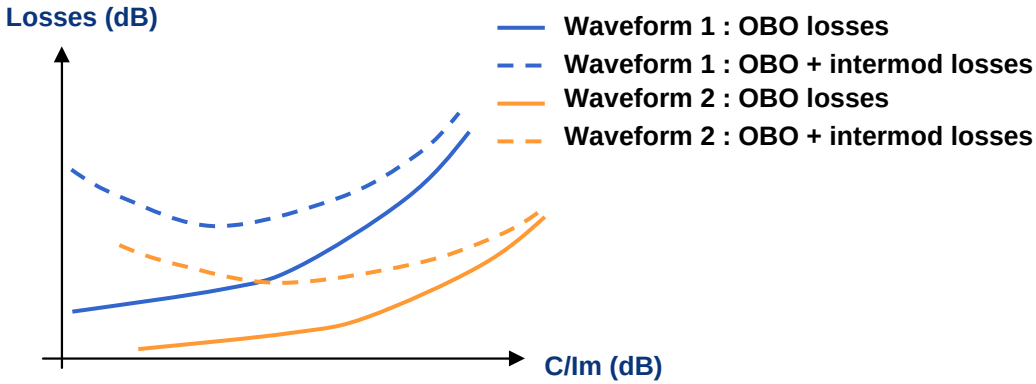


Pure Signal C to amplify

- **OBO definition : Considering a maximum deliverable amplifier power $P_{saturation}$ with a CW carrier, OBO is the difference between Psat and the ouptput power of the modulated carrier**
  - **|OBO| is therefore considered as power losses**
- **Amplified signal is including an intermodulation products term, I_m, characterized by C/I_m ratio, inducing a performance degradation**

⇒ **Trade off to do: C/I_m is increasing when |OBO| is increasing**

- **For each waveform, Goal is to assess total Non linearity losses at different working point, in order to compare them**



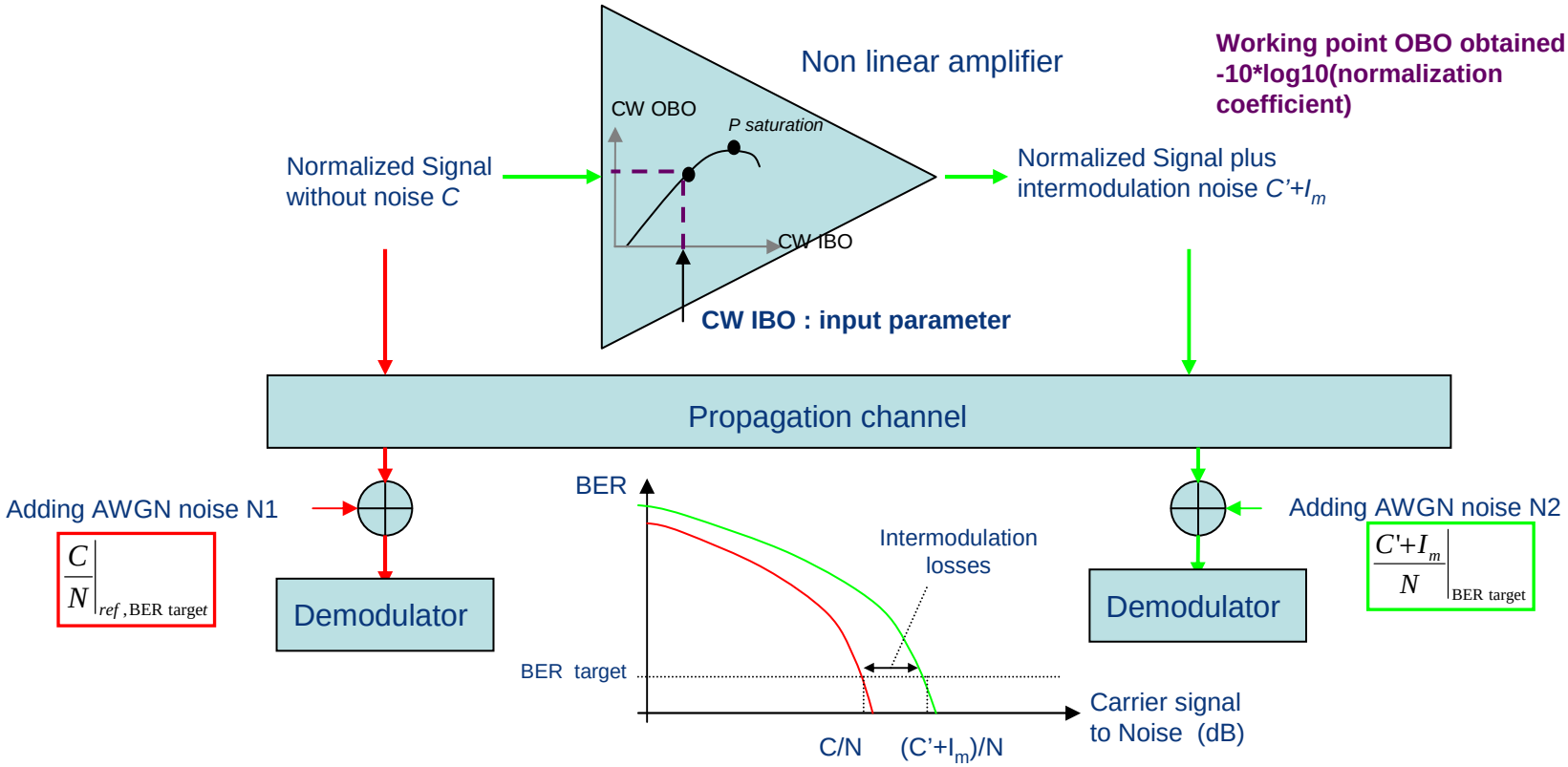
⇒ **Non linearity Losses are computed as the sum of |OBO| and I_m degradation**

