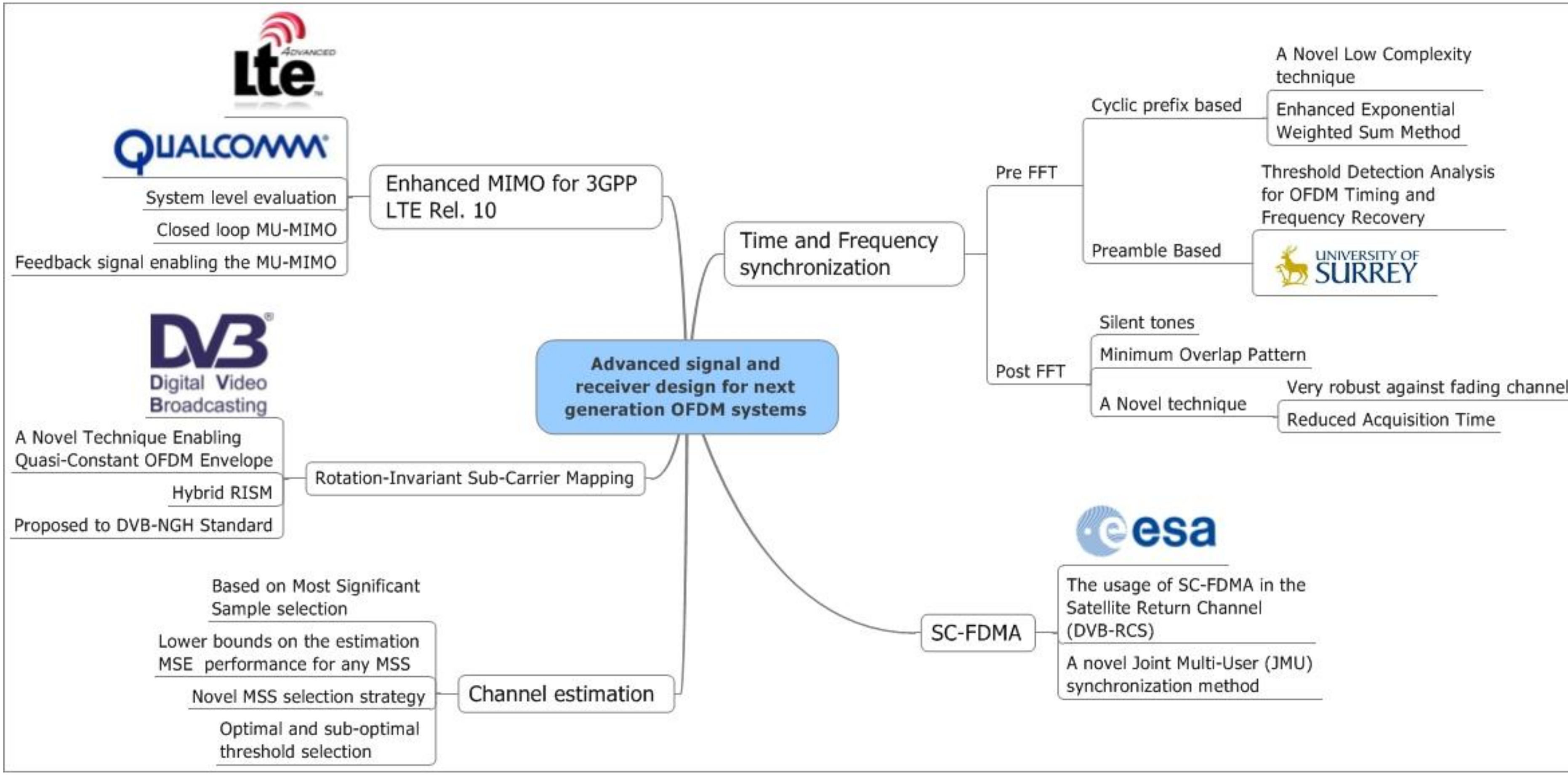
Advanced signal and receiver design for next generation OFDM systems

Stefano Rosati

Supervisor: Prof. Giovanni E. Corazza

My PhD



Advanced signal and receiver design for next generation OFDM systems
Enhanced MIMO for 3GPP LTE Rel. 10
System level evaluation
Closed loop MU-MIMO
Feedback signal enabling the MU-MIMO
Rotation-Invariant Sub-Carrier Mapping
A Novel Technique Enabling Quasi-Constant OFDM Envelope
Hybrid RISM
Proposed to DVB-NGH Standard
Channel estimation
Based on Most Significant Sample selection
Lower bounds on the estimation MSE performance for any MSS
Novel MSS selection strategy
Optimal and sub-optimal threshold selection
Time and Frequency synchronization
Pre FFT
Cyclic prefix based
A Novel Low Complexity technique
Enhanced Exponential Weighted Sum Method
Preamble Based
Threshold Detection Analysis for OFDM Timing and Frequency Recovery
Post FFT
Silent tones
Minimum Overlap Pattern
A Novel technique
Very robust against fading channel
Reduced Acquisition Time
SC-FDMA
The usage of SC-FDMA in the Satellite Return Channel (DVB-RCS)
A novel Joint Multi-User (JMU) synchronization method

