A Testbench for Analysis of Bias Network Effects in an RF Power Amplifier with DPD

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Outline

- Introduction
  - Motivation
  - Bias Network design
  - DPD
- Measurement Setup
- Experimental Results
- Conclusions
Introduction

The power amplifier is a critical component in a wireless system.

Important power amplifier parameters:
- Frequency band
- Power
- Bandwidth
- Linearity
- Efficiency
- Size, cost ...

Linearity vs. efficiency tradeoff
Linearization, efficiency enhancement
Introduction

- The scope of this work is to build a testbench where we can do most measurements necessary for a PA design.
- In addition, we want to measure the effect of different bias networks in the PA.
- A power amplifier based on a pHEMT transistor is designed for the experiments.
- A standard bias network is first used for the experiments.
- Two extreme variants where large inductors are used are tested to demonstrate the effect on the linearity.
- The measurements are done with and without DPD.
Introduction

- Bias network design
  - Isolate RF from DC
  - Important for stability at low frequencies
  - Defines the impedance at baseband
  - Often based on empirical design methods
  - More critical as the bandwidth of the signal increases
  - Traditionally simplified to a large inductor in textbooks, but recently this topic is being covered (Cripps)
Different bias configurations

- Resistor improve stability, but not desirable at drain
- Large impedance at baseband can result in drain modulation/memory effects
- Internal parasitics in SMD components
Simple memoryless DPD
- Complex baseband samples at the input and output are recorded
- A block-based least square algorithm is applied to identify the DPD coefficients
- The DPD algorithm and communication with the instruments is implemented in Matlab
- The algorithm sensitive to memory that has its origin in the bias network

The baseband DPD model based on indirect learning architecture
**Measurement Setup**

- **Measurement Setup Diagram**
  - **Signal Generator**
  - **Driver Amplifier**
  - **Circulator**
  - **Source tuner**
  - **Load tuner**
  - **Coupler**
  - **Attenuator**
  - **Power sensor A**
  - **Power sensor B**
  - **Power meter**
  - **GPIB bus**
  - **Multimeter**
  - **Signal Analyzer**
  - **PC**

**Values**

- Anritsu A: -10.05 dBm
- B: 5.01 dBm
- DUT dBm
- Volts Amps: 10.05 0.0505

**Frequency Range**

- 2.4 GHz 2 dBm

**Manufacturer**

- **ROHDE & SCHWARZ**
- **FLUKE**
- **PC**
Combinations of quarter-wavelength transmission lines isolates bias circuitry from RF at f0 and 3f0, 2f0 shorted

A 1 watt pHEMT transistor used in the experiments

The transistor is biased in deep class AB

2.4 Ghz
Experimental Results

- 1-tone measurements
  - Source- and load impedance optimized for best efficiency
  - 1-tone measurements are independent on the bias circuit

<table>
<thead>
<tr>
<th>1 dB Compression</th>
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<tbody>
<tr>
<td>Pout</td>
</tr>
<tr>
<td>PAE</td>
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1-tone measurements

1 dB Compression

<table>
<thead>
<tr>
<th>Pout</th>
<th>29.2 dBm</th>
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<tbody>
<tr>
<td>PAE</td>
<td>67 %</td>
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</table>

PAE vs. Gain vs. Output Power, dBm / Gain, dB
Experimental Results

- 2-tone measurements with reference bias
  - Close to short circuit at baseband at drain
  - Small differences between upper and lower IMD product, except one point

Bias circuit impedance
Experimental Results

- 2 tone measurements with large inductor at drain
  - Increasing differences in lower and upper IMD product

Bias circuit impedance drain
Experimental Results

- 2 tone measurements with large inductor at gate
Experimental Results

- ACPR measurements with reference bias network
  - 16 QAM, symbol rate 3.84 MHz
  - About 10 dB improvement with DPD

![ACPR measurements reference](image1)

![Spectrum with DPD reference](image2)

![Spectrum without DPD reference](image3)
Experimental Results

- Linearity measurements with large inductor at drain
  - ACPR degraded
  - DPD not able to compensate due to memory/drain modulation
Experimental Results

- Linearity measurements with large inductor at gate
  - ACPR unchanged at low power levels
  - At high output power ACPR is drastically degraded
Experimental Results

- A large inductance at drain degrades the linearity, DPD cannot compensate for this.
- A large inductance at gate doesn’t affect the linearity at low power but has a significant impact at high power, gate modulation?
Conclusions

- A testbench for PA design is presented that includes automated measurements.
- In addition to load-pull the effect of the bias network can be easily measured.
- To demonstrate the importance of the bias circuits two extreme variants are tested and their effect on the linearity are measured.
- Measurements show that large inductance at drain degrades the linearity as expected and that a simple memoryless DPD cannot compensate for this.
- A large inductance at gate only affects the linearity at high power levels, gate modulation.
Acknowledgement

We would like to thank:

- The Research Council of Norway, the research program WIWIC II

Thank you for your attention!