⇒**Advantage of the representation is to compare waveforms losses at equal C/Im level**

- **C/I_m can be easly added to other C/I sources in the link budget**

Waveform comparison criteria (1)

- **First Aim is to assess (by simulation) total degradation brought by loss of power (OBO) and Intermodulation products degradation ([C+I]/N – C/N$_{required}$)**



$$\text{Total Degrad (dB)} = \frac{C'+I_m}{N} - \left.\frac{C}{N}\right|_{ref} + |OBO|$$

waveform comparison criteria (2)

- **Second aim is to compute Equivalent Signal over intermodulation products ratio C/I_m**
  - **It's the equivalent ratio supposing intermodulated signal is behaving as thermal noise**
  - **equivalent C/I_m is derived as :**

$$\left(\frac{C+I_m}{N}\right)=\frac{\left(\frac{C}{I_m}\right)^{-1}+1}{\left(\frac{C}{N}\right)^{-1}} \quad \Rightarrow \quad \left(\frac{C}{I_m}\right)=\frac{1}{\left(\frac{C+I_m}{N}\right)\cdot\left(\frac{C}{N}\right)^{-1}-1}$$

$\left(\frac{C}{N}\right)$ is the simulator input to reach BER 10^{-5} without non linearitie s

$\left(\frac{C+I_m}{N}\right)$ is the simulator input to reach BER 10^{-5} with non linearities

remind that $\left(\frac{C+I_m}{N}\right)$ - $\left(\frac{C}{N}\right)$ is the intermodulation loss

- **Simulation process**
  - **Assess reference curves for each waveform to derive C/N_{ref}**
  - **Fixing a criteria performance : here BER 10^{-5} to not have too much longer simulations**
  - **For each waveform,**
    - for many IBO values
      - Deduce OBO value
      - Searching $(C'+I_m)/N$ values to reach BER 10^{-5} criteria
        ⇒Deduce total degradation
        => Derive equivalent C/I_m