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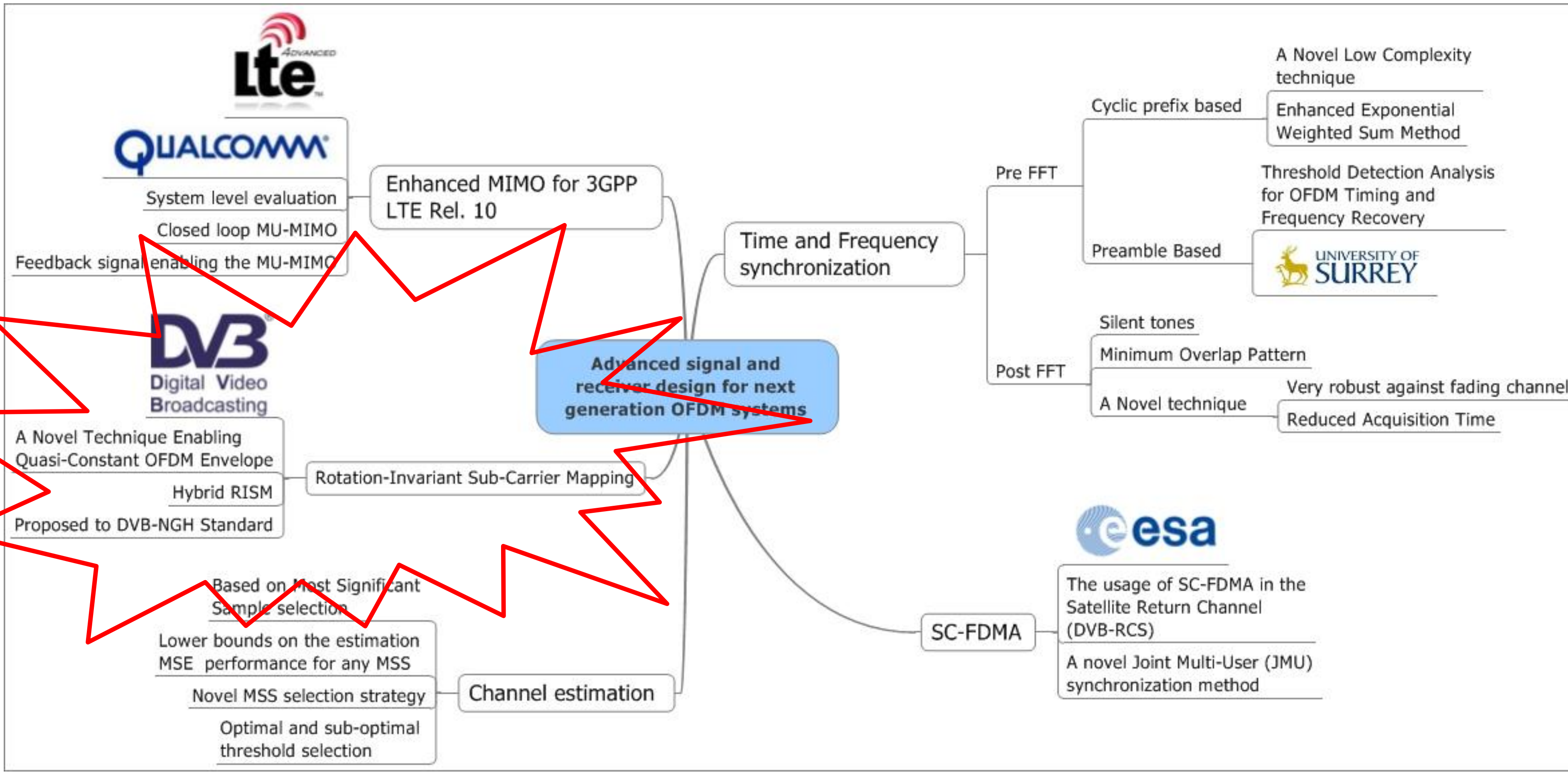
lte Advanced
QUALCOMM
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SC-FDMA
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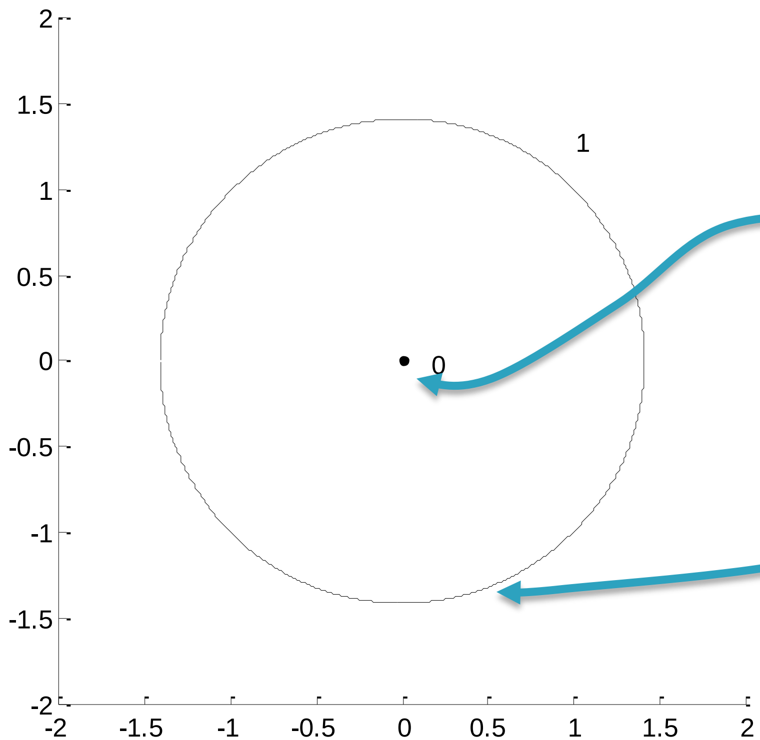
Problem and Motivation

- Effective PAPR reduction is useful in harsh scenarios:
  - Distorting HPAs
    - Satellite communications
    - Low cost gap fillers
  - Non-ideal OBO control
    - IBO instability
    - Saturation power instability
- Second-generation of DVB standards are dealing with PAPR reduction techniques
  - Active Constellation Extention (ACE)
  - Tone Reservation (TR)
- We propose a PAPR Reduction method based on the use of Reserved Tones
- But differently from TR, the Reserved Tones are able <u>to carry one or more information bits</u>

Rotation-Invariant Sub-Carrier Mapping

- RISM is a novel concept for subcarriers data mapping
  - The symbols belonging to the modulation alphabet are not anchored
  - A bit tuple is not mapped on a single point, rather it is mapped onto a geometrical locus, which is totally or partially rotation invariant
  - The final positions are chosen by an iterative optimization process to minimize the PAPR

Two level RISM constellation



Two-level data mapping

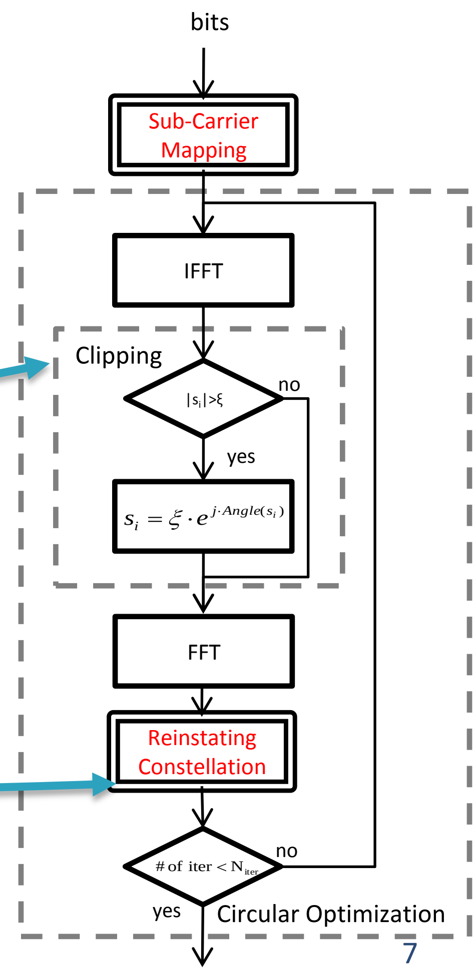
- '0' is mapped onto the origin
- '1' is mapped onto the circle with radius $\sqrt{2\,E_s}$

