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Adaptive power amplifier concepts preserving linearity under severe mismatch conditions

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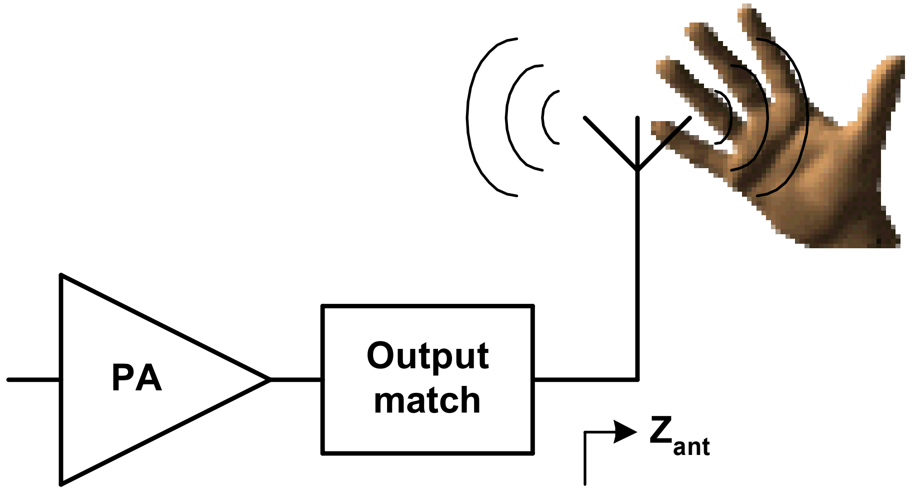
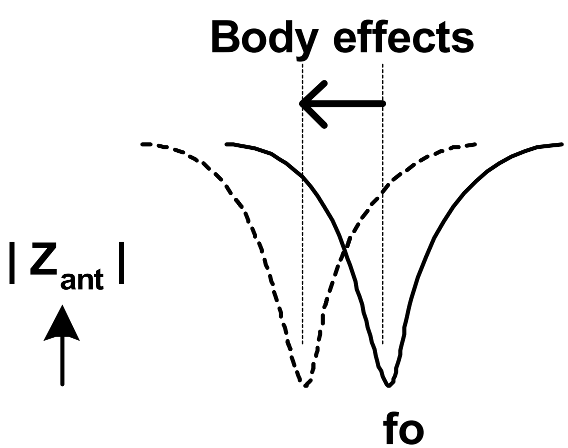
Motivation





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Outline

- Motivation
- Distortion due to antenna mismatch
- Adaptive concepts preserving PA linearity
- Experimental verification
- Conclusions

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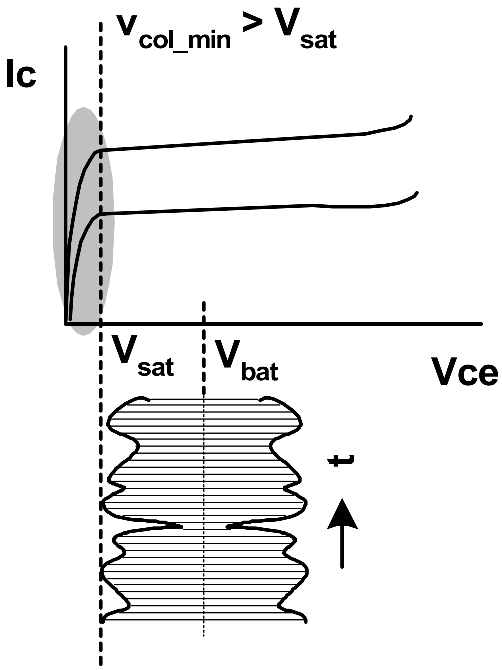
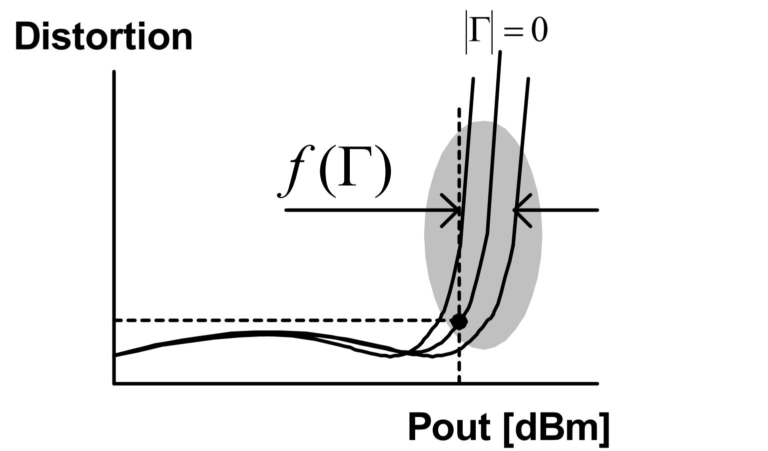
Collector voltage saturation

- Voltage **clipping** of lower–side envelope
- Severe distortion





- **EVM, ACPR and Eff. optimized at 50 Ohm**

Operating area of concern

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Control criterion

$$V_{col\_\min} > V_{sat\_NPN}$$

$$V_{col\_min} = V_{supply\_\min} - \sqrt{\hat{P}_{out\_\max} \cdot Z_{col\_\max}}$$

$$Z_{col\_\max} = R_{col\_nom} \cdot \frac{1+\Gamma_{col}}{1-\Gamma_{col}}; \angle\Gamma_{col} = 0$$

