Advanced signal and receiver design for next generation OFDM systems

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Advanced signal and receiver design for next generation OFDM systems

- Enhanced MIMO for 3GPP LTE Rel. 10
- Time and Frequency synchronization
- Rotation-Invariant Sub-Carrier Mapping
- Channel estimation

- A Novel Technique Enabling Quasi-Constant OFDM Envelope
- Hybrid RISM
- Proposed to DVB-NGH Standard
- Based on Most Significant Sample selection
- Lower bounds on the estimation MSE performance for any MSS
- Novel MSS selection strategy

- SC-FDMA

- Cyclic prefix based
- Enhanced Exponential Weighted Sum Method
- Pre FFT
- Preamble Based
- Threshold Detection Analysis for OFDM Timing and Frequency Recovery
- Post FFT
- Silent tones
- Minimum Overlap Pattern
- Very robust against fading channel
- Reduced Acquisition Time

- The usage of SC-FDMA in the Satellite Return Channel (DVB-RCS)
- A novel Joint Multi-User (JMU) synchronization method

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My PhD

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- Cyclic prefix based
- Pre FFT
- Threshold Detection Analysis for OFDM Timing and Frequency Recovery

- A Novel Low Complexity technique
- Enhanced Exponential Weighted Sum Method
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- SC-FDMA
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- Qualcomm
- DVB
- Digital Video Broadcasting
- Advanced LTE
- System level evaluation
- Closed loop MU-MIMO
- Feedback signal enabling the MU-MIMO
- A Novel Technique Enabling Quasi-Constant OFDM Envelope
- Hybrid RISM
- Proposed to DVB-NGH Standard
- 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

- University of Surrey

- ESA
- The usage of SC-FDMA in the Satellite Return Channel (DVB-RCS)

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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 to carry one or more information bits
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 $\sqrt{2E_s}$
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

\[ s_i = x \cdot e^{-j \cdot \text{Ang}(x)} \]

bits

Sub-Carrier Mapping

IFFT

Clipping

yes

no

Reinstating Constellation

FFT

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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

For this case the best clipping level is 2.2 dB

FFT size= 2k
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

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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

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Using one RISM tone every $P_s$ without any other form of PAPR reduction
Modulation Error Rate (MER)

\[
MER = \frac{E}{E(x - x_d)^2}
\]
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
• **OFDM Channel estimation**


• **SC-FMDA in Broadband Satellite Return Channel**


• **OFDM PAPR Reduction**


• **On LTE Adaptation for Mobile Satellite Networks**


• **PRE-FFT Joint Symbol Timing and Carrier Frequency Recovery based on cyclic prefix redundancy**

Papers 2/2


- PRE-FFT Carrier Frequency Recovery using a preamble

- PRE/POST-FFT Symbol Timing and Carrier Frequency Recovery