Iterative Optimization

- It freely arranges the phases of the RISM symbols in order to decrease the PAPR
- It works alternately in time and frequency

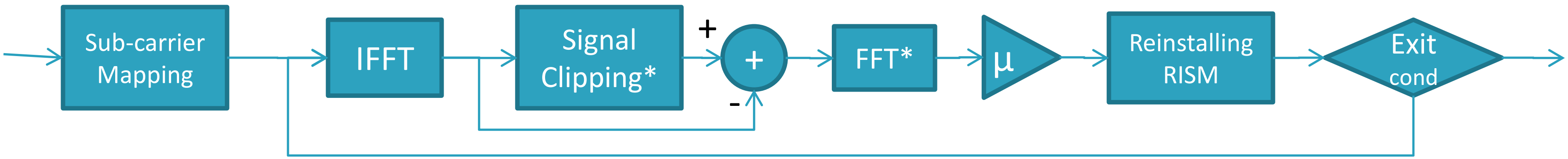
1. Time domain clipping

2. Frequency domain reinstating



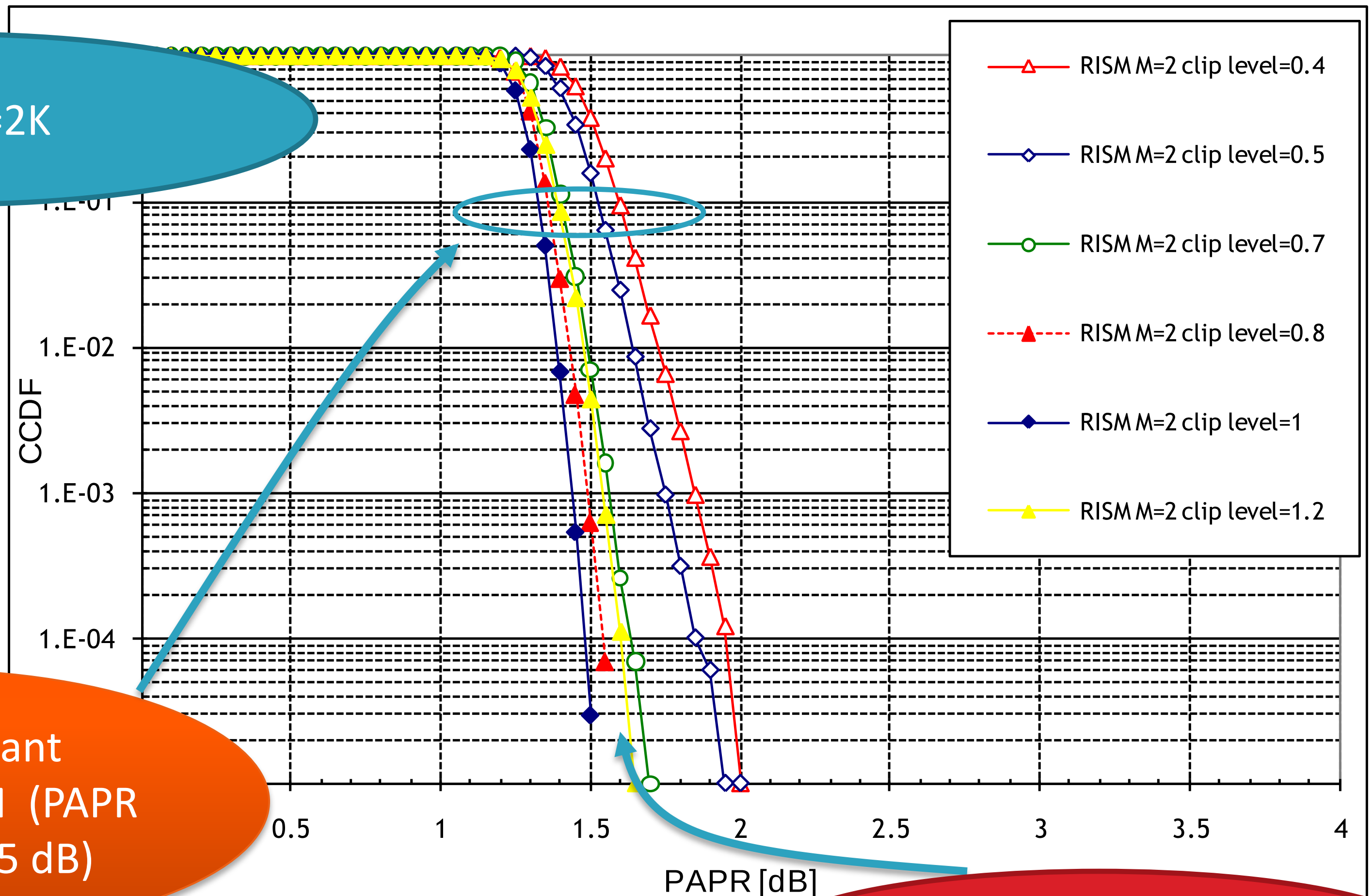
Low Complexity Optimization

- Keeps the same PAPR Performance with 10 FFT/IFFT iterations
- The FFT* is computed on a sparse vector
- The complexity has been reduced more than 10 times