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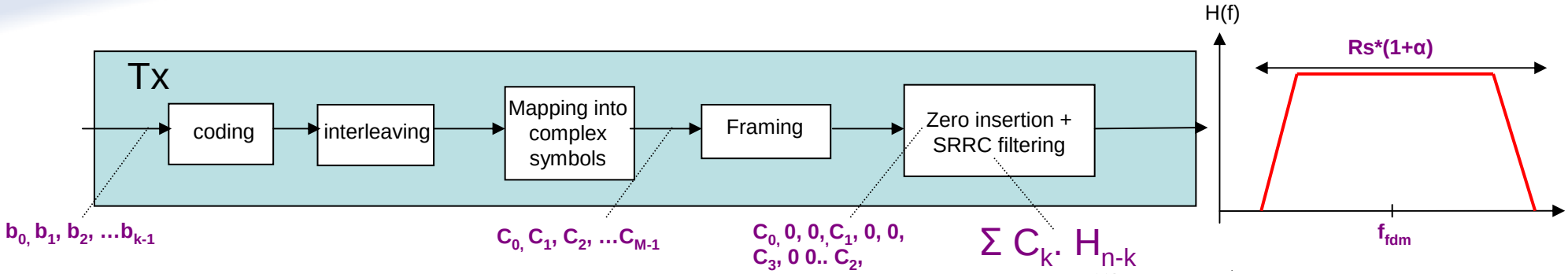
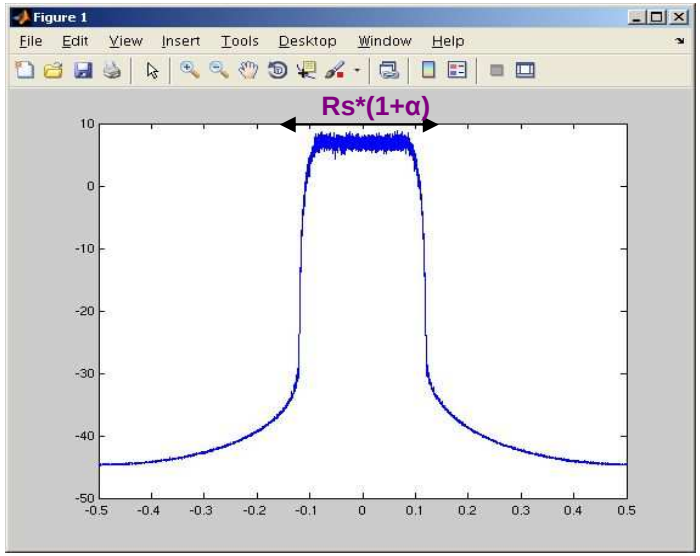
Waveforms quick summary