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Detection and correction

- Detection:
  - Minimum collector peak voltage
- Correction:
  - Output power
  - Supply voltage
  - Collector load impedance

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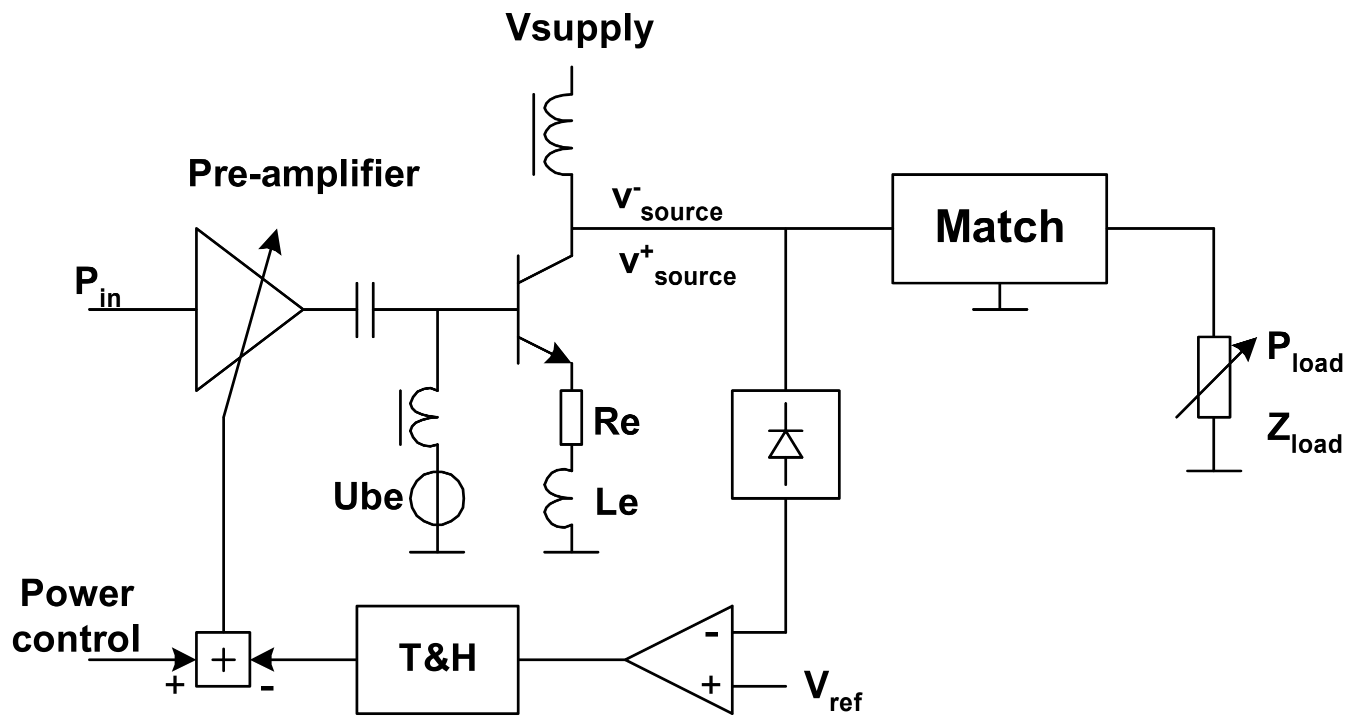
Output power adaptation

- Adaptation via existing power control blocks
- Very low cost implementation



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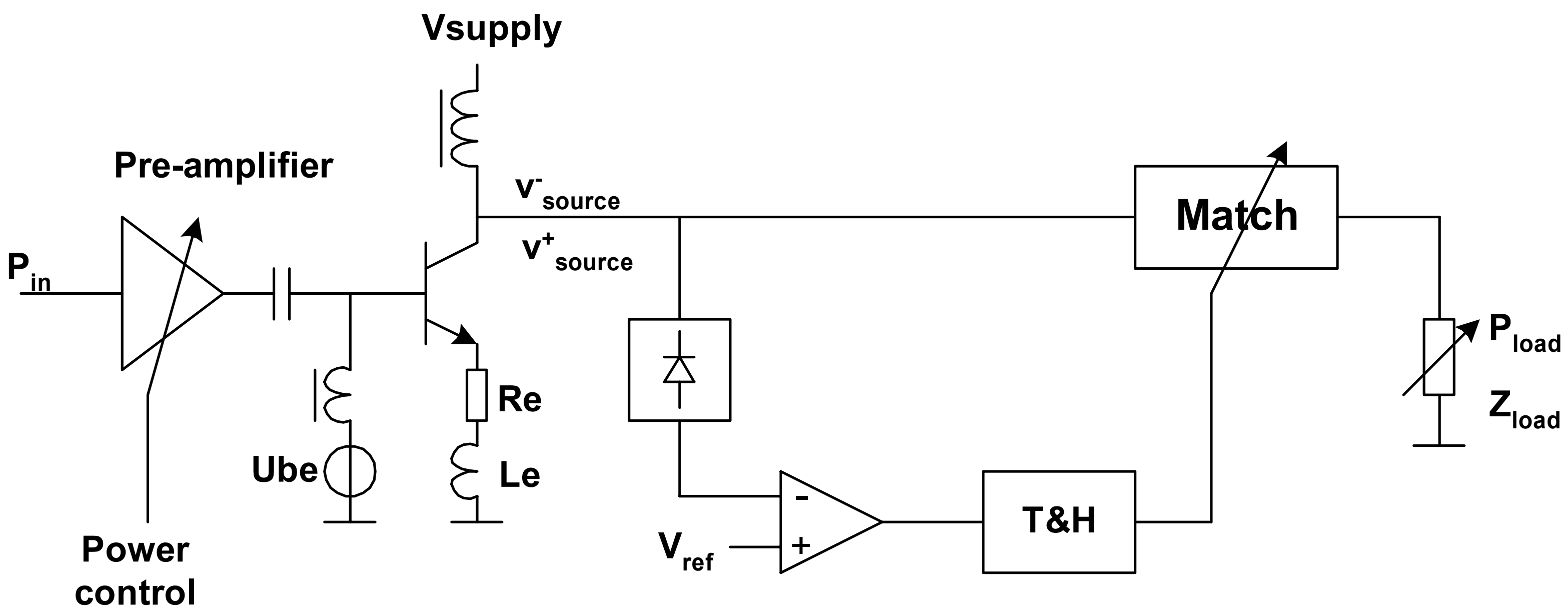
Load line adaptation

