Carrier per Carrier Analysis of SDR Signals Power Ratio

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Ideal software radio (SWR)

- digitize the globality of the RF spectrum at Rx
- generate all the channels of a multi-standard BTS with a single DAC and RF amplifier at Tx

Example of a future mini-BTS on-board a transatlantic plane
Software Defined Radio

- Technology constraints
  - ADC, DAC speed and quality
  - processing power of processors, FPGA...
  - power consumption
  - analog components bandwidth and linearity...

- Restricted to sub-parts of the spectrum
  - channels of one standard for instance

Spectrum of a multiplex of GSM Carriers
• A SDR RF signal at least, and moreover a Software Radio RF signal
  – multi-band signal
  – multiplex of carriers

• Major drawback of a multiplex of carriers
  – suffer from high Power Ratio (PR)
  – known also as the PAPR (Peak-to-Average Power Ratio)

• Cause
  – non constant envelop of the signal
• The difference between the average power and the max power is high
  – either under use the amplifier (input back-off)
  – or generate non linearities
• Non linearities
  – area 1: linear
  – area 2: non linear
  – area 3: saturation
• Signal corruption
• BER degradation
• PR is an old issue
  – 70’s on satellite communications
  – 80’s till now: OFDM (DVB-T, DAB, 802.11g)

• OFDM signal
  – a multiplex of carriers
  – very close to SWR and SDR signal
  – particularly suffers from PR issue

• Idea: take advantage of solutions investigated for OFDM and apply to SDR signals
• OFDM PR definition
  – based on a time PR calculation
  – on the samples after IFFT (all generated from a single time signal)
  – definition

\[ PR_{c,m} = \frac{\text{Max} \left| S(t) \right|^2}{E\left(\left| S(t) \right|^2\right)} \]

• SDR approach
  – a multiplex of signals on several carriers
  – each generated independently from the others
  – a frequency approach would be more suitable
  – each standard one by one
• Computing the PR in the frequency domain would better fit to SDR signal
  – SDR signals are a set of signals at different carriers
  – compute the global PR from each carrier PR

• Three questions

(Q2)– Is it equivalent to compute the PR in the time and the frequency domains?  
(Q1)– Is it correct to apply it to SDR signals?  
(Q3)– How to compute or approximate the PR in the frequency domain?
Carrier per carrier analysis

- Multi-standard SDR signal

\[ S_i(t) = \sum_{p=1}^{P_i} r_{i,p}(t) e^{2i\pi f_{i,p}t} \]

- SDR single-standard signal made of a plurality of equidistant carriers

\[ S_i(t) = \sum_{p=1}^{P_i} r_{i,p}(t) e^{2i\pi (f_{i,0} + (p-1)\Delta f_i) t} \]

- OFDM signal

\[ Z(t) = \sum_{k=0}^{N-1} C_k e^{2i\pi f_k t} \]

(Q1)
Demo for an OFDM signal

- PR upper-bound usually computed in the time domain: $PR_{temp}$
  - on each OFDM symbol (line)
  - then the max $PR_{Ns,freq}$ is computed from the set of time PR
- New calculation of PR
  - frequency PR on each column: $PR_{fr}(p)$ then max
- We find the same $PR_{Ns,freq}$ (Q2)
• PR approximation in the frequency domain
  – probabilistic
    \[
    PR_{\text{temp}} \leq \sum_{p=1}^{N} A_p \cdot PR_{fr}(p) + K
    \]
  – \( P[PR_{\text{temp}} > \text{threshold}] \) (complementary cumulative distribution function)

obtained by the new \( PR_{fr} \) approach

\( (Q3) \)
Example on a GSM signal

- Time PR and upper-bound
  - 10 GSM carriers
  - 1000 symbols
  - 20 experiments

- Results
  - only 2 dB upper-bound
  - perfectly follows time PR variations
• This new PR approach (in the frequency domain) may help in the SDR domain for
  – applying OFDM reduction methods to SDR signals
  – for the PR evolution analysis through a transmission chain
• Equivalence for SDR single-standard
• Perspective
  – to be proven for multi-standard SDR signals
Thank you for your attention