TDM

■ Generic Emitting chain



Spectral Shot

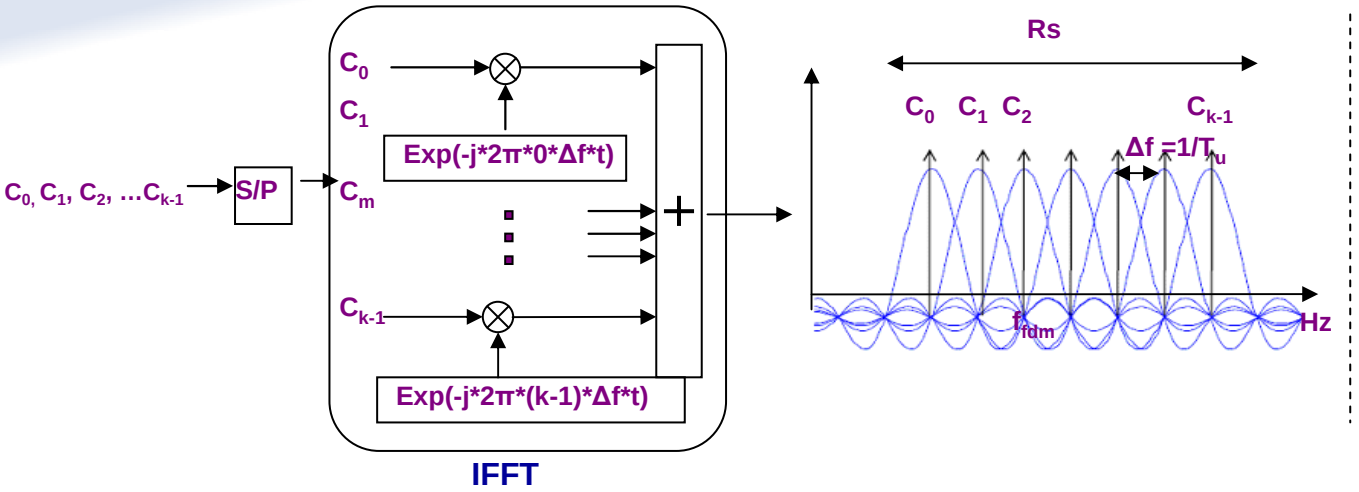


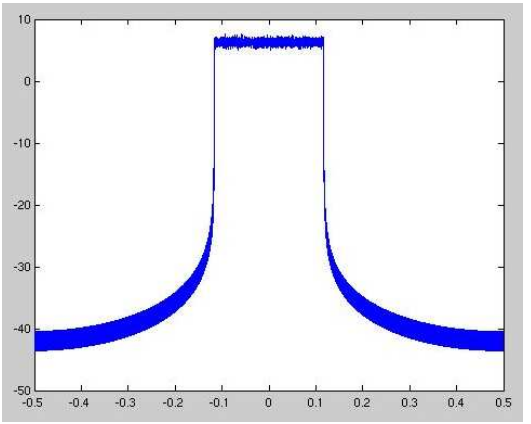
■ Main characteristics

- Low enveloppe fluctuations
- Well suited for fix transmission
- Not well suited for multipath environment
- Spectral occupancy of Rs*(1 + roll_off)
- Widely used in satellite communcations systems

OFDM

Waveform construction





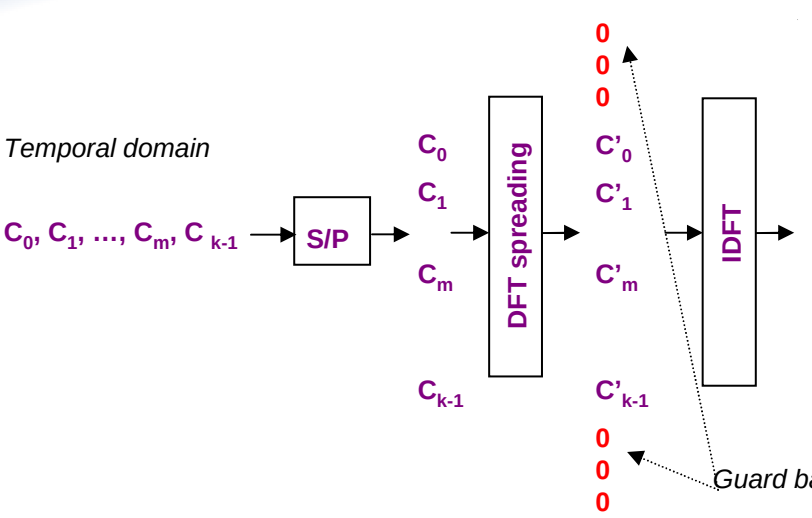
Power Density Spectrum shot

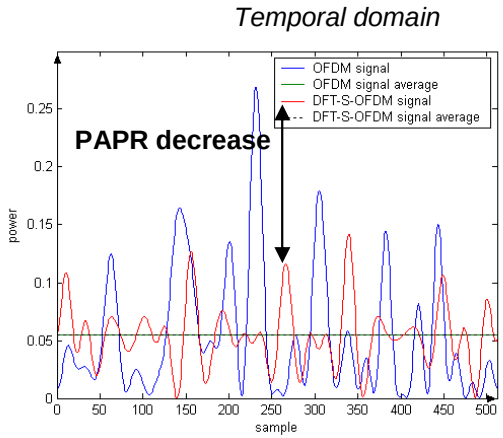
Main characteristics

- Well suited for multipath environment thanks to guard interval
- OFDM enveloppe behaves as white noise => high fluctuations
- Spectral occupancy : Rs