- Compensation of the mismatch is best
- Needs linear high-Q variable Ls or Cs (RF-MEMS)



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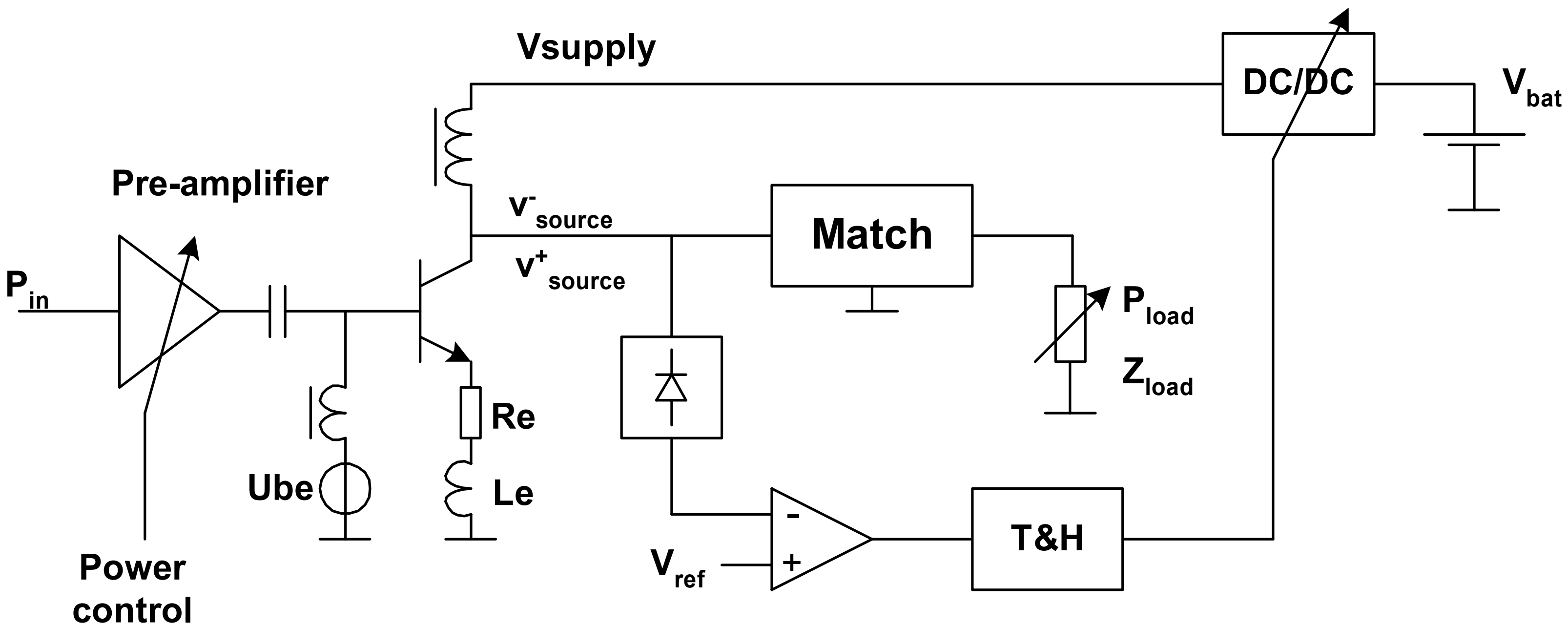
Supply voltage adaptation

- Needs (slow) up-conversion of the supply voltage
- Can be combined with efficiency enhancement by down-conversion of the supply voltage