PAPR Distribution, RISM M=2

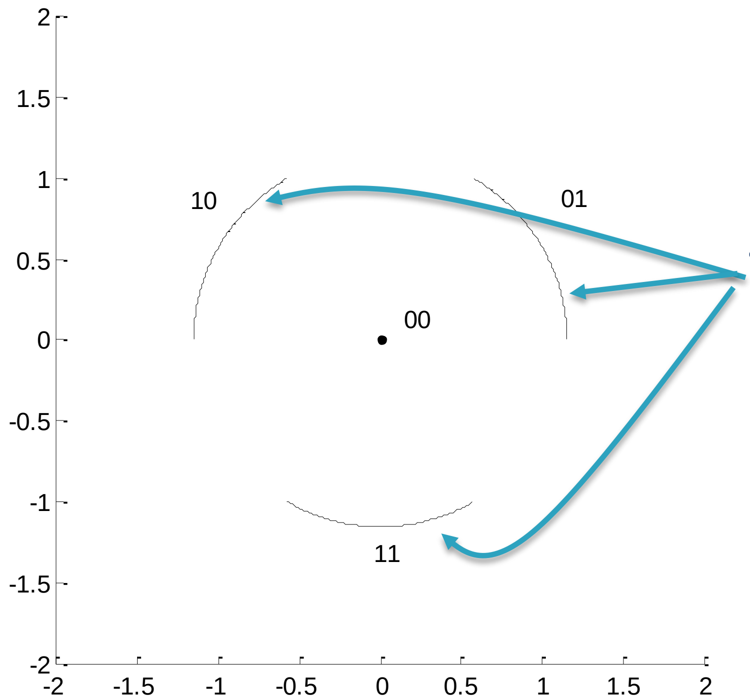
FFT size=2K



Quasi-constant envelope OFDM (PAPR lower than 1.5 dB)

For this case the best clipping level is 1 dB

Four level RISM constellation



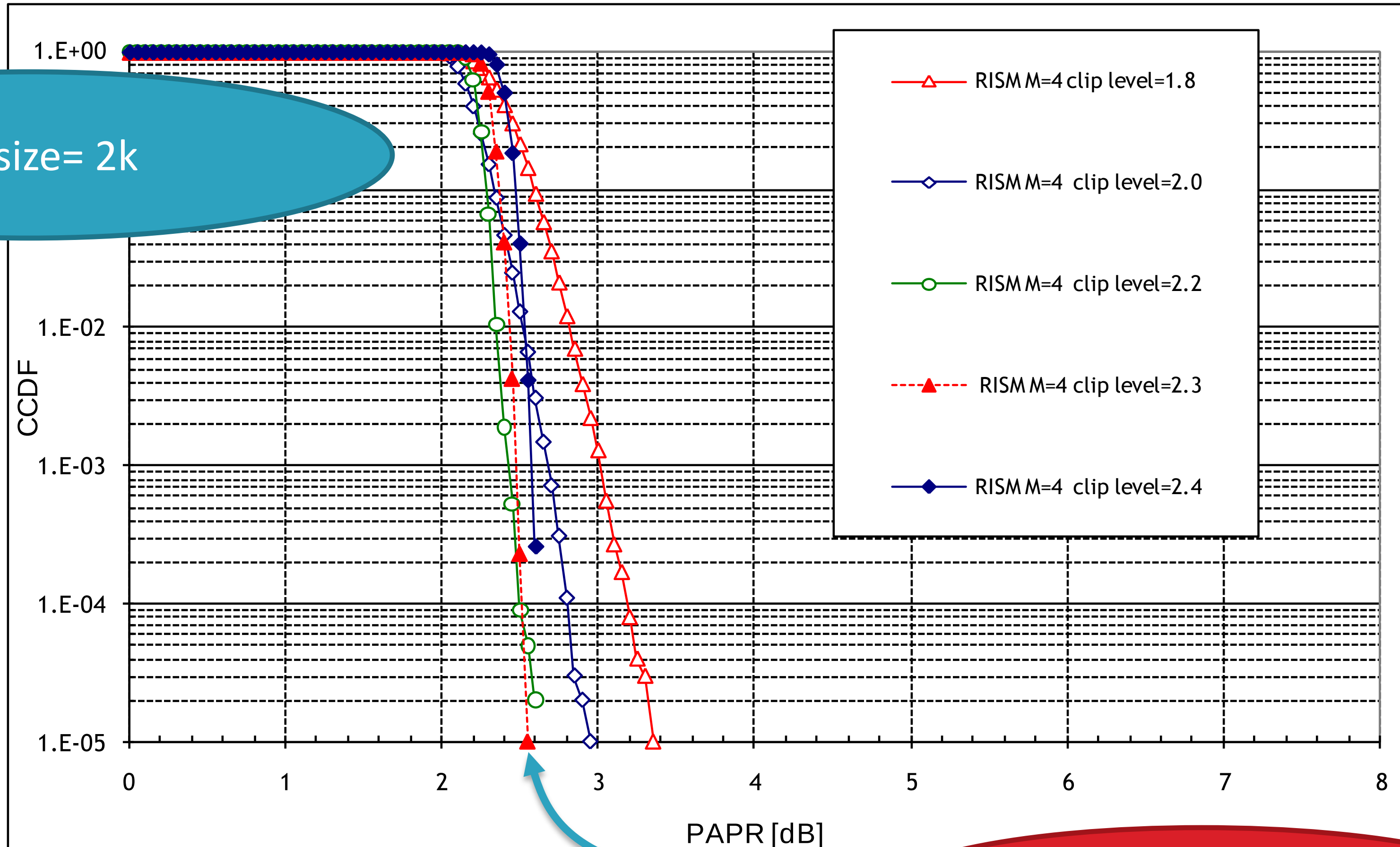
'00' is mapped onto the origin

The remaining couples are mapped onto three equidistant circular arcs

Trade off between the amount of flexibility to reduce the PAPR and robustness to Gaussian noise

