Friedrich-Alexander-Universität
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Institute for Electronics Engineering

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Tunable BST-Varactor-Based Matching Networks for Mobile Radio Applications

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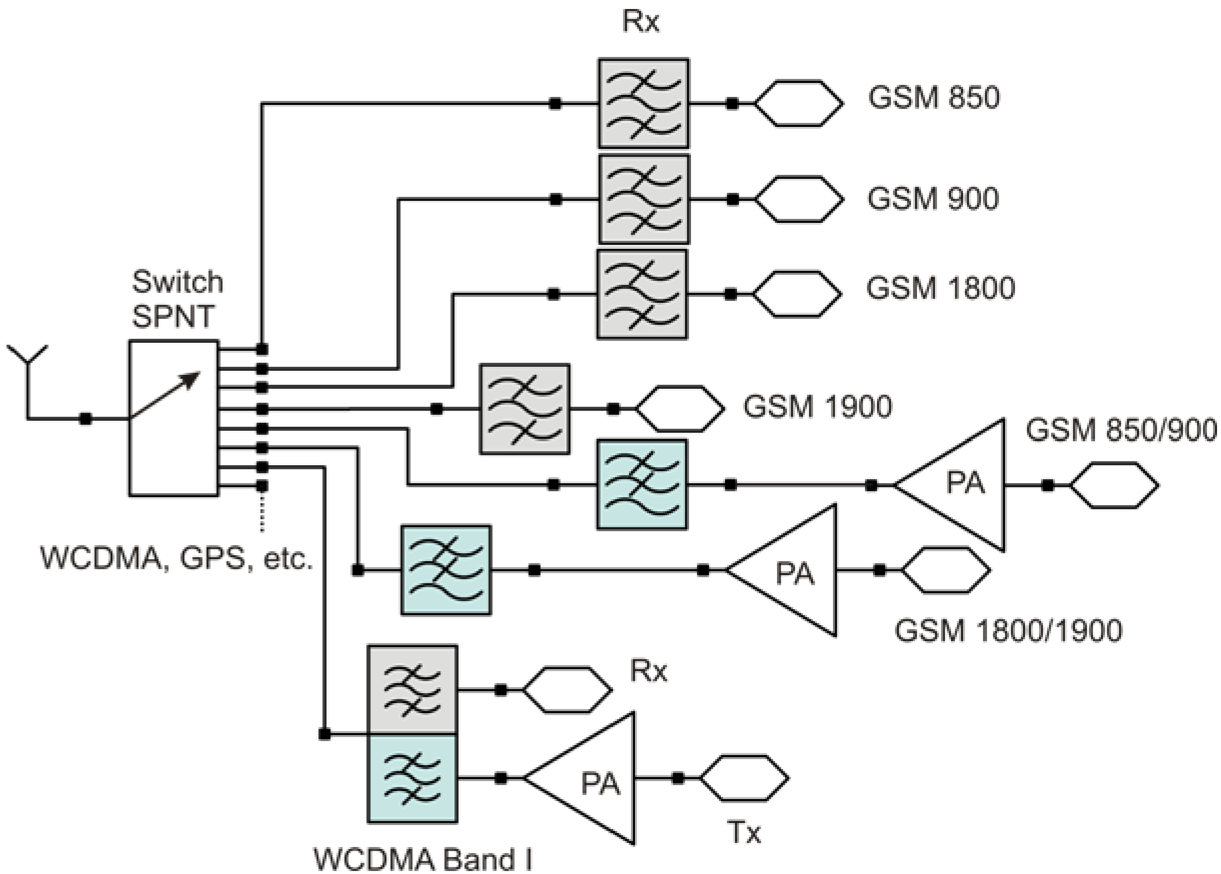
IMS 2008 - Workshop

Outline

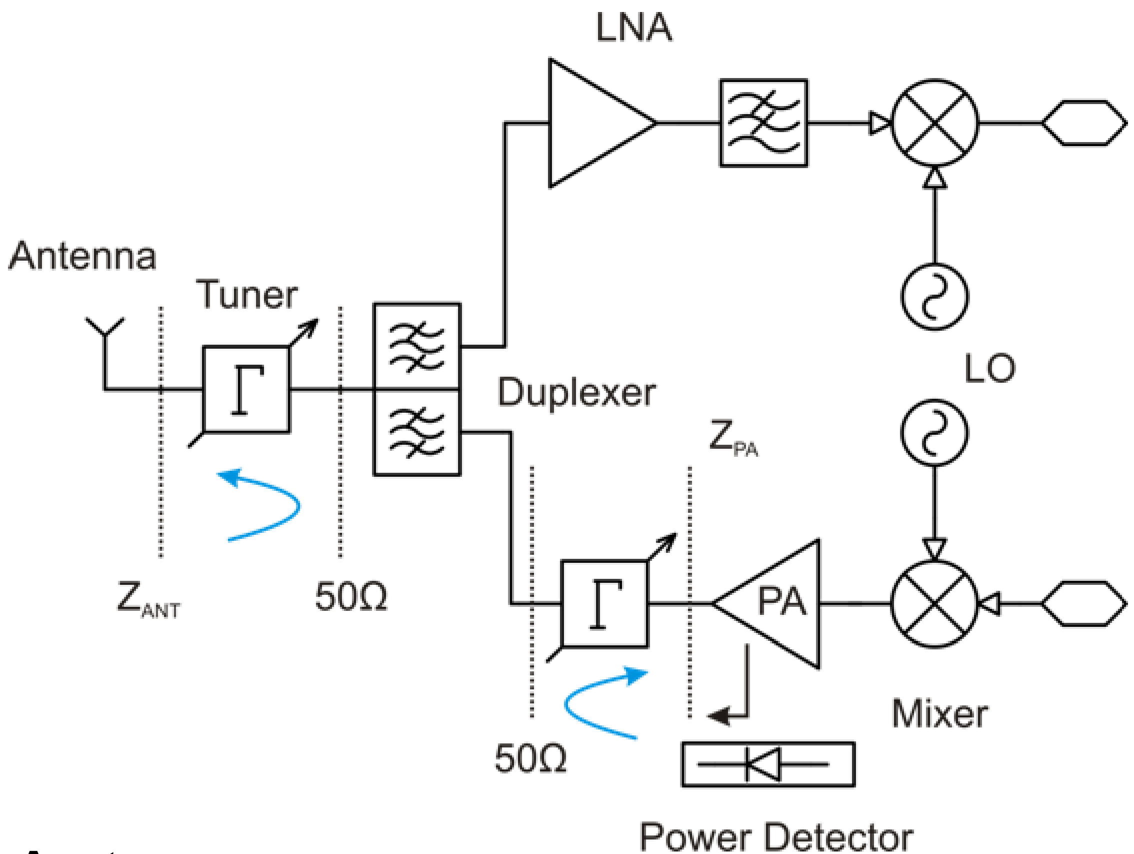
- Motivation
- BST Thin-Film Varactors
- Matching Network Topologies
  - L, Π, T, and Reflection-type
- Linear and Nonlinear Behaviour
- Measurement Results
- Summary

Motivation



- Increasing number of mobile standards

Mismatch Conditions



- Antenna
- Power amplifier

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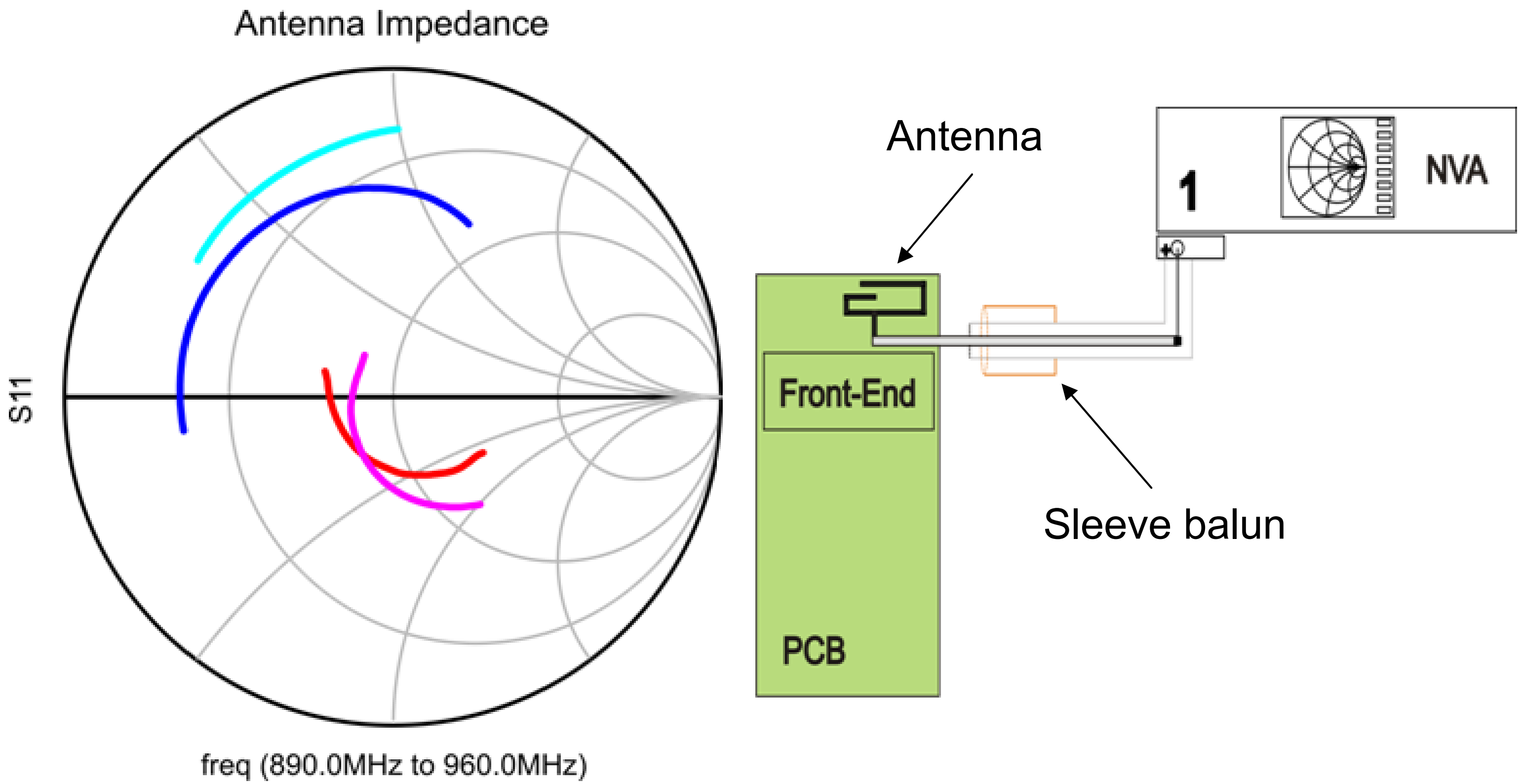
Antenna Mismatch