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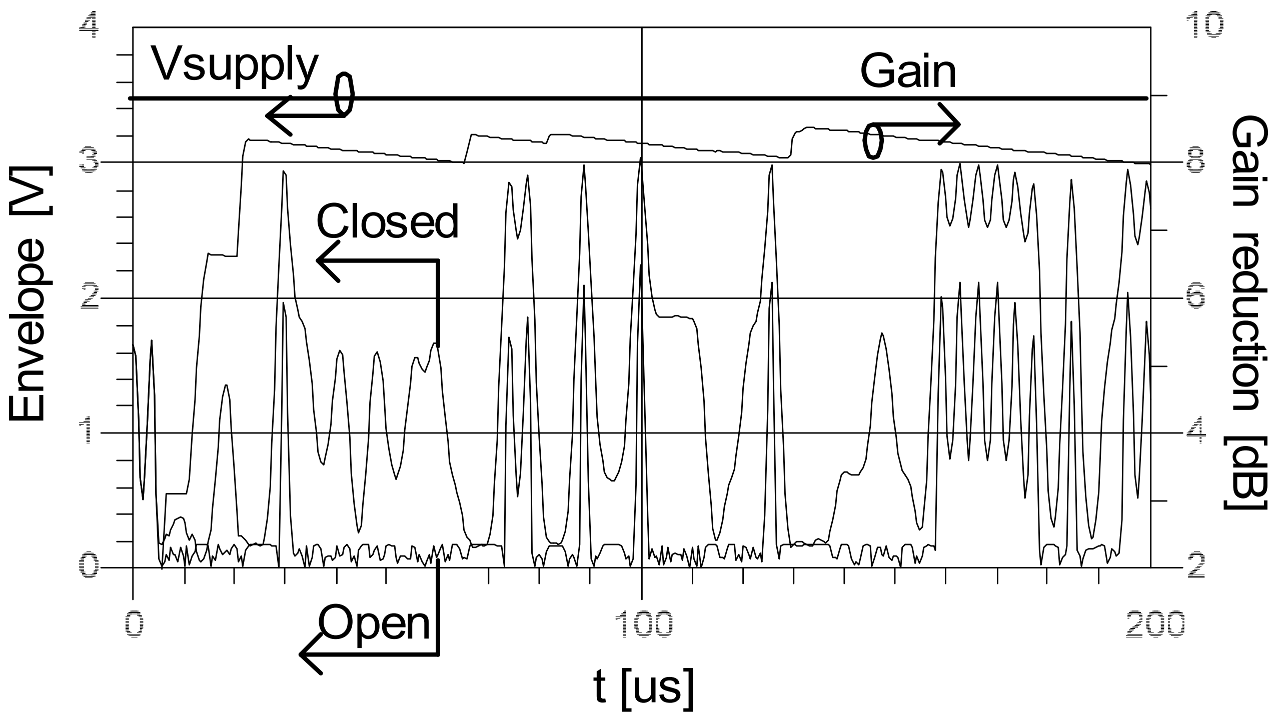
Simulated acquisition of power adapting loop

- Closing the loop avoids collector voltage clipping
- Pre-amplifier gain reduction with ripple due to re-activation of T&H circuit



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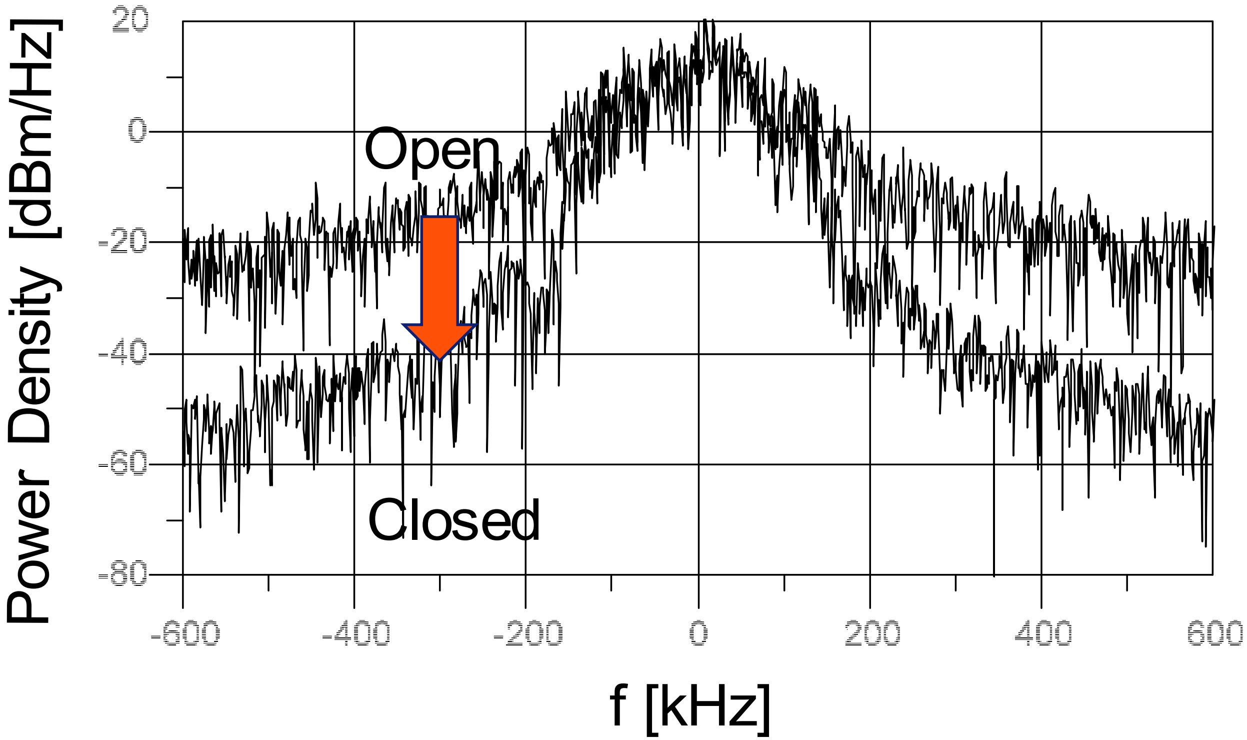
Simulated spectral re-growth