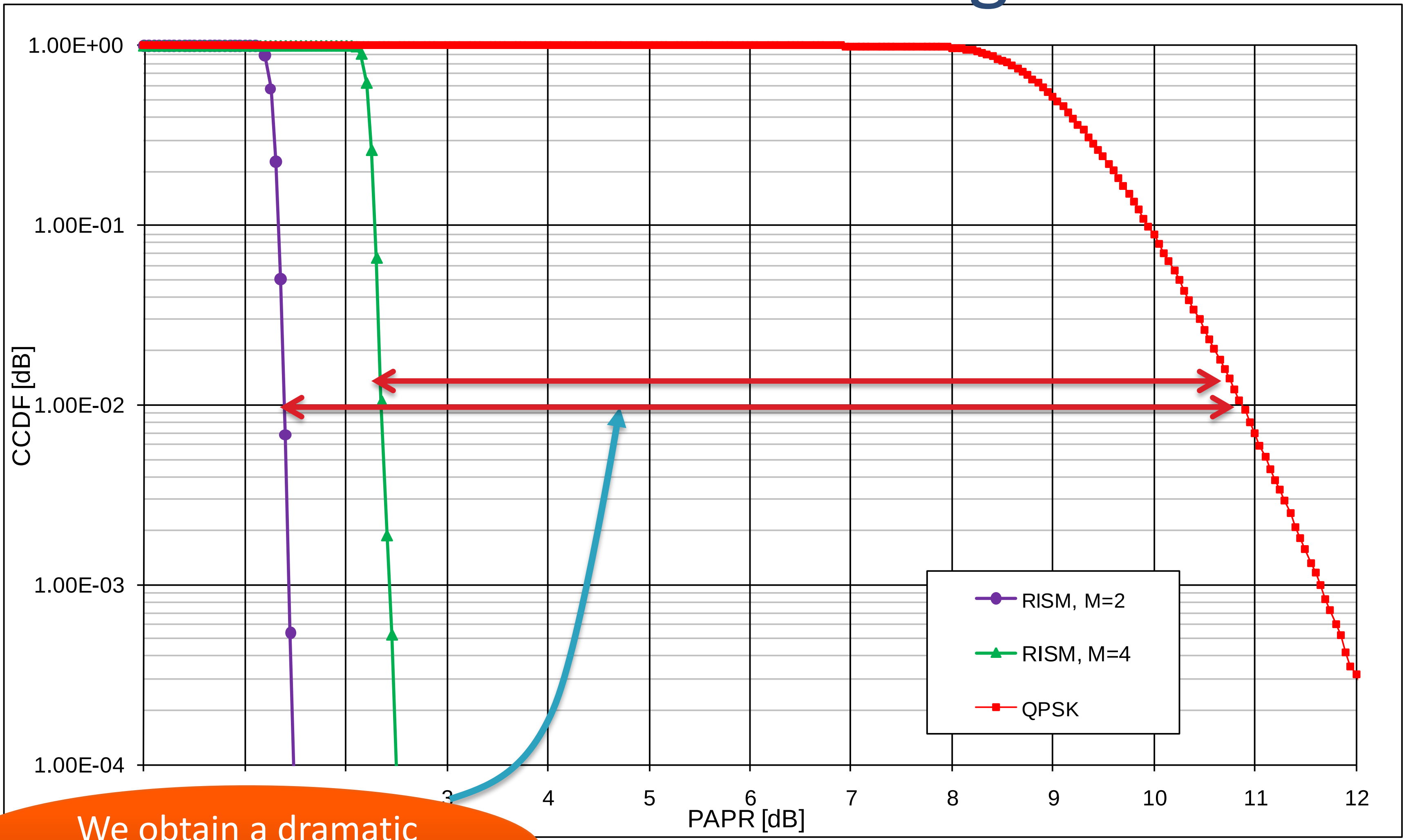
PAPR Distribution, RISM M=4

FFT size= 2k



For this case the best clipping level is 2.2 dB

PAPR Distribution using RISM

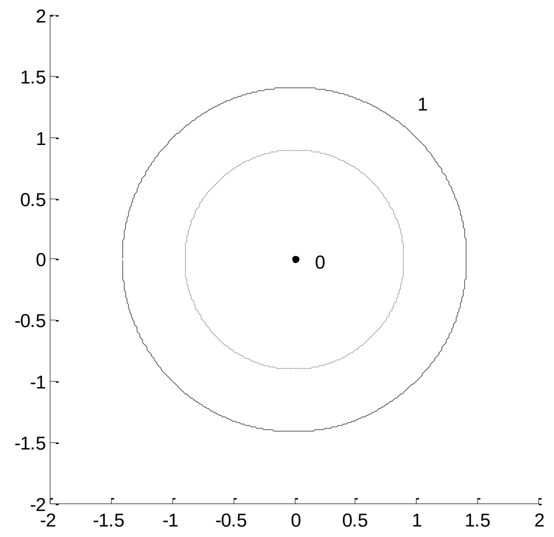


We obtain a dramatic reduction of PAPR

RISM Detectors

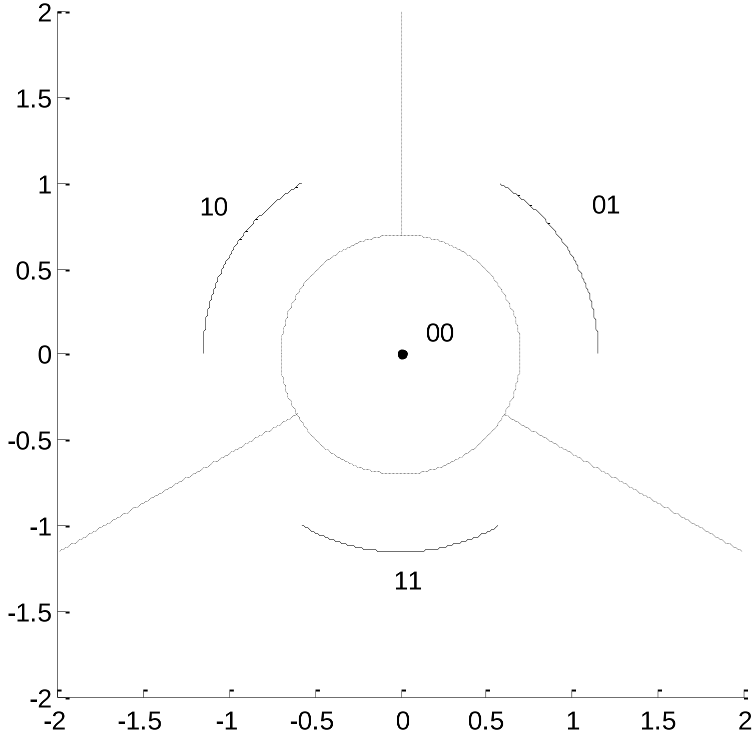
- The detection of Two level RISM is performed by means of a simple **energy detector**

- Robust detector
  - Totally to phase errors
  - Fairly to channel amplitude estimation errors