- Detuning of antenna impedance
- Near-field distortion

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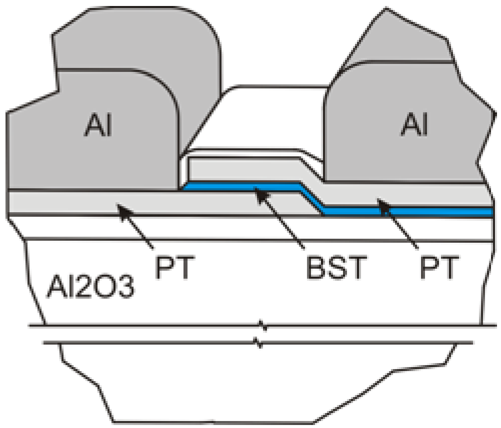
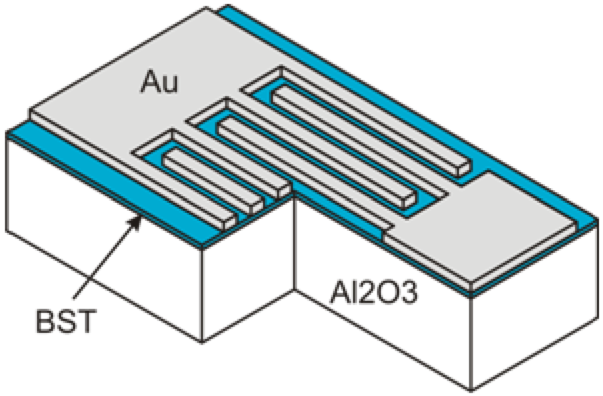
Ferroelectric Varactors





- Thin-film
  - Low bias voltage
  - High C value
  - High tunability
  - Resonances
- Thick-film
  - High bias voltage
  - Low C value
  - Low tunability
  - Large area

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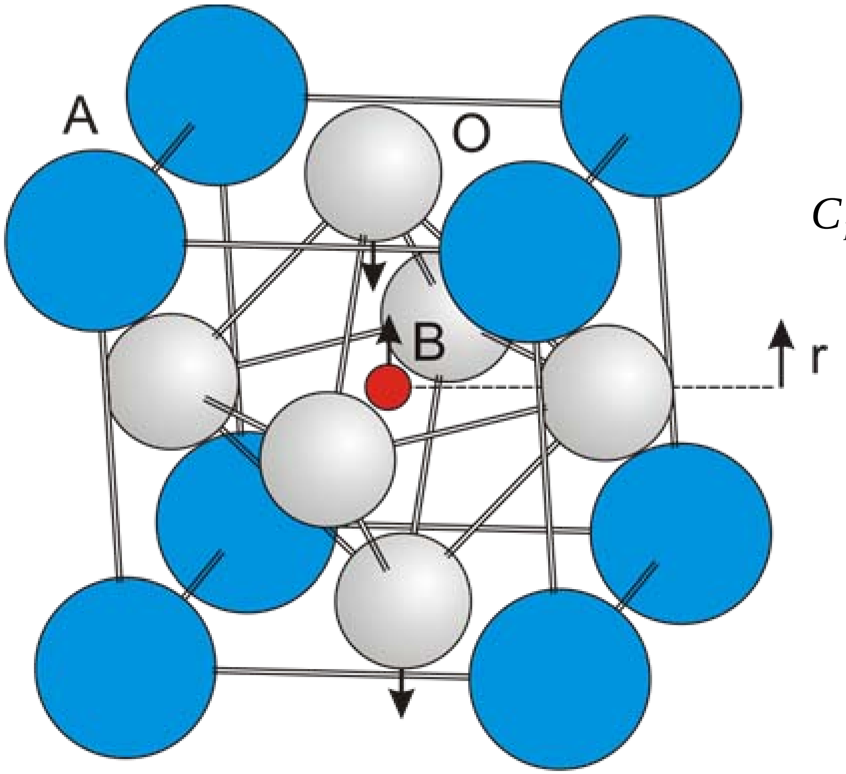
$Ba_xSr_{(1-x)}TiO_3$ – Crystal

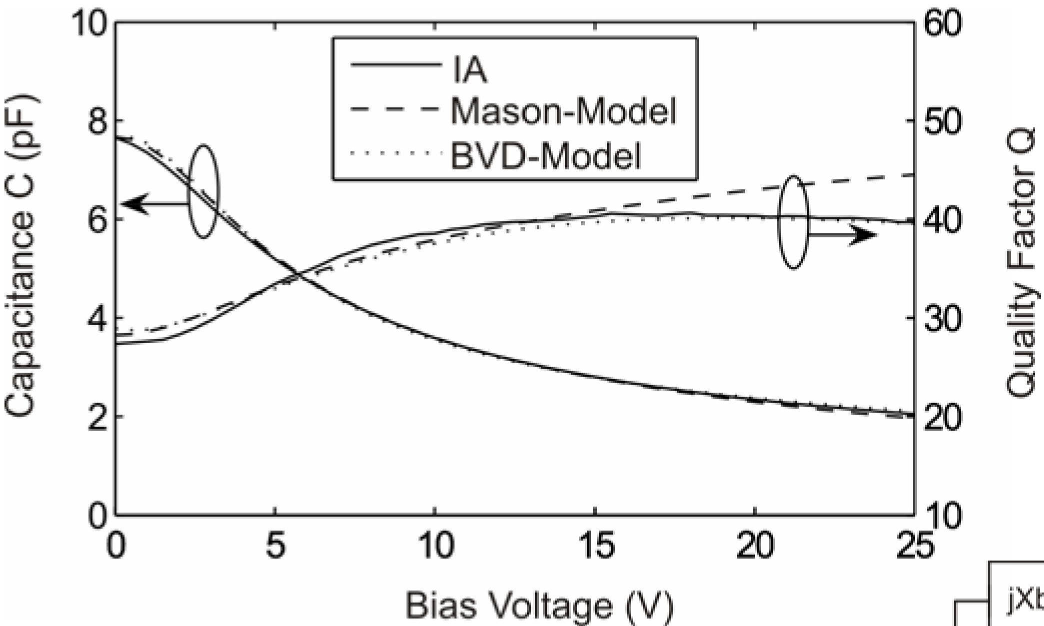


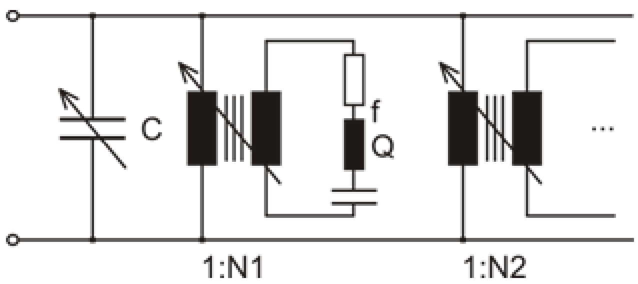
$$C_{BST}(U) = \frac{C_{max}}{2\cosh\left(\frac{2}{3}\sinh^{-1}\left(\frac{2U}{U_{C\max/2}}\right)\right) - 1}$$

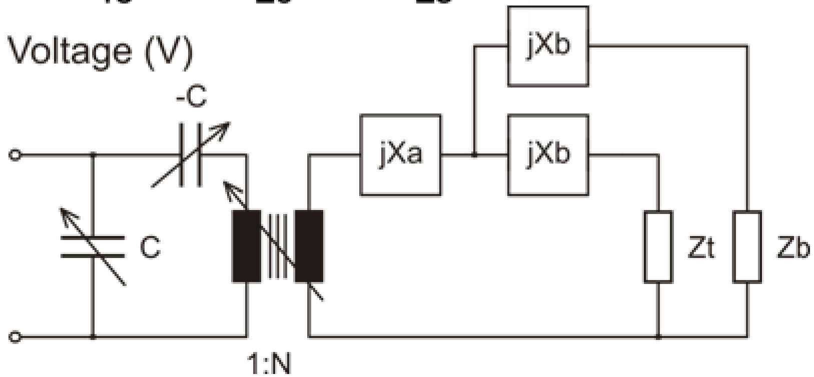
- Perovskite-type crystal
- Ba / Sr ratio