- VSWR = 4, worst case phase;Pout = 28.5dBm at 50 Ω
- Closing the loop reduces spectral re-growth



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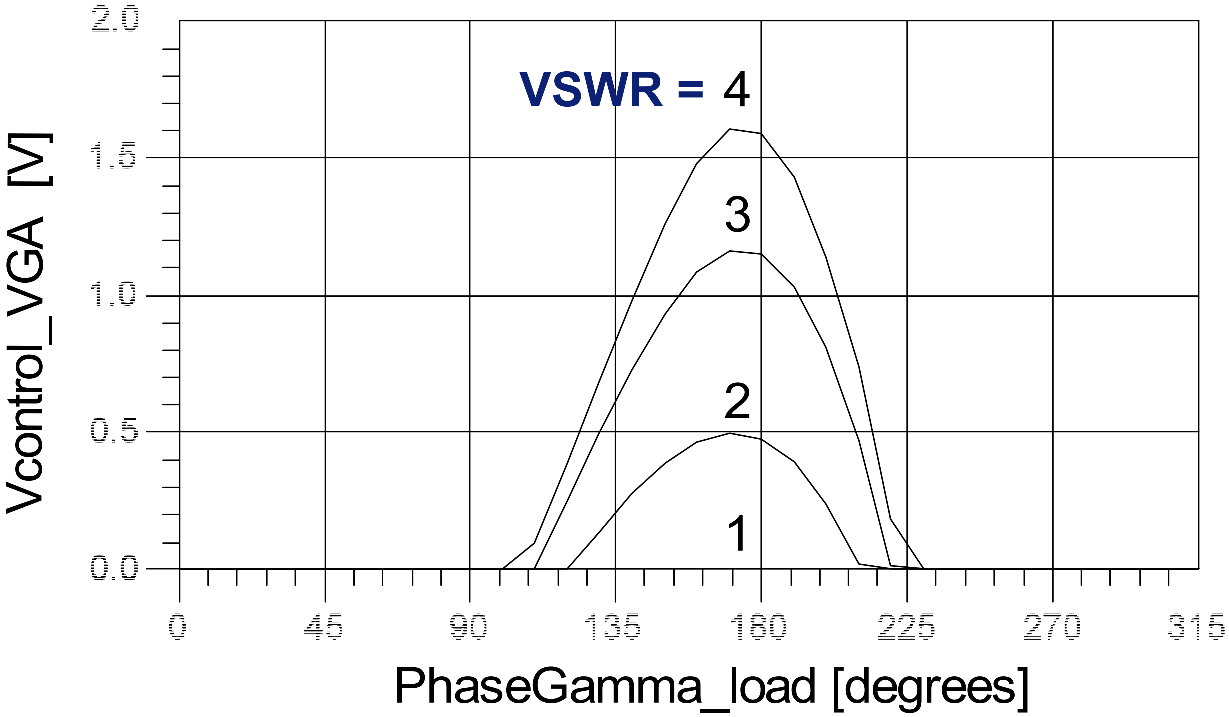
Simulated Vcontrol vs. mismatch phase

- Limited range of mismatch phases
- Largest correction when Z_{col} is largest



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Comparison based on simulations

- Load line adaptation gives best compromise

Method to preserve linearity	**Pout** [dBm]	**Vsupply** [V]	**Zcol** [Ω]	**ACPR** [dBc]	**EVM** [%]
None (50 Ω ref.)	28.6	3.5	2.5	-59	2.5
None	27.3	3.5	7.7	-43	22
Isolator	26.7	3.5	2.5	-59	2.5
Output power	**24.1**	3.5	7.7	-59	3.1
Load line	29.0	3.5	**2.8**	-58	2.5
Supply voltage	28.6	**6.1**	7.7	-59	2.5