RISM Detectors

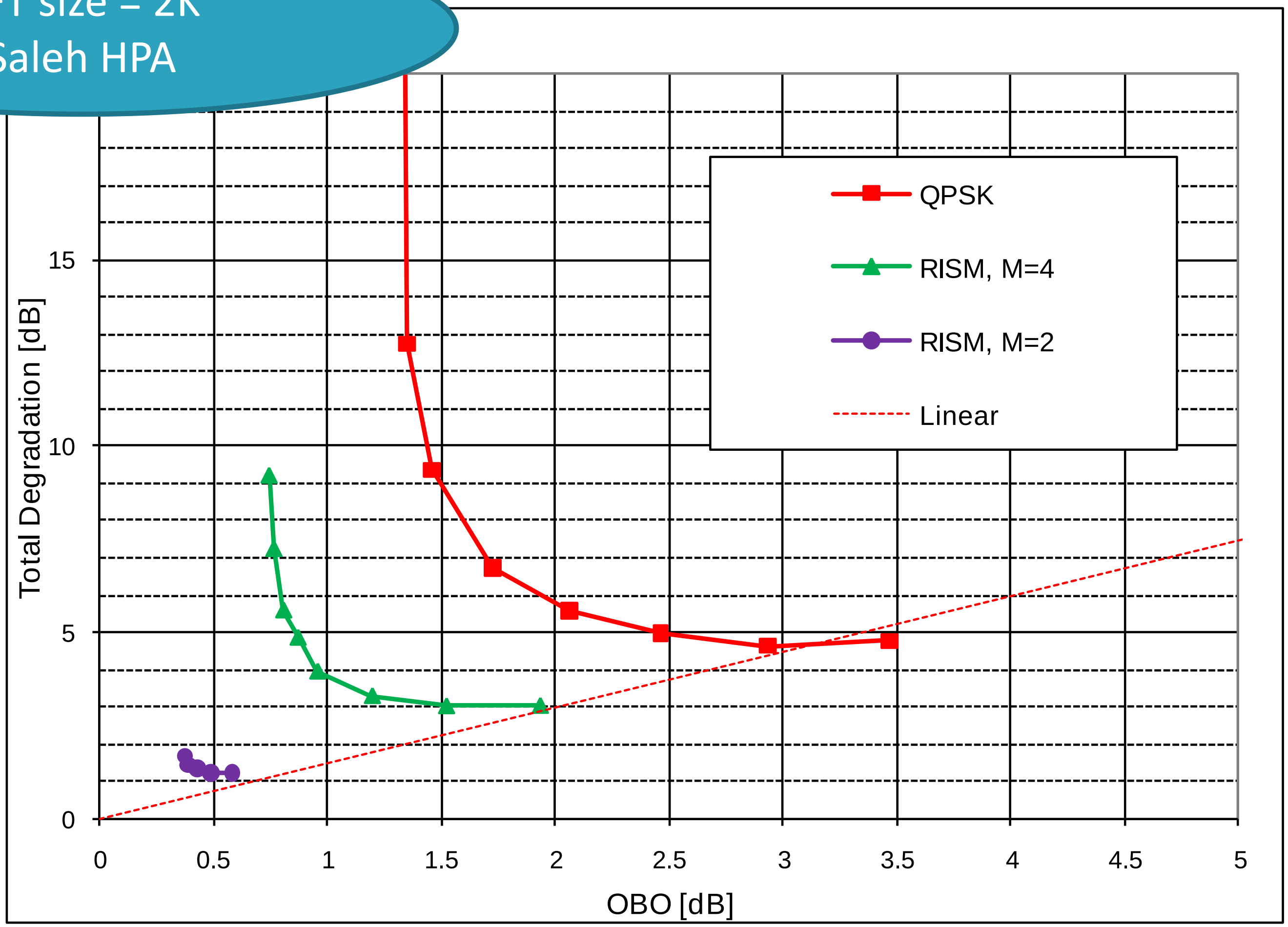
- The detection of Four level RISM is performed in two stages
  - Energy detection
  - Phase detection



- Suboptimal detector
  - Less complex

Total Degradation

FFT size = 2K
Saleh HPA



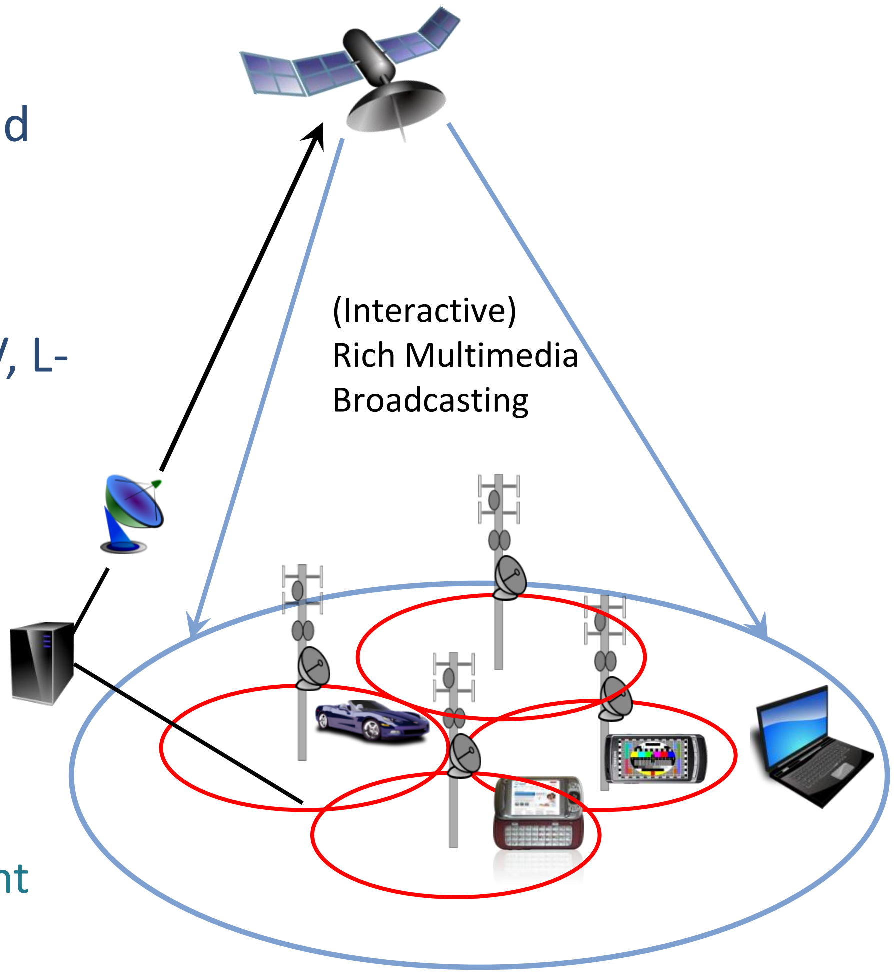
Sparse RISM

- Insert RISM tones only in selected sub-carriers in order to reduce the PAPR
  - Increasing the throughput
  - While keeping a good non-linearity resilience