Making Bits Fly

Varactor Modelling

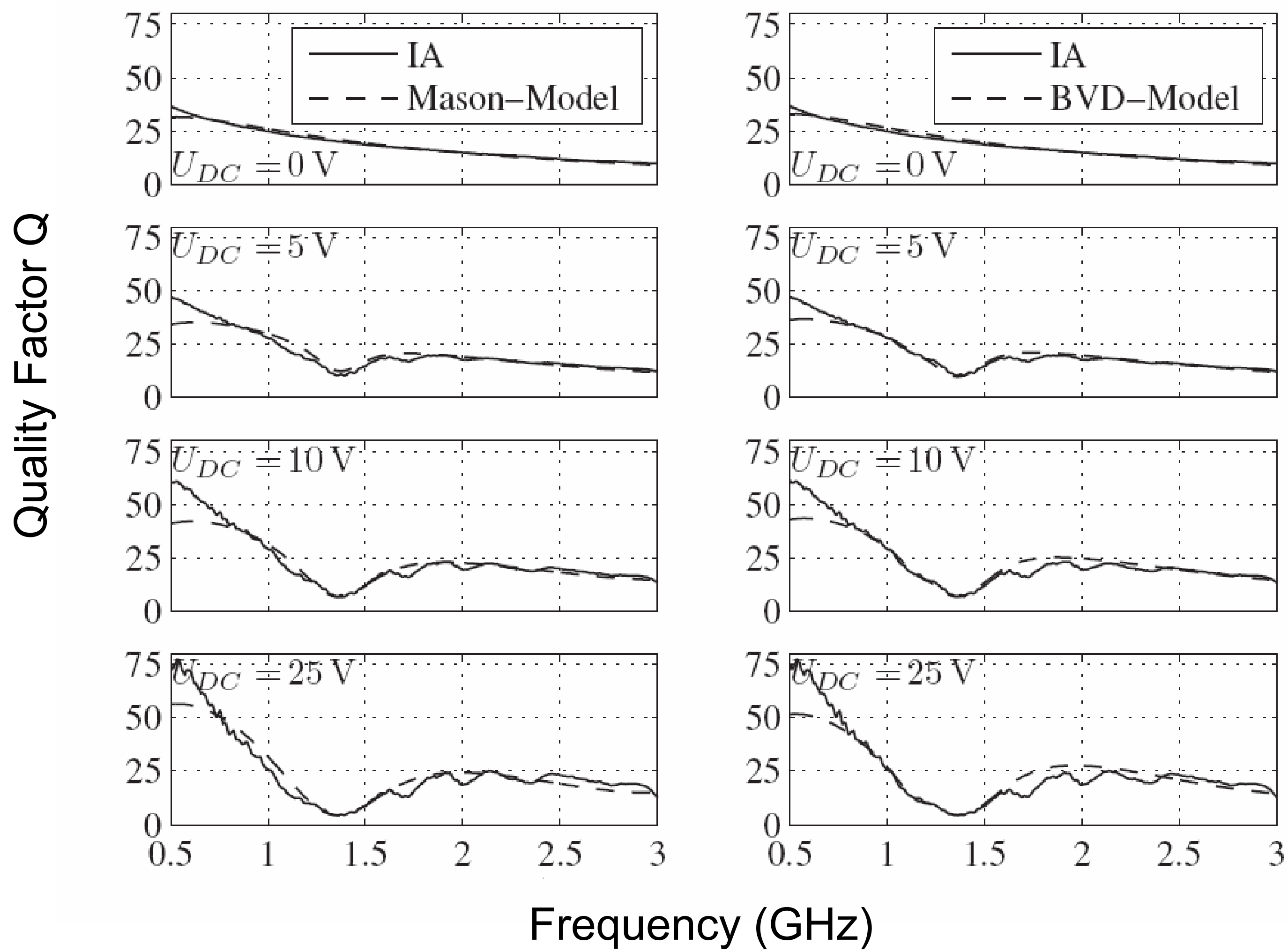






- BVD model
- Mason model

Varactor Modelling (2)



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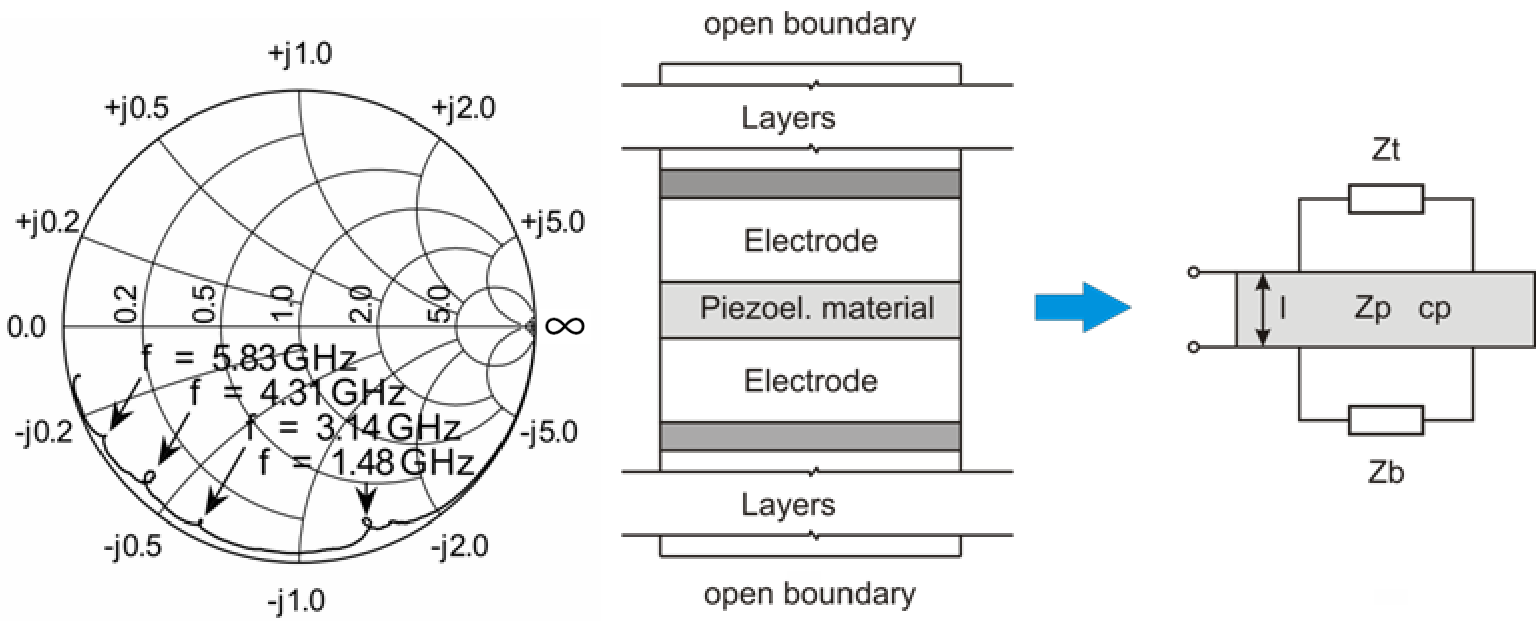
06 / 16 / 2008

Acoustic Resonances



- Layered material stack
- Discrete acoustic impedances
- Parasitic “FBAR”

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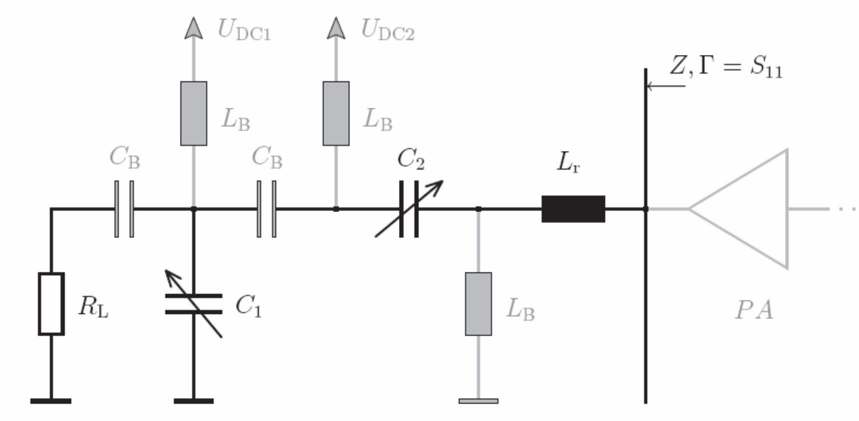
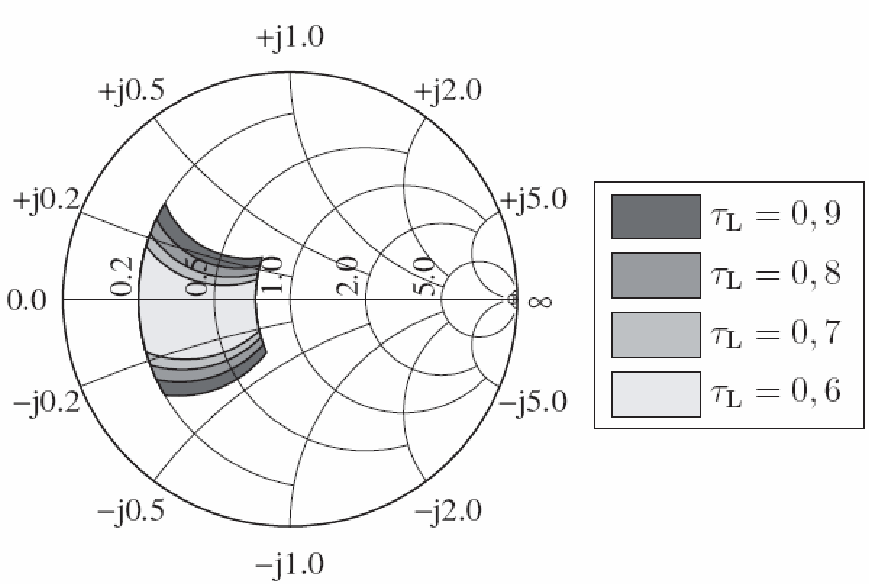
L - Matching Network