VSWR = 4; worst case phase

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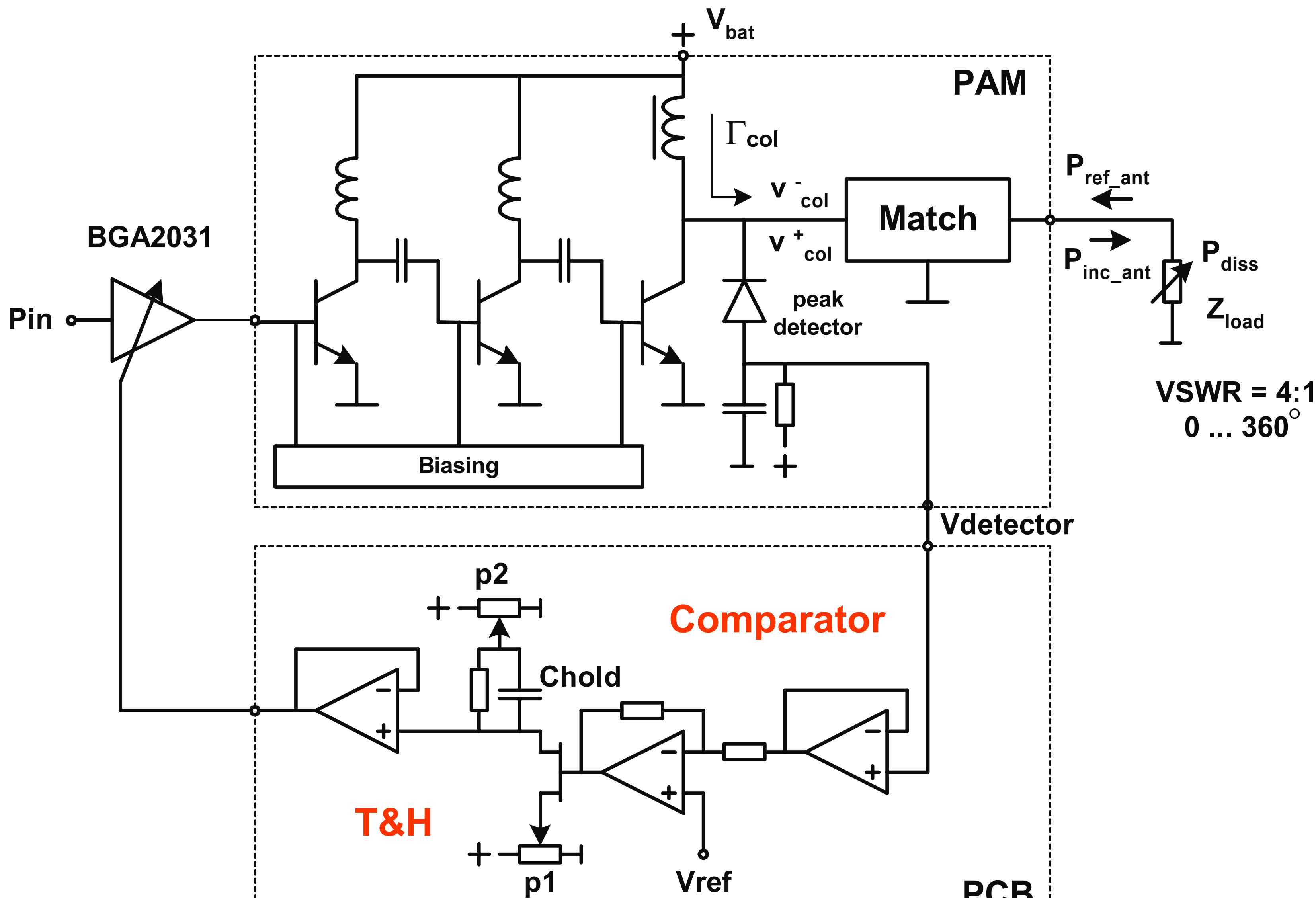
Adaptive PA used for measurements



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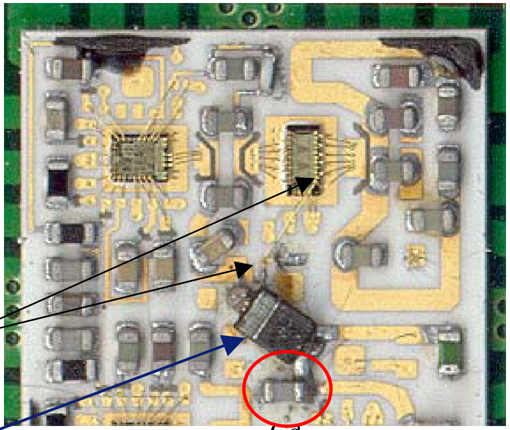
Prototypes

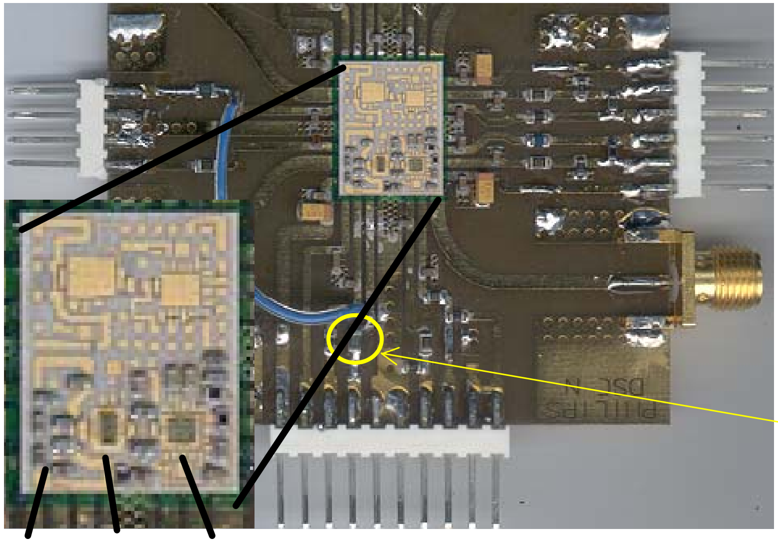
GSM/Edge PAM with discrete detection diode