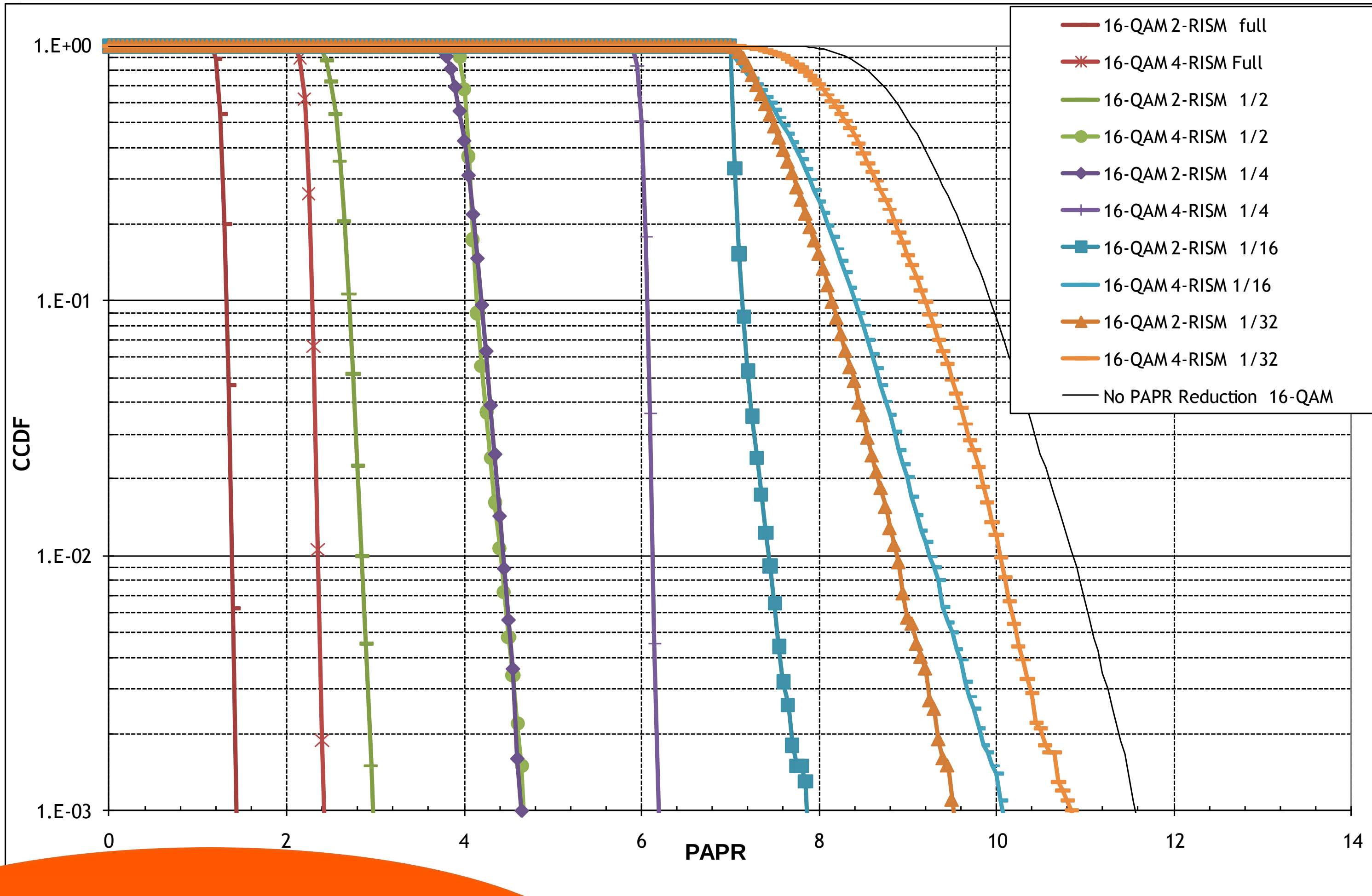
This technique has been presented at DVB-TM-H forum, for a possible inclusion in the DVB-NGH specifications

DVB-NGH: Next Generation Handheld

- Rich Multimedia Broadcasting over Hybrid Terrestrial-Satellite network
  - Terrestrial SFN network
  - Complementary Satellite coverage
- Designed to operate in bands III, IV and V, L-band and S-band
- Bandwidth from 1.7 to 20 MHz
- Based on OFDM Modulation
- Timeline
  - Call for Technology 26 February 2010
  - Kicked off 25 March 2010
  - The publication of the related ETSI standard(s) is expected in 2011
  - The first commercial NGH devices might then become available in 2013