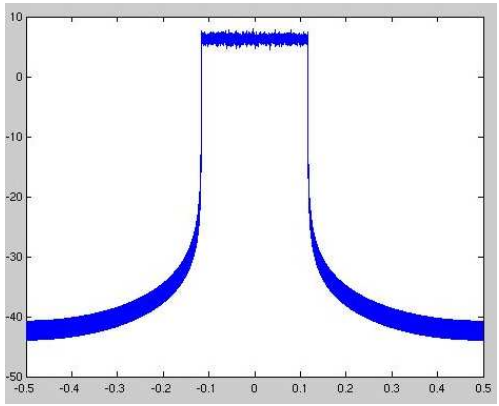
SC-OFDM

- In forward link, DFT spreading is done over all used subcarriers, with no pilots, to take benefit of fluctuation enveloppe reduction, like « single carrier »





Temporal signal results in the Complex symbol interpolation with a non integer sampling factor

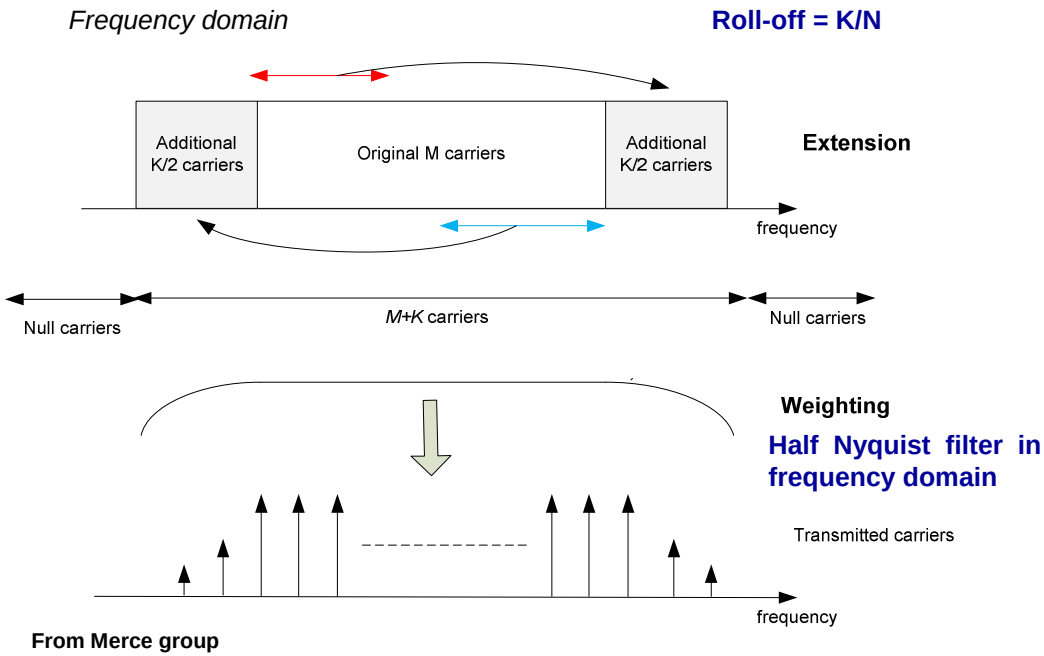


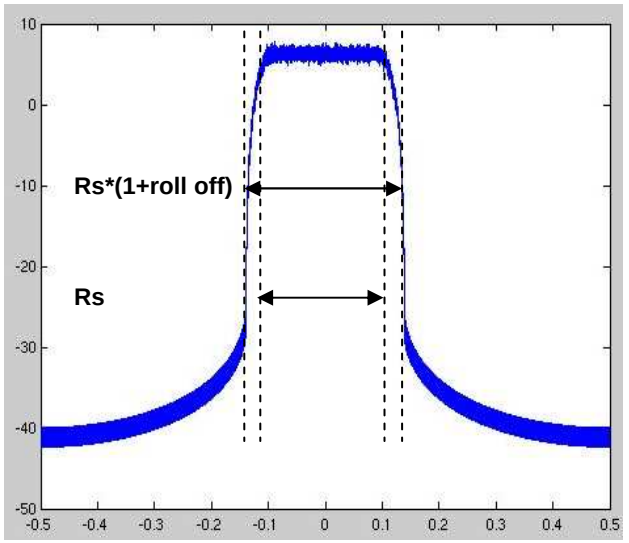
Spectral shot near from OFDM

- Near from OFDM architecture
- Spectral occupancy : Rs
- Keep advantage of OFDM multipath environment
- Receiving algorithms remain low computationnal but are a bit different
  - Equalization performed with MMSE filtering subcarrier by subcarrier
  - LLR calculation is made considering filtered pounds of channel estimates