Bond wire

Det. Diode



Integrated detection diode



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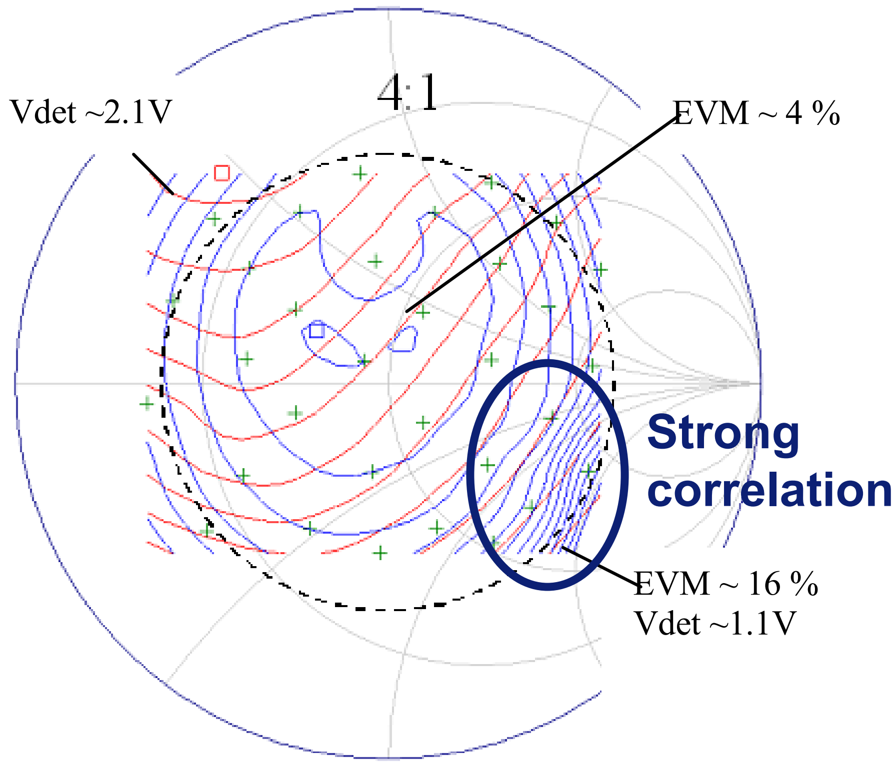
Measured EVM and peak voltage

- Strong correlation between EVM and minimum detected collector peak voltage; Pout = 28.5dBm



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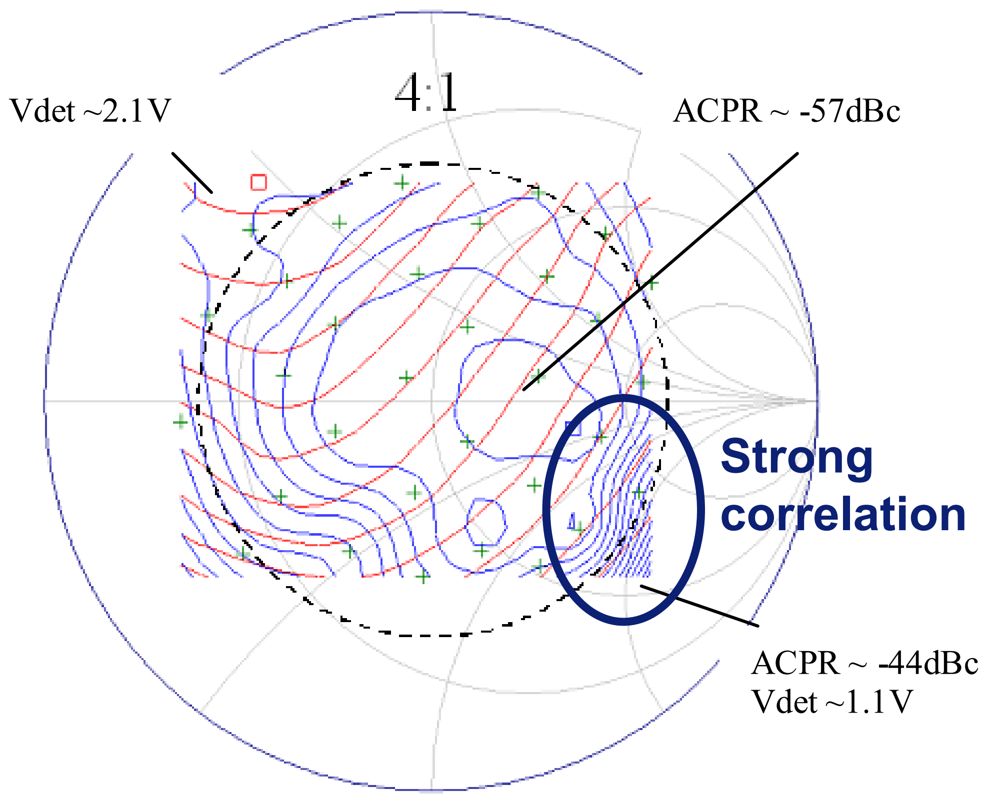
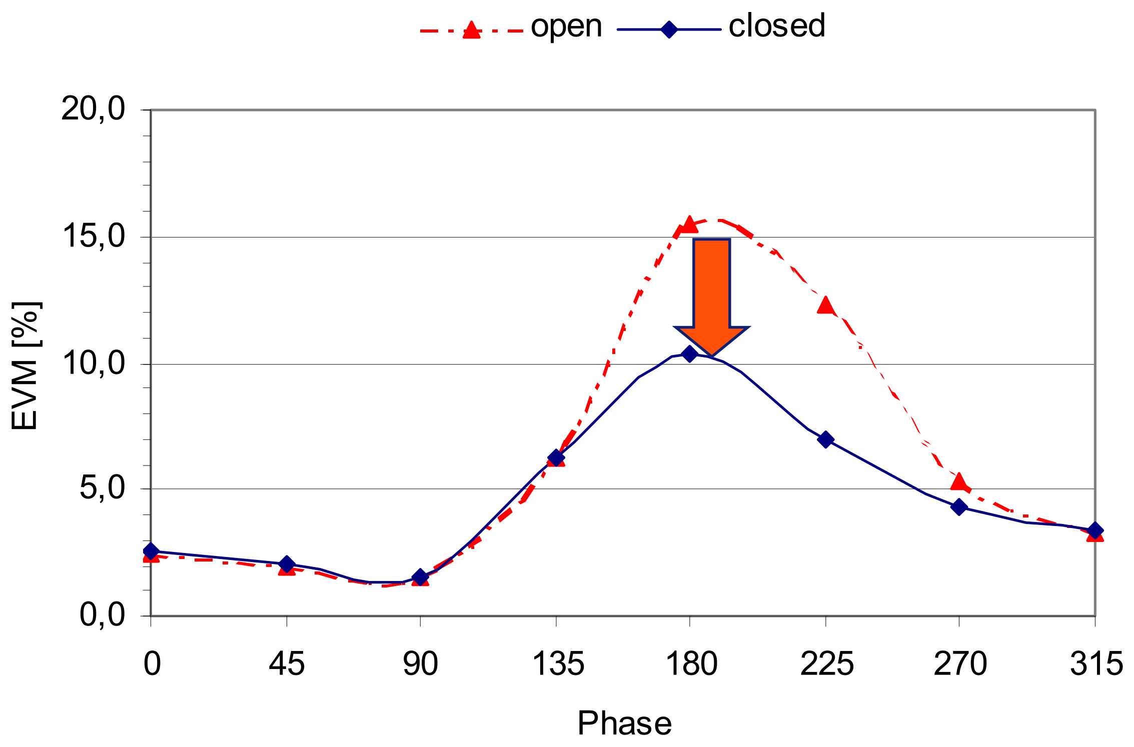
Measured ACPR and peak voltage