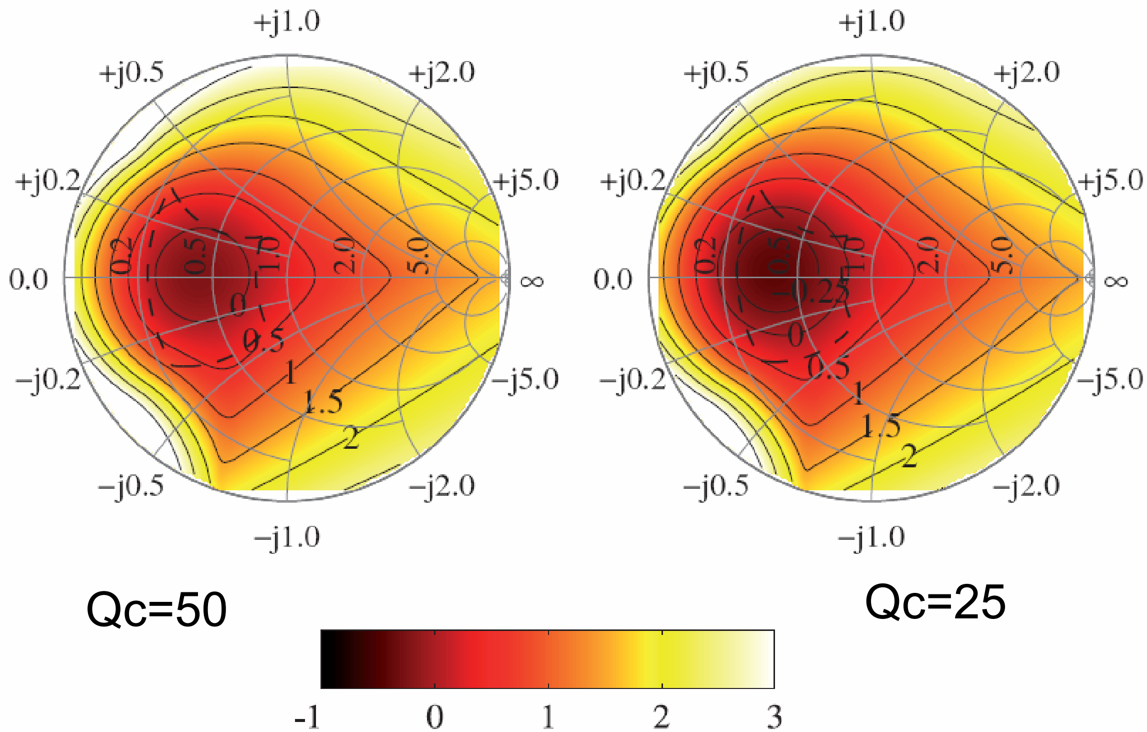


- PA Matching
- Tunable L is series LC
- Small matching area

L - Network Gain

Fixed MN with Zin=25Ω

SMD 0402 components



Qc=50

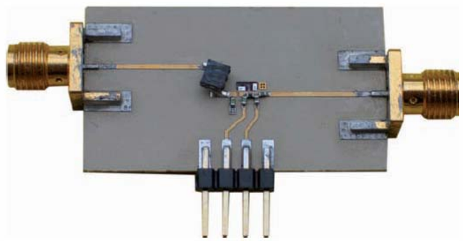
Qc=25

-1 0 1 2 3

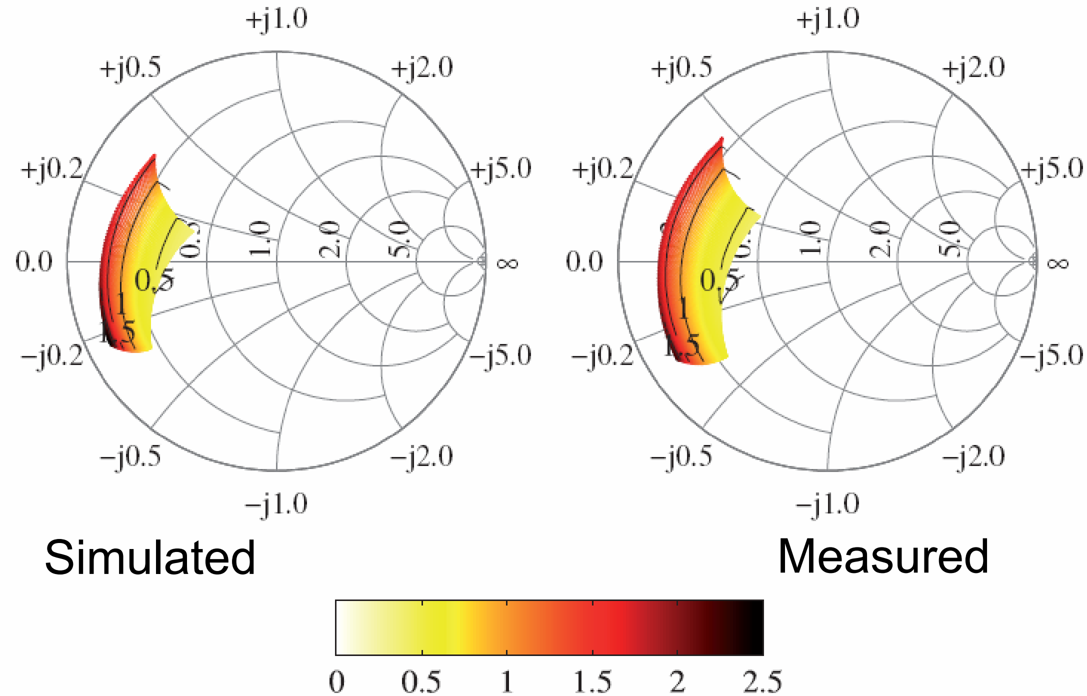
Gain (dB)

- Losses for minor impedance variations

L - Matching Area



Bias



Transducer Power Loss (dB)

- Excellent agreement
- Dynamically adjustable PA impedance

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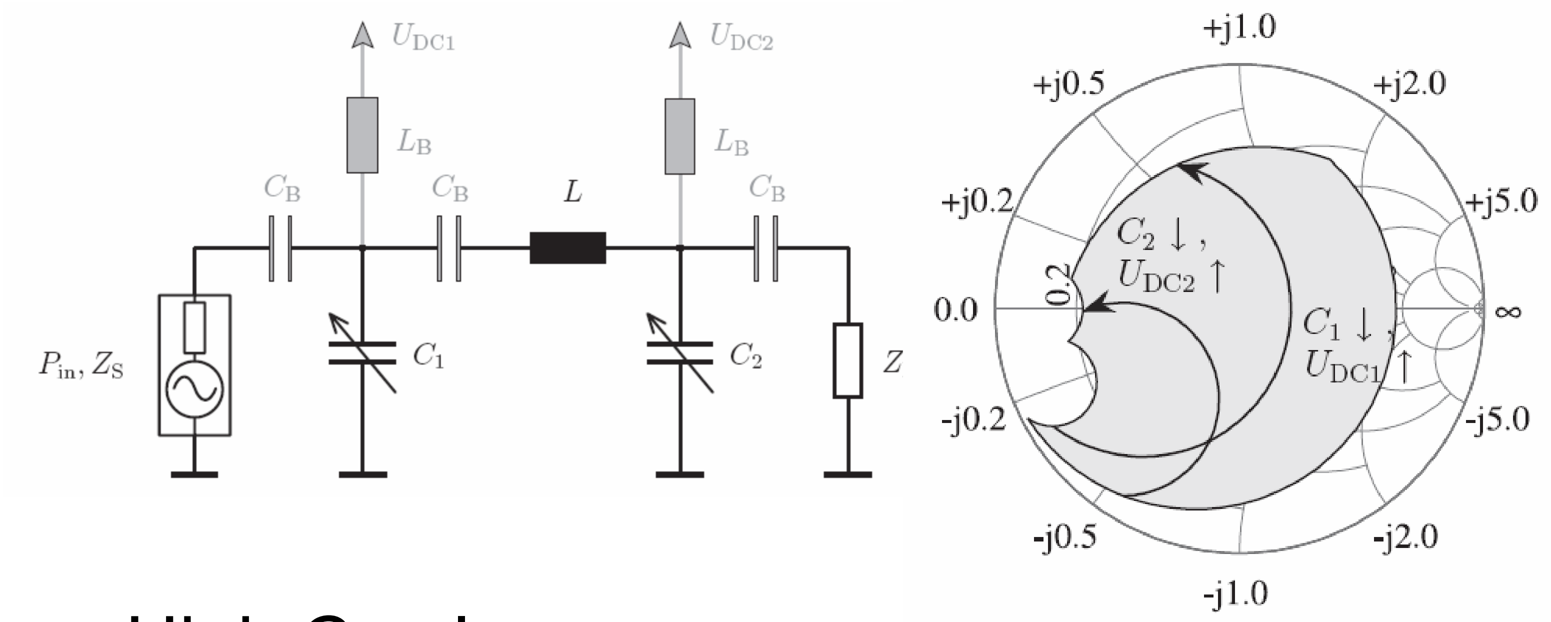
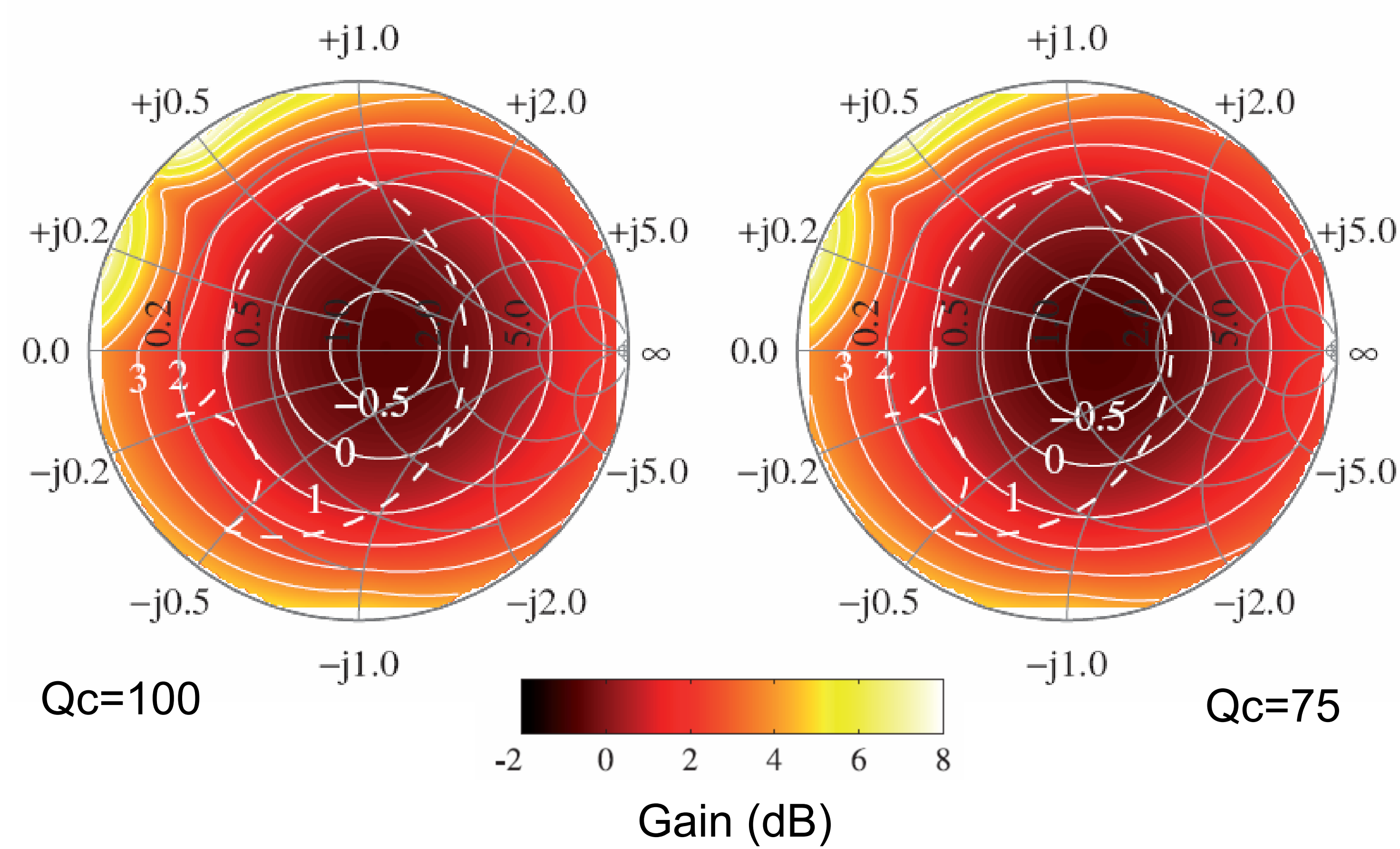
Π - Matching Network



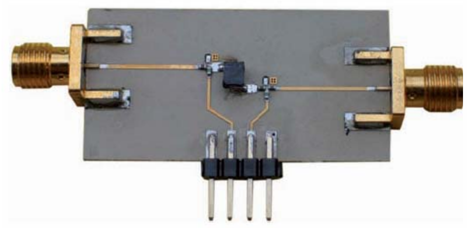
- High C value
- Suitable for low impedances
- Low IMD