EW-SC-OFDM

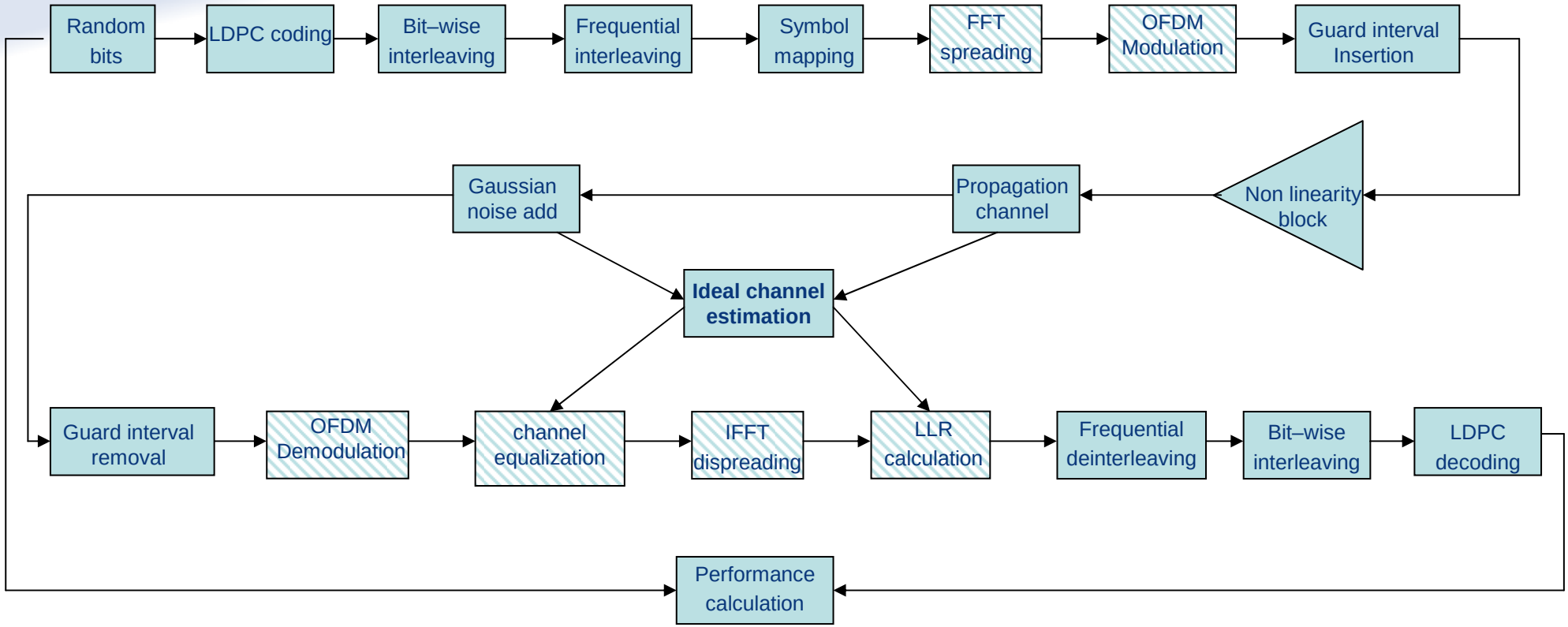
- **EW-SC-OFDM concept was proposed in order to introduce a roll-off to SC-OFDM and to have the possibility to trade-off spectrum occupancy and PAPR**





- **Enveloppe fluctuation reduced compared to SC-OFDM**
- **Density Power Spectrum near TDM => spectral occupancy Rs*(1 + roll off)**
- **Receiving algorithms near from SC-OFDM with half Nyquist filtering introduced in the equalization**