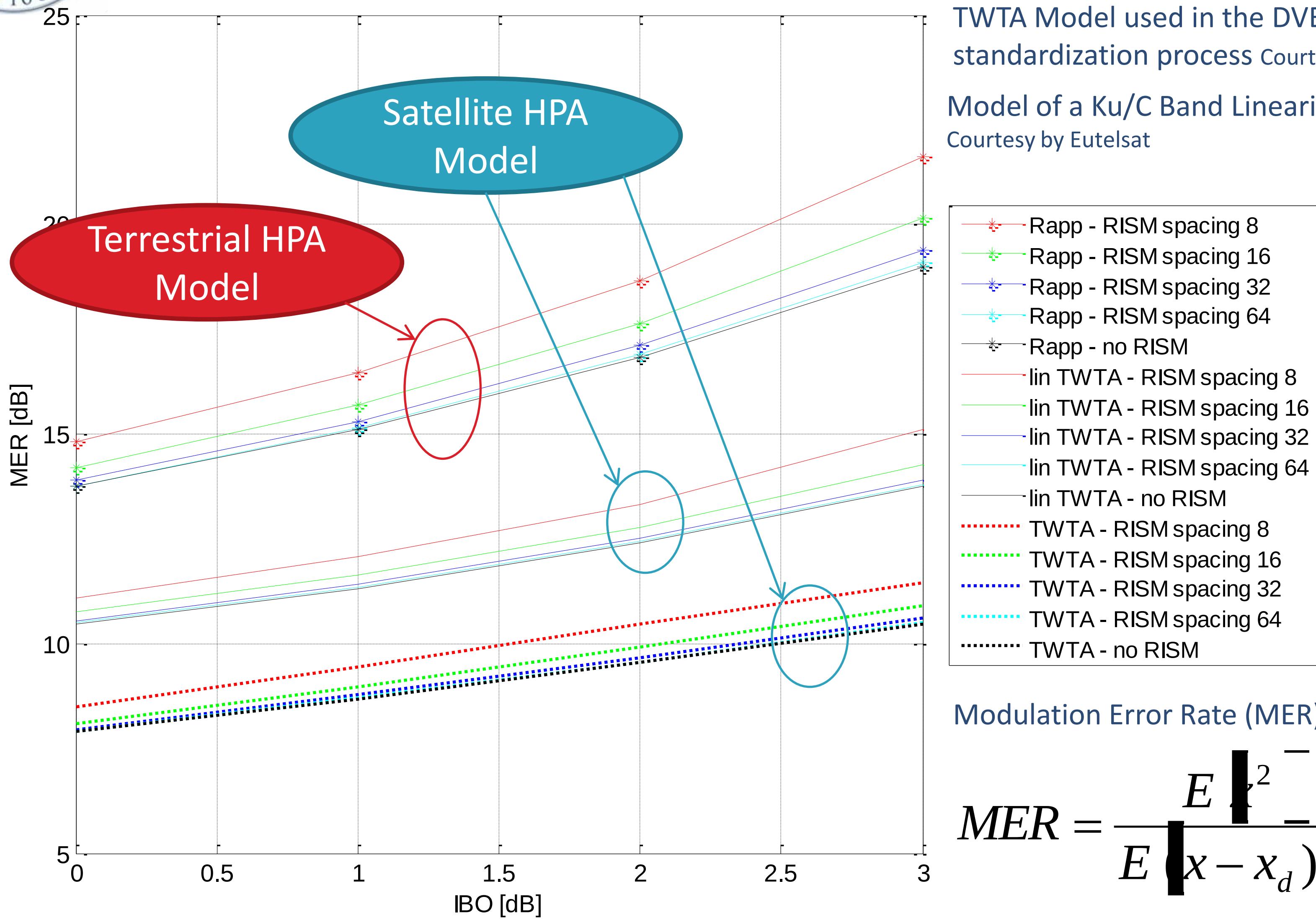


PAPR RISM (16 QAM)



Using one RISM tone every P_s without any other form of PAPR reduction

MER performance comparison



TWTA Model used in the DVB-SH standardization process Courtesy by ESA

Model of a Ku/C Band Linearized TWTA Courtesy by Eutelsat

Modulation Error Rate (MER)

$$MER = \frac{E\{|x|^2\}}{E\{|x-x_d|^2\}}$$

Conclusions

- Strong PAPR reduction can be useful in
  - Satellite communications
  - Low cost gap fillers
  - OBO uncertainty - IBO instability
- If all subcarriers are RISM-modulated, PAPR can be below 1.5 dB
  - OFDM modulation will not be degraded by non-linear distortion (Quasi Constant envelope)
- We propose a flexible method for PAPR reduction
  - Trade-off between PAPR reduction and throughput
  - This method is into the evaluation phase for the inclusion in DVB-NGH

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Papers 1/2

- OFDM Channel estimation
- [1] S. Rosati, G. E. Corazza, A. Vanelli-Coralli, “OFDM Channel Estimation with Optimal Threshold-Based Selection of CIR Samples", accepted to IEEE Global Telecommun. Conf. (GLOBECOM09), Honolulu, USA, Dec. 2009.

- [2] S. Rosati, G. E. Corazza, A. Vanelli-Coralli, “OFDM Channel Estimation based on Impulse Response Decimation: Analysis and Novel Algorithms", submitted to IEEE Transaction on Communications

- SC-FMDA in Broadband Satellite Return Channel
- [3] S. Rosati, S. Cioni A. Vanelli-Coralli, , G. E. Corazza, G. Gallinaro, A. Ginesi, “A Joint Multi-User Synchronization Method for SC-FMDA in Broadband Satellite Return Channel", accepted to IEEE Global Telecommun. Conf. (GLOBECOM10), Miami, USA, Dec. 2010

- OFDM PAPR Reduction
- [4] S. Rosati, E. A. Candreva, G. E. Corazza, Rotation-Invariant Sub-Carrier Mapping: A Novel Technique Enabling Quasi-Constant OFDM Envelope", IEEE 5th Advanced Satellite Multimedia Systems Conference (ASMS 2010), Cagliari, Italy, Sep. 2010

- On LTE Adaptation for Mobile Satellite Networks
- [5] F. Bastia, C. Bersani, E. A. Candreva, S. Cioni, G. E. Corazza, M. Neri, C. Palestini, M. Papaleo, S. Rosati, A. Vanelli-Coralli “LTE Adaptation for Mobile Broadband Satellite Networks", to appear in EURASIP Journal on Wireless Communications and Networking.

- PRE-FFT Joint Symbol Timing and Carrier Frequency Recovery based on cyclic prefix redundancy
- [6] S. Rosati, S. Cioni, M. Neri, A. Vanelli-Coralli, and G.E. Corazza, “Joint Symbol Timing and Carrier Frequency Recovery for DVB-SH System", Proc. of International Workshop on Satellite and Space Communications (IWSSC) 2007, Salzburg, Austria, 13-14 Sep. 2007.

Papers 2/2

- **[7] S. Rosati, M. Villanti, A. Vanelli-Coralli, G.E. Corazza, “OFDM Post-FFT Frequency Recovery based on Silent Sub-Carriers", Proc. of IEEE 10th International Symposium on Spread Spectrum Techniques and Applications, (ISSSTA) 2008, Bologna, Italy, 25-28 Aug. 2008.**

- **PRE-FFT Carrier Frequency Recovery using a preamble**
- **[8] F. Bastia, G. E. Corazza, C. Palestini, S. Rosati, A. Vanelli-Coralli, “Preamble Insertion in Future Satellite-Terrestrial OFDM Broadcasting Standards", Proc. of International Communications Satellite Systems Conference (ICSSC) 2009, Edinburgh, 1-4 Jun. 2009.**

- **PRE/POST-FFT Symbol Timing and Carrier Frequency Recovery**
- **[9] S. Rosati, A.B. Awoseyila, A. Vanelli-Coralli, C. Kasparis, G.E. Corazza and B.G. Evans, “Threshold Detection Analysis for OFDM Timing and Frequency Recovery", accepted to IEEE Global Telecommun. Conf. (GLOBECOM09), Honolulu, USA, Dec. 2009.**