Fully Orthogonal Multi-Carrier Predistortion Linearization & Soft Crest Factor Reduction Technique

Authors:
Xi Yang, Jiwoo Kim, Patrick Roblin
Mohammed Ismail

PI: P. Roblin
C1 NSF PI: John Volakis
The Ohio State University
• The development of auto-adaptive linearization algorithm has become more and more important for wireless base-station RF multi-carrier power amplifiers, and is expected to play a key role in software defined radio applications.

• Orthogonality between each band is required for auto-adaptive linearization, greatly reducing the channel bandwidth needed by the receiver.

• Based on previous two-band frequency selective predistortion linearization work, implement orthogonality constraints between each band (USB inband and interband, LSB inband and interband).

• Iterative steps between inband and interband linearization are no longer required in the optimization.
Two-band Frequency-Selective Predistortion Linearization (Previous Work)

Results demonstrated for frequency-selective predistortion linearization with two-band WCDMA.

Interband predistortion linearization (blue) exhibits a non-orthogonal inband component (see green squares).

By adding an orthogonality constraint, the non-orthogonal inband component of interband linearization can be removed.

Intermodulation correction for enforcing the orthogonality:

\[
IMD_{corrO} = \frac{(\alpha_3^* + j\beta_3^*)}{1 + j} \\
IMD_{corrE} = \frac{(\alpha_3 + j\beta_3)}{1 + j}
\]

\[
\alpha_{A,IMD}(t) = 0 - 2 \text{Re}[IMD_{corrO}]E_e^2 \\
\beta_{A,IMD}(t) = 0 - 2 \text{Im}[IMD_{corrO}]E_e^2 \\
\alpha_{B,IMD}(t) = 0 - 2 \text{Re}[IMD_{corrE}]E_e^2 \\
\beta_{B,IMD}(t) = 0 - 2 \text{Im}[IMD_{corrE}]E_e^2
\]
Fully Orthogonal Multi-Carrier Predistortion Linearization

FPGA Implementation

Digital Test-bed

PAPR: 8dB@0.01% CCDF
Linearization Results

1. Without Carrier
2. Lower Side Band
3. Upper Side Band
4. Final
• Soft CFR algorithm is proposed to reduce peak to average power ratio (PAPR) as well as minimize spectral regrowth
• Basic Idea of Soft CFR is a pulse shaping so that minimizing spectral
• The algorithm has been extended to 2-band OFDM signals
• Results
Two-band Soft CFR

Basic Idea of Soft Clipper

Peak detector measures instantaneous sample power, $P(k)$ and it is fed into pulse shaping filter. If $P(k)$ is greater than pre-defined threshold, $M$, then correction signal (factor) is calculated by pulse shaping block.

Soft CFR Algorithm for 2-band

Hilbert Transform

Correction Factor Calculation

$\begin{align*}
I_L &\quad \rightarrow \quad Q_L \\
I_U &\quad \rightarrow \quad Q_U \\
-I_{CL} &\quad \rightarrow \quad -Q_{CL} \\
-I_{CU} &\quad \rightarrow \quad -Q_{CU}
\end{align*}$
Results

Spectral Regrowth for two-band WiMax Signal
(10 MHz BW of each band, 20 MHz BW total)

CCDF Comparison

CCDF for Samsung WiMax Signal (20 MHz)

Hard CFR

Soft CFR

PAPR Reduction

Original
• Novel aspects of this project & benefits:
  – OFDM signal generator implemented in FPGA is capable of generating 128 tones with BPSK or QPSK modulation
  – New FPGA development platform incorporating Nios_II processor economizes the onboard LUT recourses
  – Matlab GUI gains more flexibility
  – Orthogonality implementation facilitates further auto-adaptive predistortion linearization realization, especially for reducing channel bandwidth of the receiver
  – Soft CFR improves the digital predistortion linearization performance for input signals with high power level
• Risks/challenges:
  – Complete polyphase RFIC IQ modulator
  – Complete Auto-adaptive linearization scheme
• Potential applications & benefits:
  – Predistortion linearization with broader bandwidth for multicarrier OFDM LTE and WiMAX communication system
  – Less expensive adaptive linearization system owing to the multiband approach (receiver with narrow bandwidth: 10 MHz instead 90 MHz for 3 bands)
• **Tasks Accomplished for 2007/2008**
  - Development of new FPGA environment (incorporating Nios_II processor and Matlab GUI)
  - Implementation of OFDM signal generator
  - Implementation of two band frequency selective predistortion linearization with orthogonality constraints
  - Implementation of auto-adaptive IQ Balancing scheme
  - Implementation of 4-path poly-phase Mixer
  - Implementation of the Crest Factor Reduction scheme

• **DELIVERABLES & MILESTONES 2008/2009**
  - Auto-adaptive two band predistortion linearization
  - A novel poly harmonic distortion algorithm to remove the remaining non-linearities which are not cancelled by using poly-phase multipath techniques
  - Implementation of 8-path poly-phase Mixer