Analog/digital predistortion techniques for multi-band/broadband Power Amplifiers

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Outline

- Introduction & Motivation
- Limitations of state-of-the art techniques
  - Digital Predistortion
  - Analog Predistortion
  - Hybrid (digital/analog) predistortion
- Analog/digital predistortion technique
- Measurement results and Discussion
- Conclusion
Introduction

- Compromise between Energy Efficiency Vs. Linearity due to PA in the transmitter

**Linear Region**
- Linearity
- PAE

**Non Linear Region**
- Linearity
- PAE

**DC Power Consumption**
- Cooling system

**Spectral regrowth**
- High bit error

Air Conditioning: 10-25%
Signal Processing: 5-15%
Power Supply: 5-10%
**Power Amplifier** 50-80%
Motivation

- Spectrum efficient waveforms to enhance data rate
- Broadband Transmission
- Single device for multiband Transmission
Pre-distortion as linearization solution

Time Domain representation

Frequency Domain Representation

Signal BW

BW of predistorted signal

Resultant IM3=Resultant IM5≈0
Digital Predistortion linearization

- Configurability
- Accuracy and superior linearization performance
- Drop in DAC/ADC dynamic range with BW.
- DPD requires 3 to 7 times BW of the signal to be transmitted.

1. Distortion generation
2. Control of synthesized distortion
Analog Predistortion

- DAC speed constraint is relaxed
- Feedback receiver/ADC is not required.
- Baseband information not required
- Limited linearization due to imperfections of analog components
- DUT dependent Rigid solution

- Distortion generation in analog domain
- Control of synthesized distortion in analog domain
Digital/Analog Predistortion

- DAC speed constraint is relaxed.
- High BW signals can be supported.
- ADC is not required.
- Accurate characterization
- ADC should capture 5 to 7 times signal bandwidth
- Baseband Signal is required.

- Distortion generation in digital domain
- Control of synthesized distortion in analog domain
Adaptive Analog predistorter

- Adaptation of parallel branch analog predistorter
Adaptive analog predistorter: Components

Rat-Race Hybrid Coupler
- P1: Input, P2: Output
- P3: HSMS 2822 Schottky anti-parallel diode as nonlinear element
- P4: 120Ω resistor and the 1pF capacitor as RC pair for main signal cancellation.

Vector multiplier ADL5390 VM:
- Operating frequency range 20 MHz to 2.4 GHz
- Continuous magnitude control range +5 dB to -30 dB
- Cartesian I/Q baseband frequency range dc to 230 MHz
- Output third order intercept +24 dBm
S-parameters

(a) Power Divider

(b) Rat-race hybrid Coupler
Rate Race coupler performance for 8CC (160 MHz bandwidth) LTE signal
Selection of R & C

![Graph showing output power vs. resistance and capacitance](image-url)
Hybrid Digitally controlled APD

- More precise Control of phase/ gain of distortion signal
- Distortion creation in analog domain
- Control of distortion signal is digital domain

Signal processing unit
FPGA + Transceiver
APD
PA

Control limitations of Vector modulator

Small portion of out-of-band signal taken as feedback
Measurement setup: PoC
DUT Characteristics

DUT: 10W HMC8500 GaN PA
SUT: Single tone CW

Linear Gain:
- P1-dB: 13.2 dB
- Gain@P1-dB: 12.1 dB

Gain @ P3-dB:
- 10.2 dB

DUT: 10W HMC8500 GaN PA
SUT: 8CC 160 MHz UBB LTE

Linear Gain:
- P1-dB: 12.5 dB
- Gain@P1-dB: 9.28 dB

Gain @ P3-dB:
- 11.4 dB

Measured Output Power
Ideal Output Power
Measured Gain
Measurement Results

Contiguous 8CC, 160 MHz LTE signal

Non-contiguous 8CC, 160 MHz LTE signal
Dual-Input APD for 5G communication

Digital control: ZYNQ board ZC706 FPGA from Xilinx
RF Front end: Dual channel Transceiver AD9371 from Analog Devices

**The laminate used is the RT/duroid 5780,**
**The Schottky diode used is HSMS 2822.**
Analog/ digital predistorter

- IMD terms are generated in parallel path and added at out-of-phase with original signal.

T1: Without digital control: Gain-phase adapted in design
T2: With digital control to adapt gain and phase
Performance with respect to frequency

- Phase rotation and power loss due to APD varies with the frequency.
- PA distortion characteristics also change with respect to frequency

**Graph 1:**
- ACPR (dB) vs. Frequency (GHz)
- Lines represent different OPBO levels and PA configurations.

**Graph 2:**
- NMSE (in dB) vs. Frequency (GHz)
- Lines show performance trends for different configurations.

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# Qualitative Comparison

<table>
<thead>
<tr>
<th></th>
<th>APD</th>
<th>DPD</th>
<th>DIGITAL/ANALOG PD</th>
<th>HYBRID DC-APD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BW of ADC</strong></td>
<td>(NA)</td>
<td>5 X BW</td>
<td>5 X BW</td>
<td>&lt;1 X BW</td>
</tr>
<tr>
<td><strong>BW of DAC</strong></td>
<td>NA</td>
<td>5 X BW</td>
<td>1XBW</td>
<td>1 X BW</td>
</tr>
<tr>
<td><strong>BW of VM</strong></td>
<td>5X BW</td>
<td>NA</td>
<td>5 X BW</td>
<td>NA</td>
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<tr>
<td><strong>ACPR correction</strong></td>
<td>+</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
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<tr>
<td><strong>ADC</strong></td>
<td>-</td>
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<td>1</td>
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<tr>
<td><strong>DAC</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>DSP power</strong></td>
<td>+</td>
<td>++++</td>
<td>+++</td>
<td>++</td>
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</tbody>
</table>
Conclusion

- Limitations imposed by broad bandwidth of 5G communication system on linearization methods are reviewed.
- The potential of Adaptive APD is discussed.
- Limitations of Vector modulator based adaptive APD investigated.
- Digital control of APD for performance enhancement is discussed.
- Hybrid analog/ digital PD methods are compared with state-of-the art in terms of resources and bandwidth requirement.
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References


Thank you for your attention

Any Questions!