Π – Network Gain

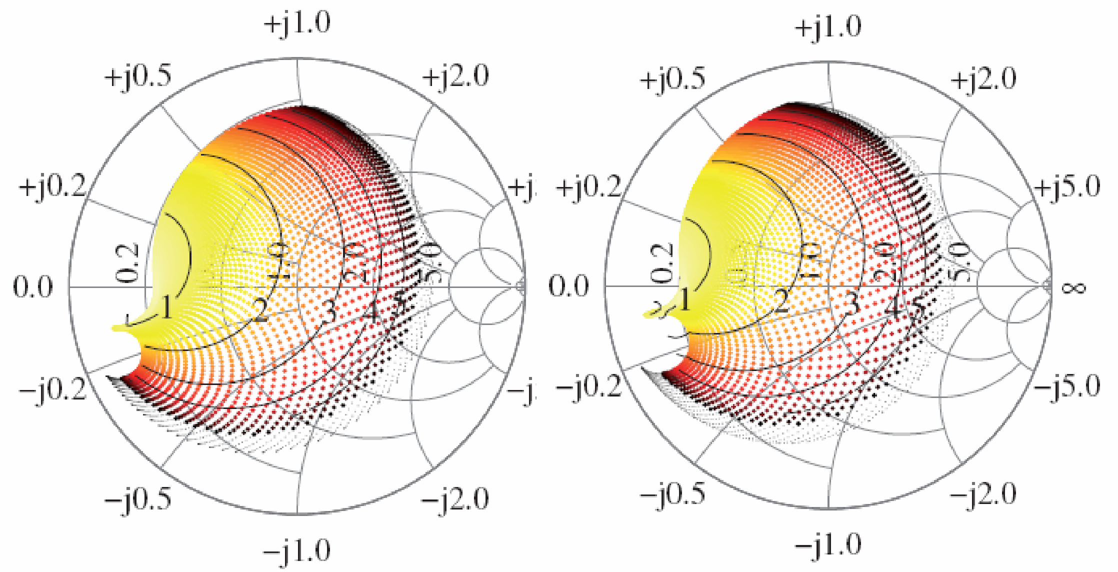


- Gain for significant impedance variations

Π – Matching Area



Bias



Simulated

Measured

Transducer Power Loss (dB)

- Excellent agreement
- Losses increase for higher impedances

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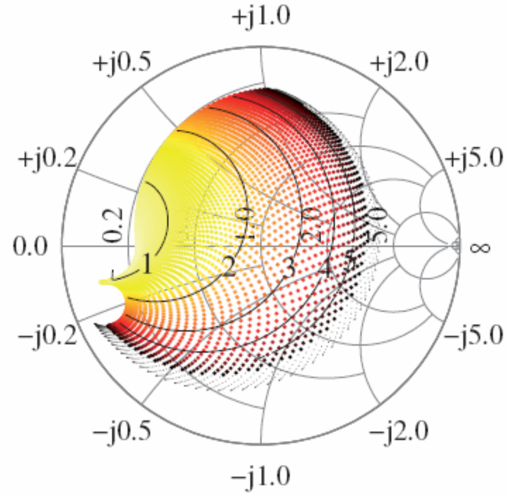
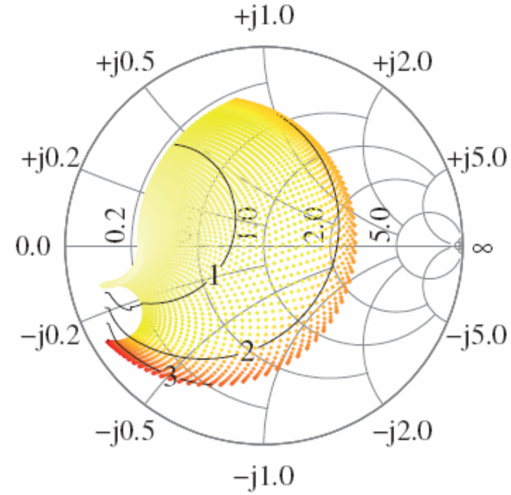
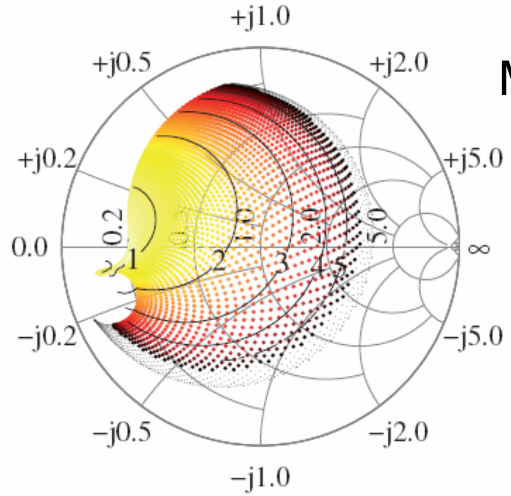
Assembly Parasitics



Simulated with bond wires



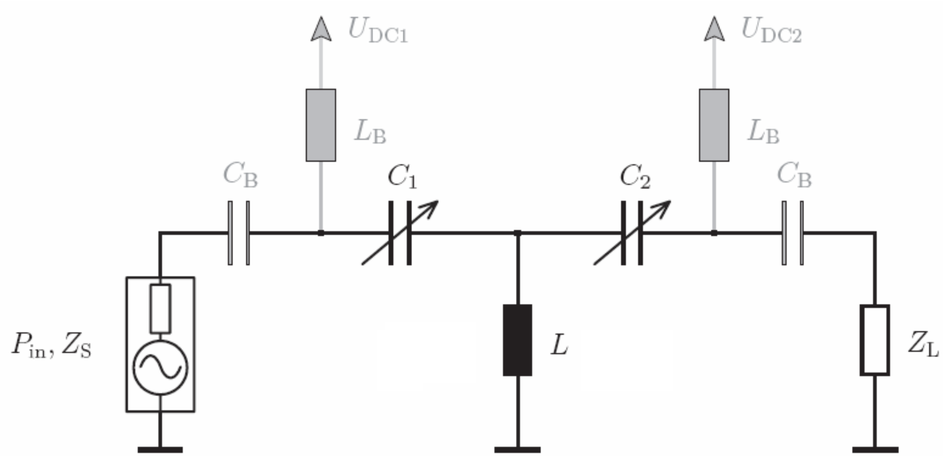
Simulated without bond wires

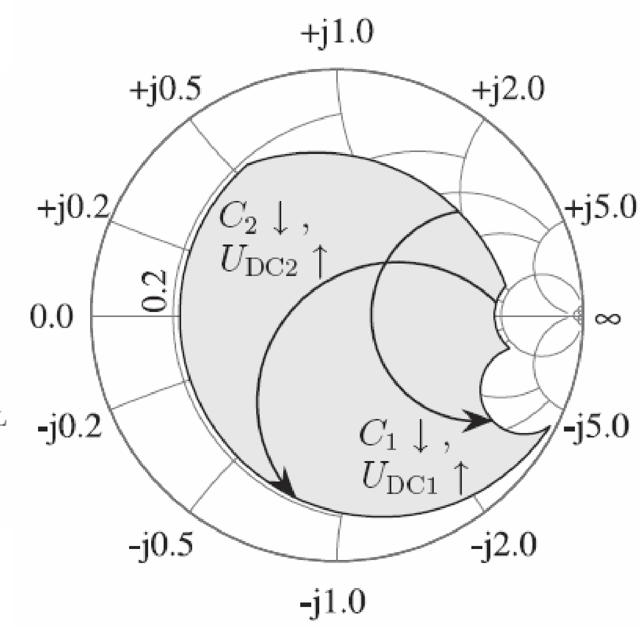


Measured

Transducer Power Loss (dB)

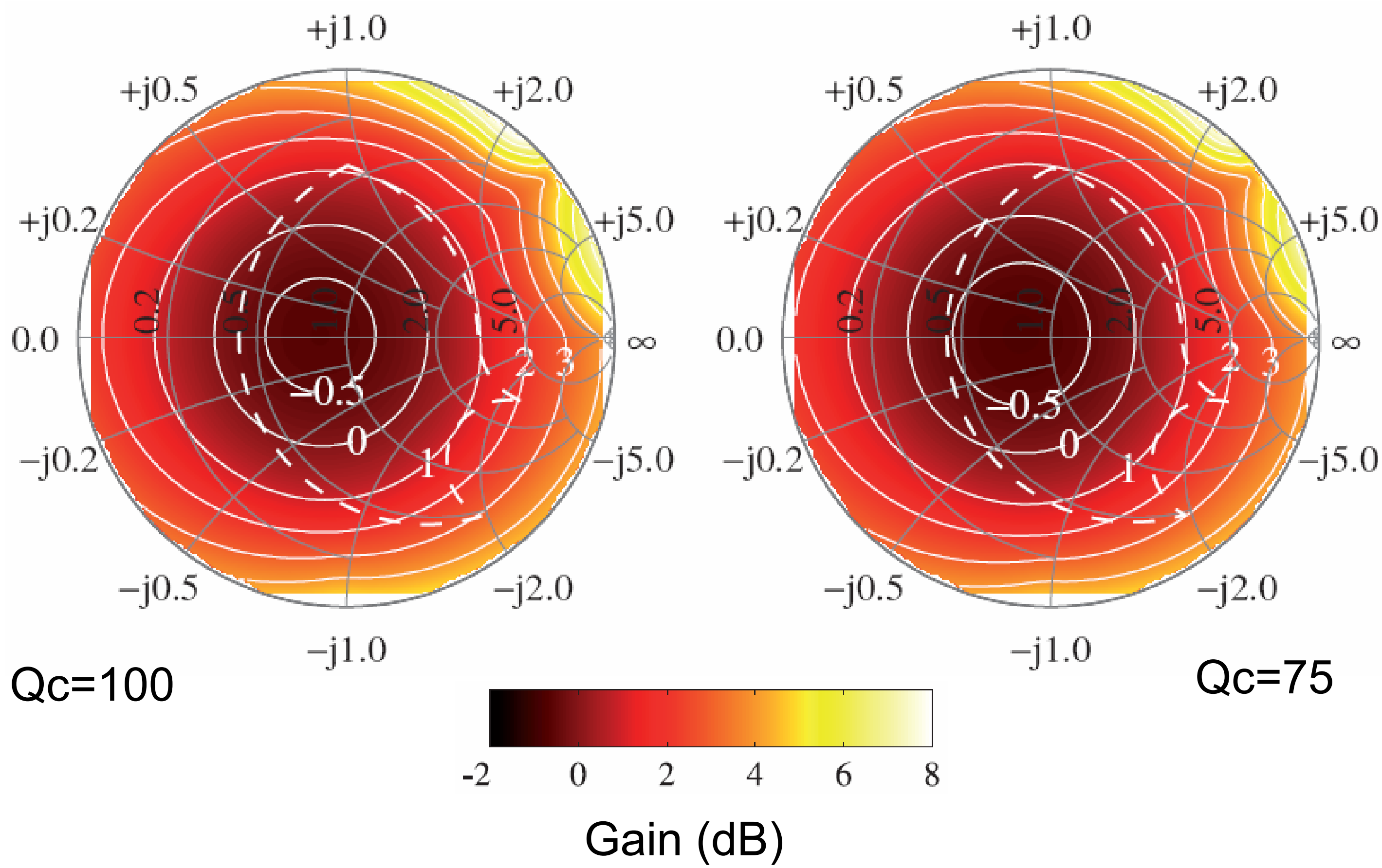
T – Matching Network





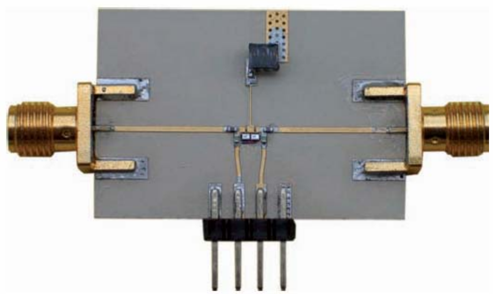
- Low C values
- Suitable for high impedances
- High IMD