Simulation chain

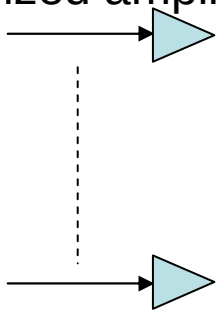


Modified or added block from OFDM chain to encode SC-OFDM and EW-SC-OFDM waveforms

Payload amplification architectures

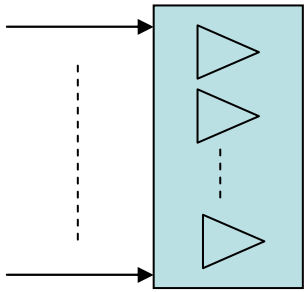
- **2 main satellite payload options : depending on the flexibility level needed**

Channelized amplification



⇨**Back Off choice waveform dependent**

Distributed amplification (W2A case)

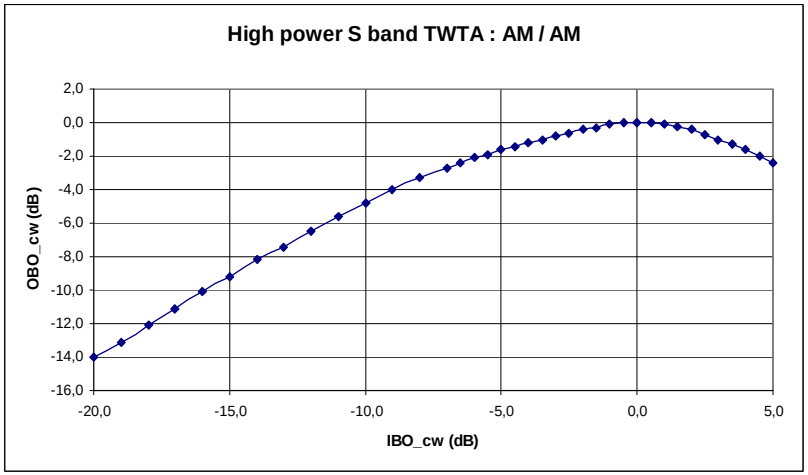


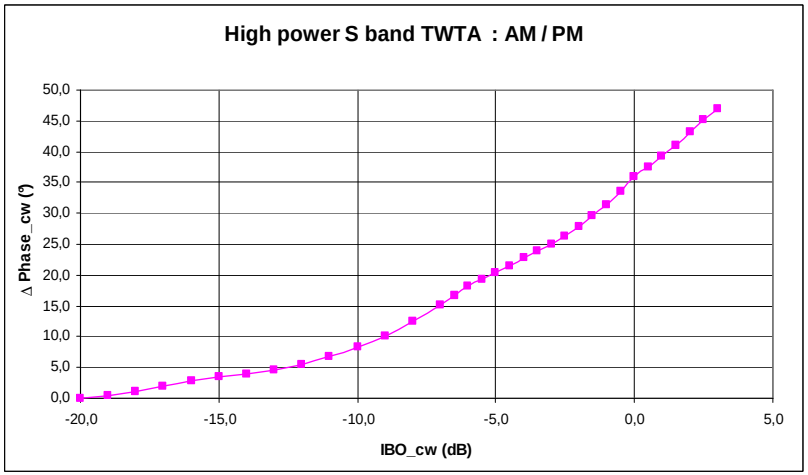
⇨**Need of Back Off operation**

⇨**Less waveform dependent**

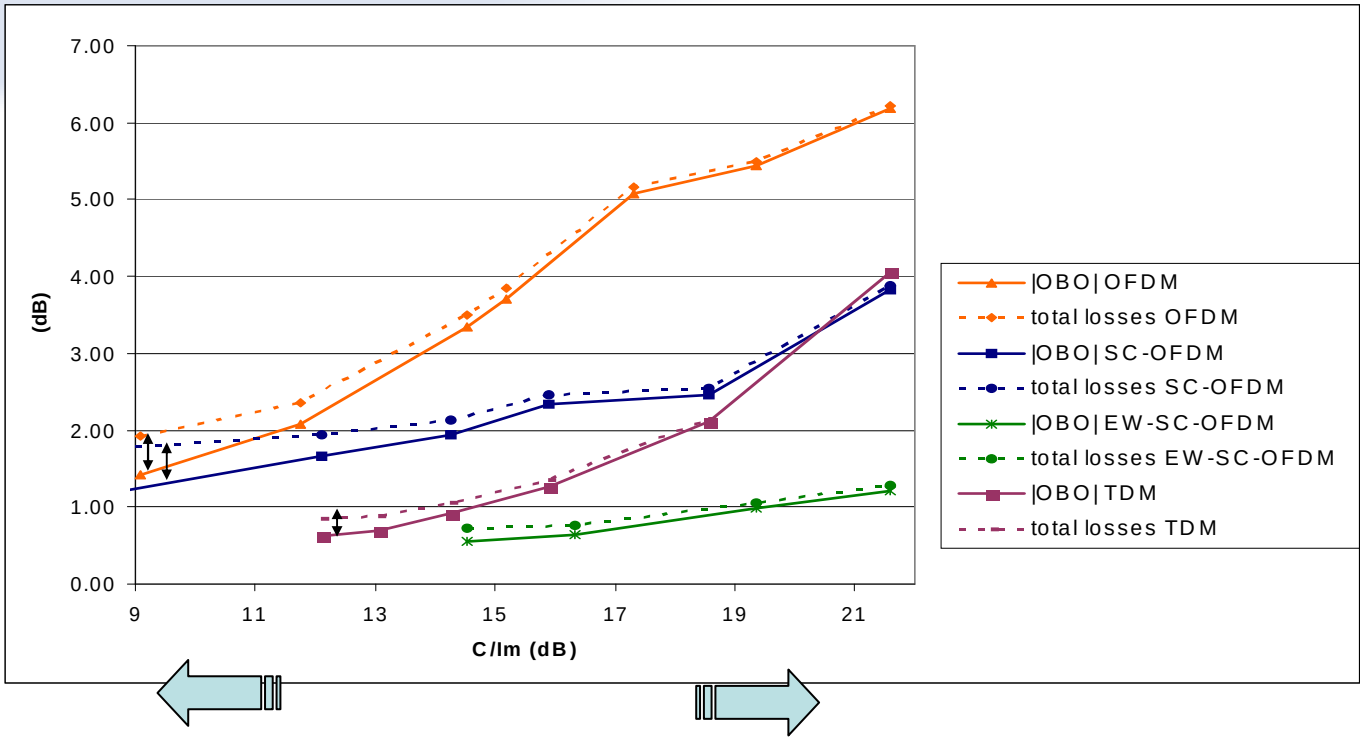
Simulations Hypothesis summary

- QPSK 1/3 modcod , AWGN channel
- Target BER 10^{-5}
- reference C/N of -1.2 dB
- TDM and EW-SC-OFDM waveforms are set with 15% roll off
- Using of fixed point 6 bits LDPC decoding
  - Optimization of LLR weigthing has been changed for SC and SC-EW OFDM waveform
- Channelized amplification
- S band non linearized TWTA
  - AM/AM and AM/PM curves from DVB-SH IGv1





Non linearity results with single channel amplification



↕ intermodulation products
Losses

For low C/Im gaps between waveforms is decreasing

SC-(EW)-OFDM and TDM appear very interesting for high C/Im working point

EW-SC-OFDM outperforms other waveforms even TDM

Conclusions

- **SC-OFDM and EW-SC-OFDM present a performance enhancement for satellite link compared with OFDM,**
  - **EW-SC-OFDM even outperforms TDM**
  - **Both new modulations can reuse OFDM receiver architecture, with limited modifications**
  - **They take advantage of OFDM properties in mobile channel**
- **Gap between waveforms are C/Im dependant**
  - **Low C/Im shows limited difference between waveforms**
    - It is the prefered working point with low required SNR modulation and for inter-beam interference
  - **(EW)-SC-OFDM advantage is growing with C/Im**
- **OFDM remains a pertinent waveform solution for non linear satellite transmission**
  - **It is Reinforced for payload with distributed amplification**