- Strong correlation between ACPR and minimum detected voltage; Pout = 28.5dBm



Measured EVM vs. mismatch phase

- VSWR = 4; Pout = 28.5dBm at 50 Ω
- 5% EVM improvement at worst case phase



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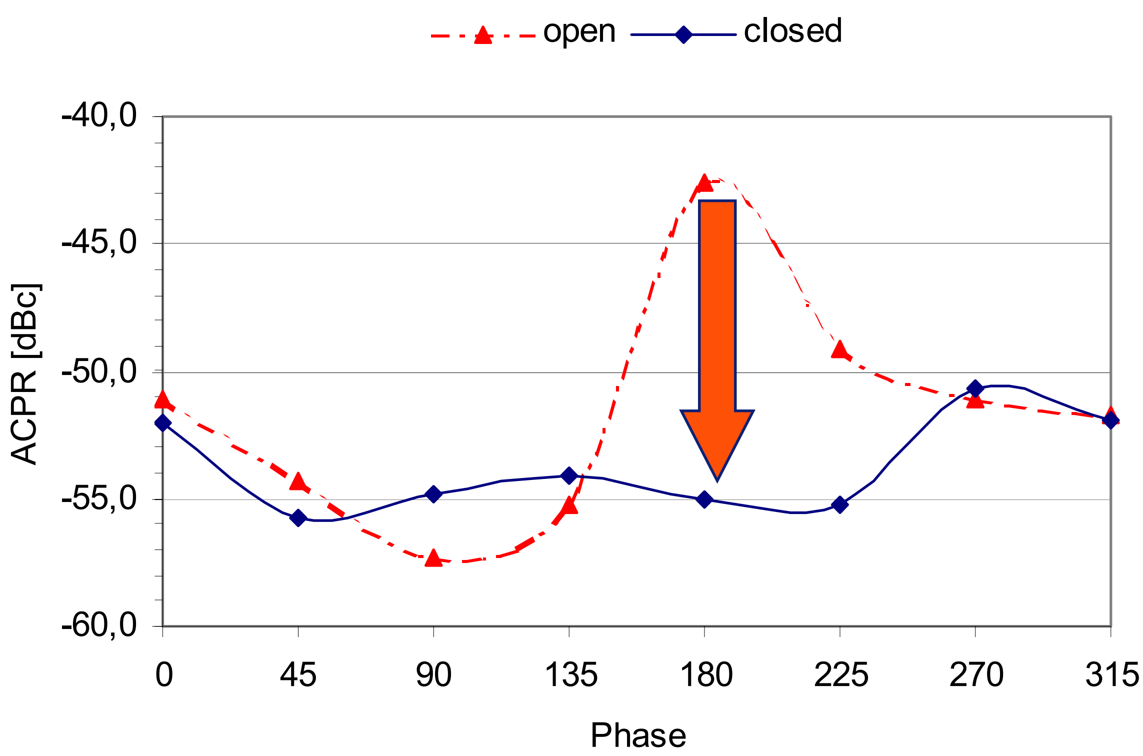
Measured ACPR vs. mismatch phase

- VSWR = 4, worst case phase; Pout = 28.5dBm at 50 Ω
- 10% ACPR improvement at worst case phase



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Conclusions

- Minimum collector voltage can be used as control criterion to preserve linearity adaptively
- Output power adaptation can be implemented at very low cost
- Load line adaptation is very promising and needs linear high-Q Ls or C's (RF-MEMS)
- Supply voltage adaptation needs (slow) up-conversion and can well be combined with efficiency enhancement methods
- Adaptation makes isolators redundant

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Thanks for your attention

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