T – Network Gain

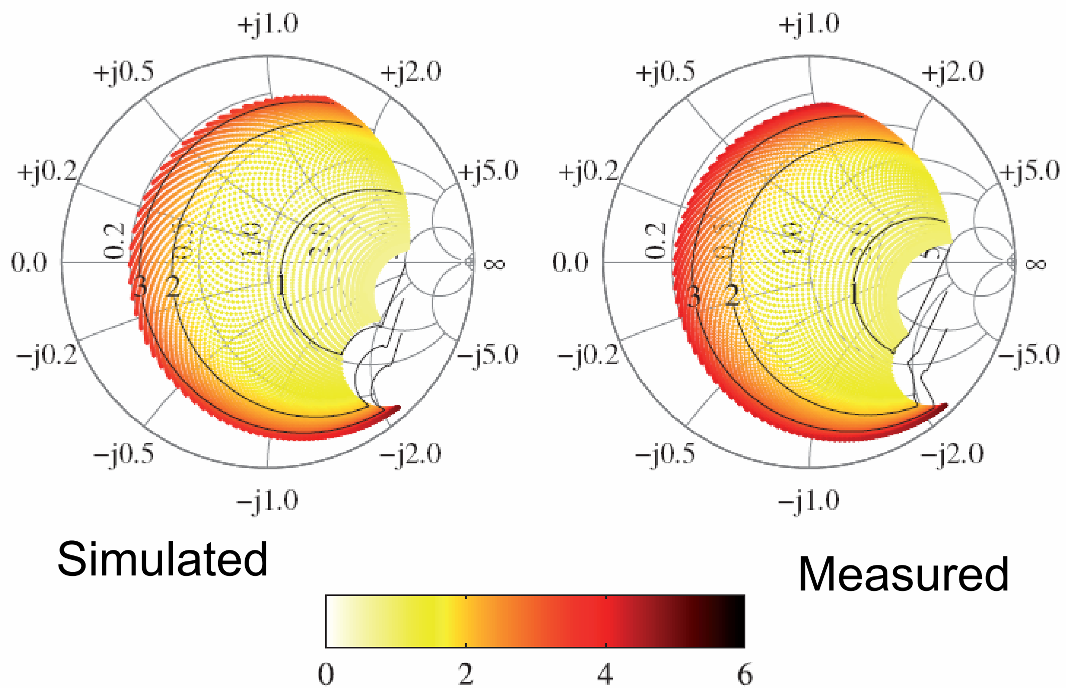


- Gain for signifficant impedance variation

T – Matching Area



Bias



Transducer Power Loss (dB)

- Excellent agreement
- Higher losses for low impedances

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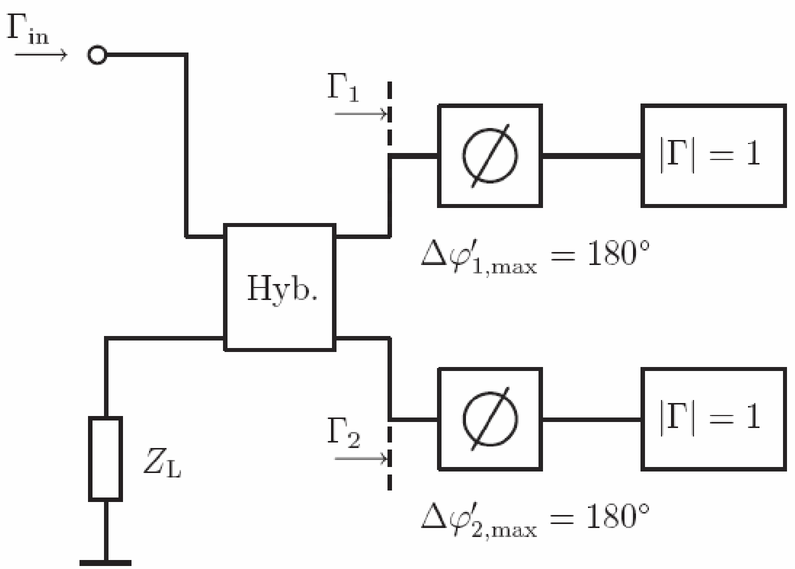
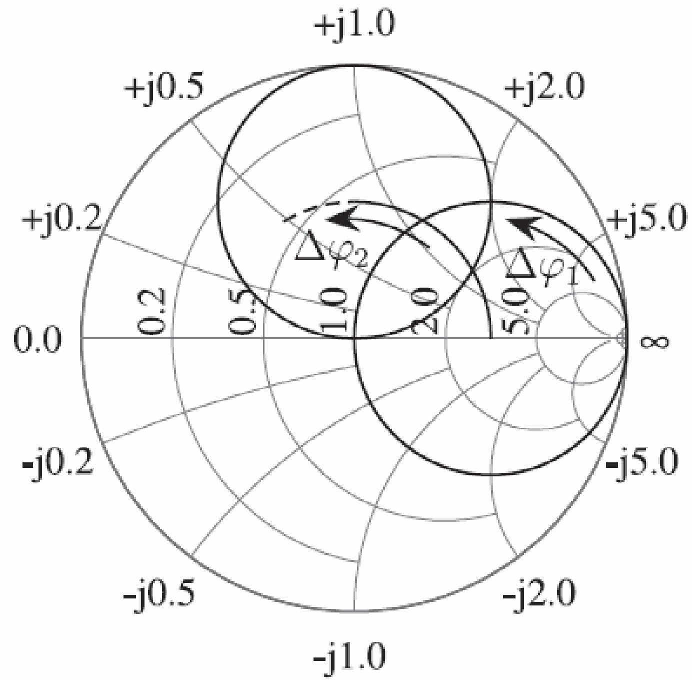
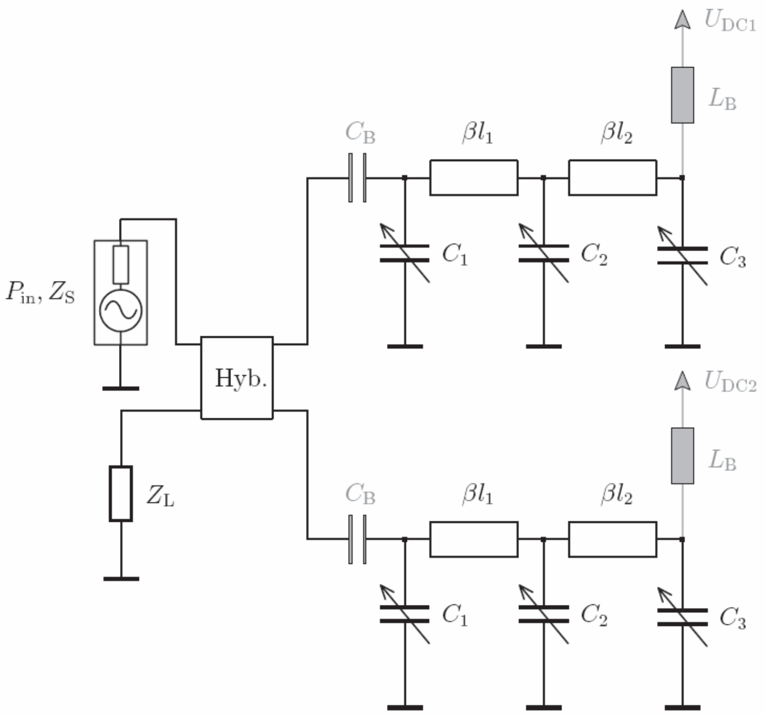
Reflection – Matching Network

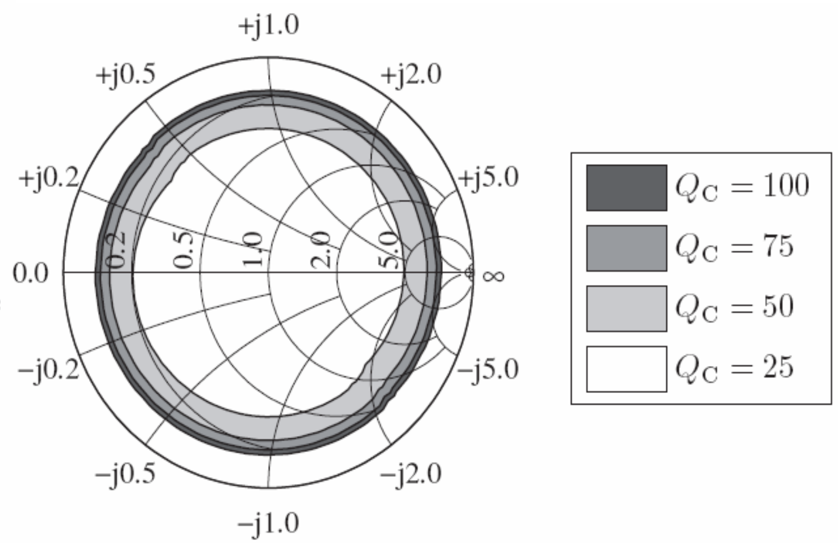




- Total Smith-chart area coverage
- Hybrid coupler and phase shifters
- Large circuit dimension

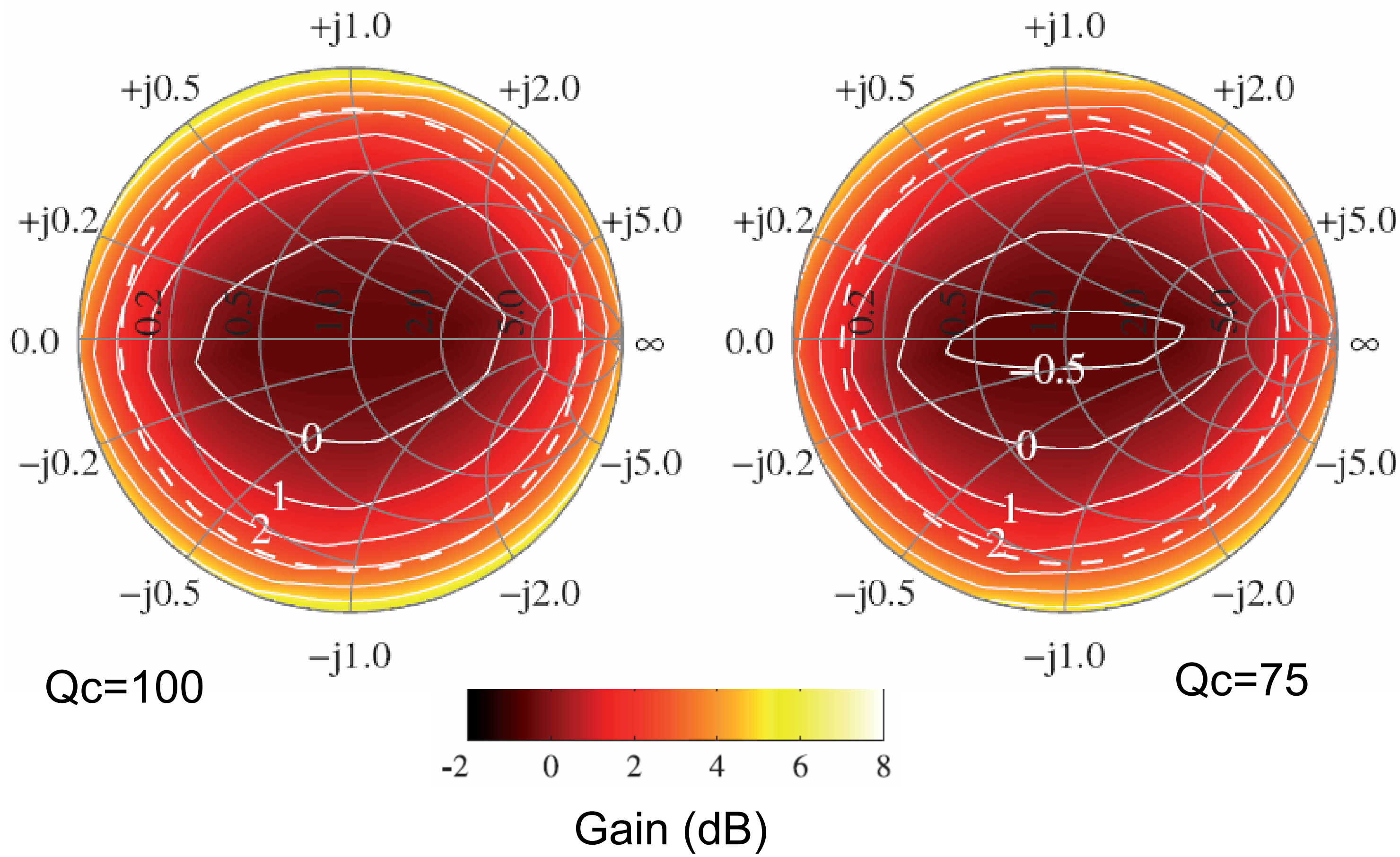
Reflection Type Circuit





- High Q values for varactors lead to large matching area

Reflection – Network Gain



- Gain for signifficant impedance variation

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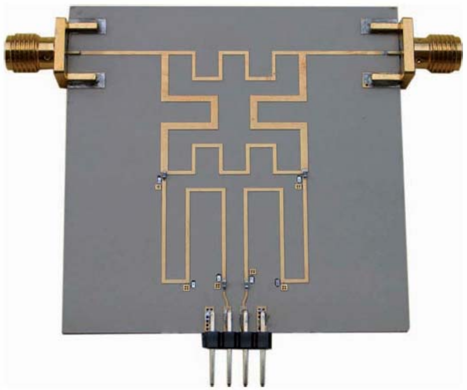
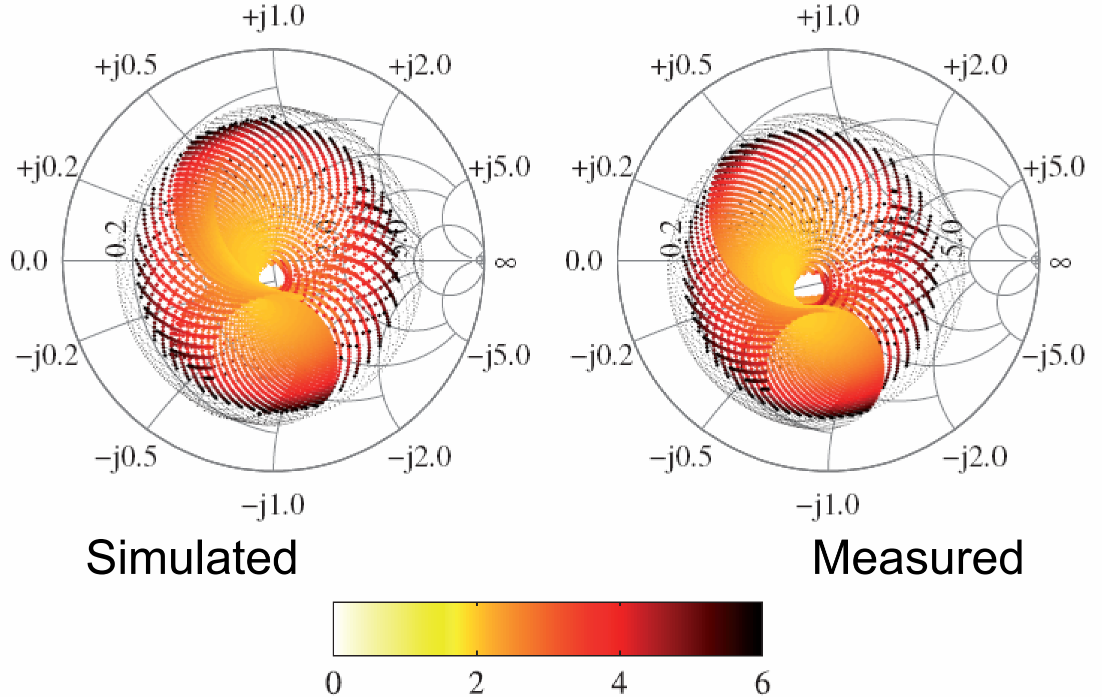
Reflection – Matching Area



Bias



Simulated

Measured

Transducer Power Loss (dB)

- Excellent agreement
- Symmetric matching area

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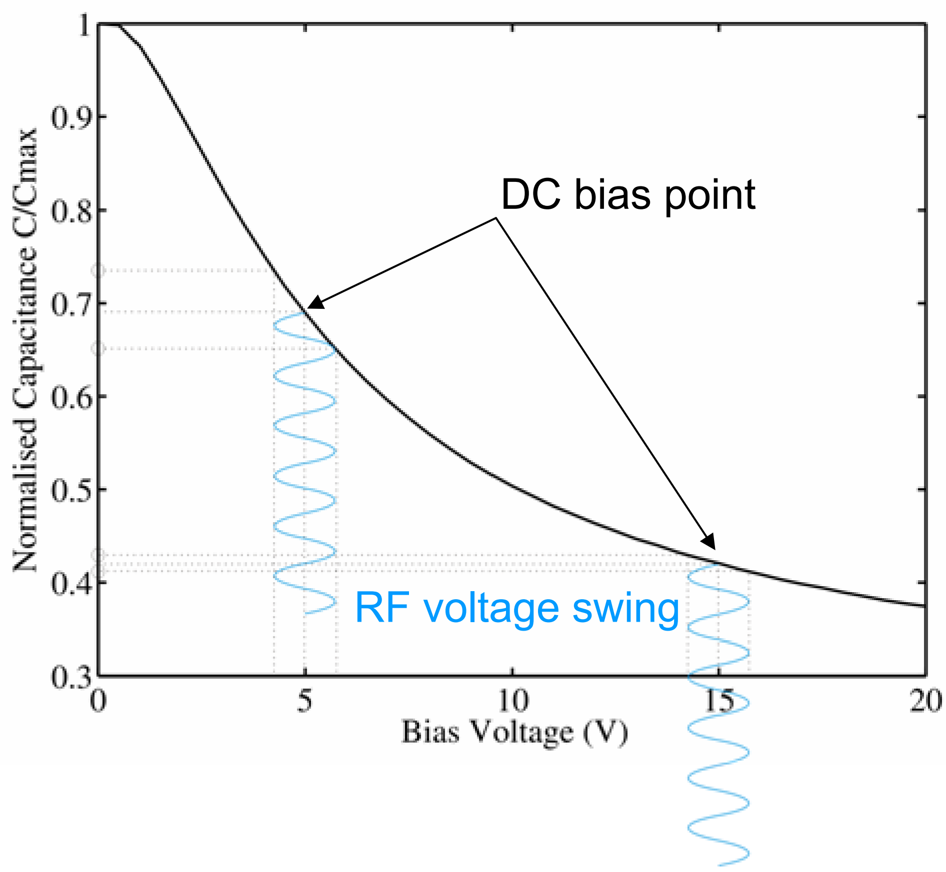
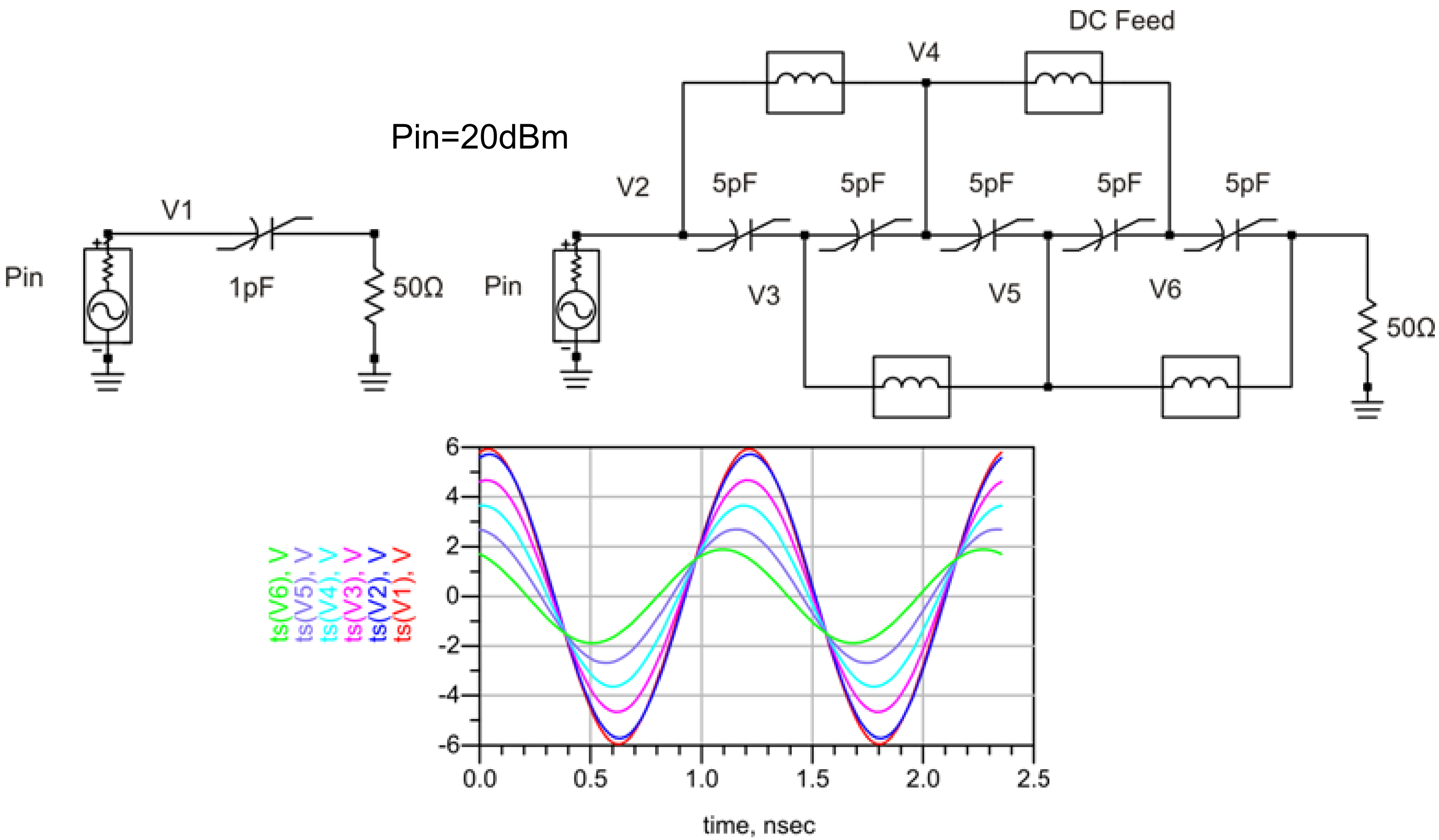
Varactor Nonlinearity



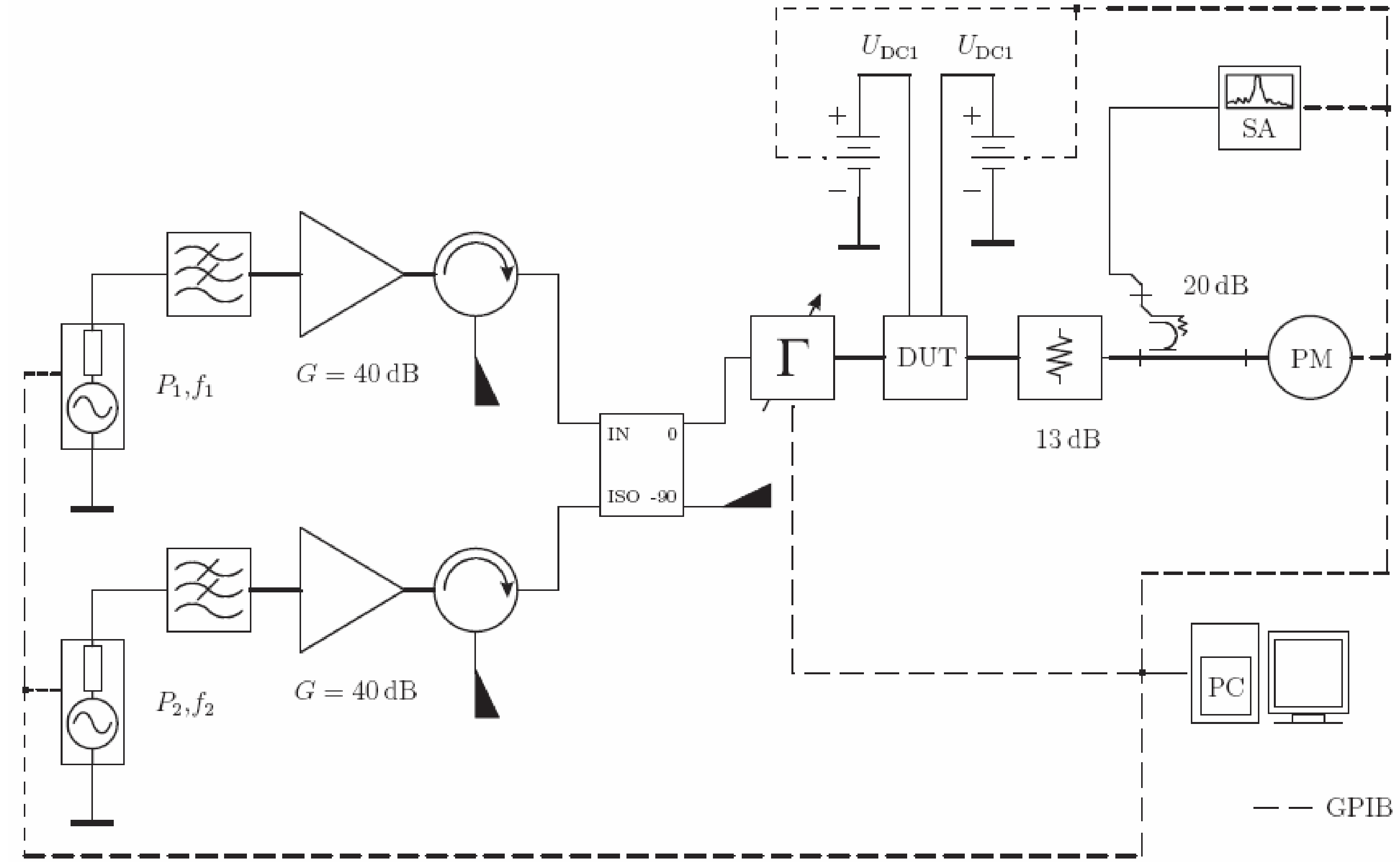
- High tunability results in high IMD

Cascaded Capacitors



- Smaller voltage swing for cascaded C

Two-Tone Setup



- Typical 2-tone setup

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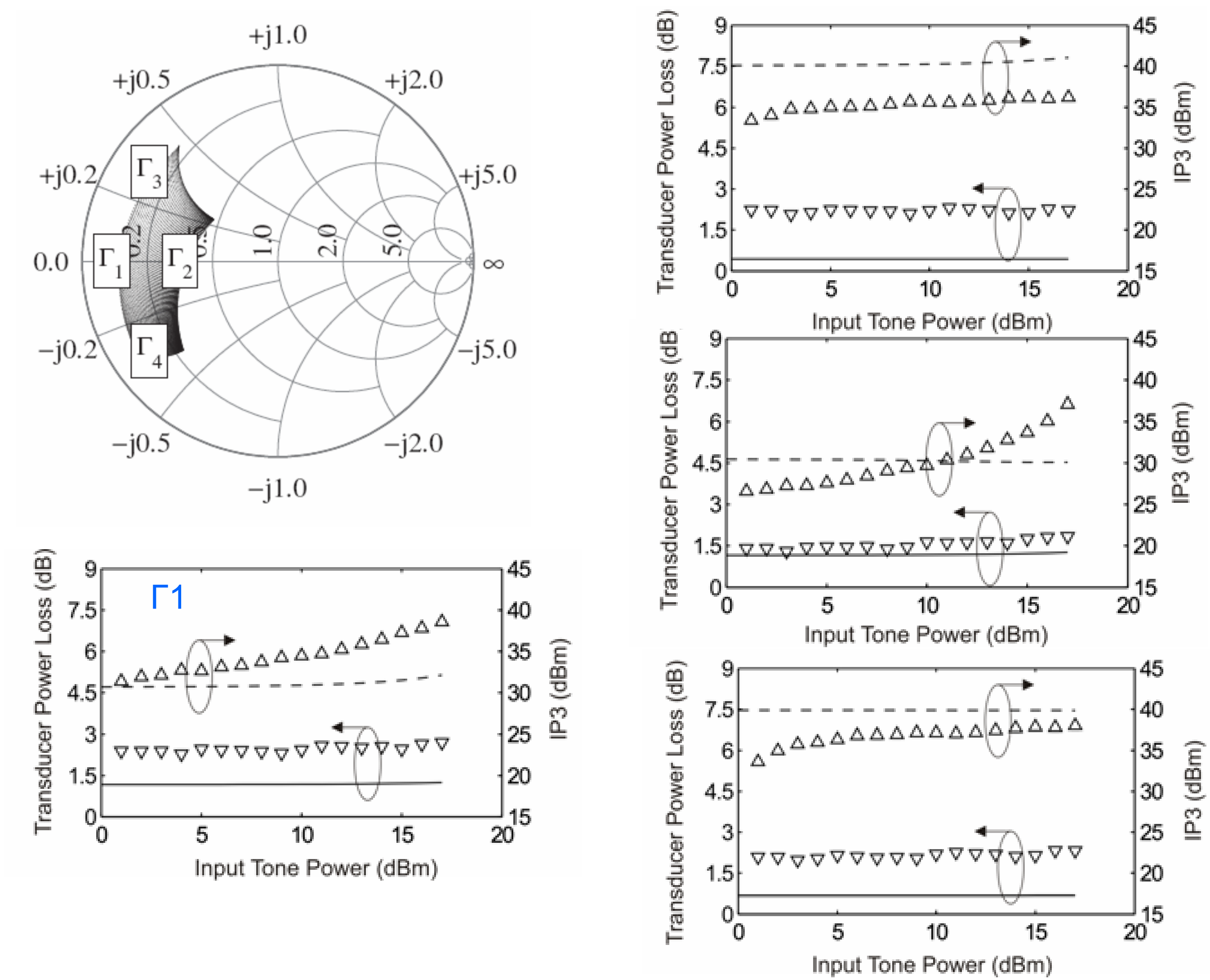
L – Linearity



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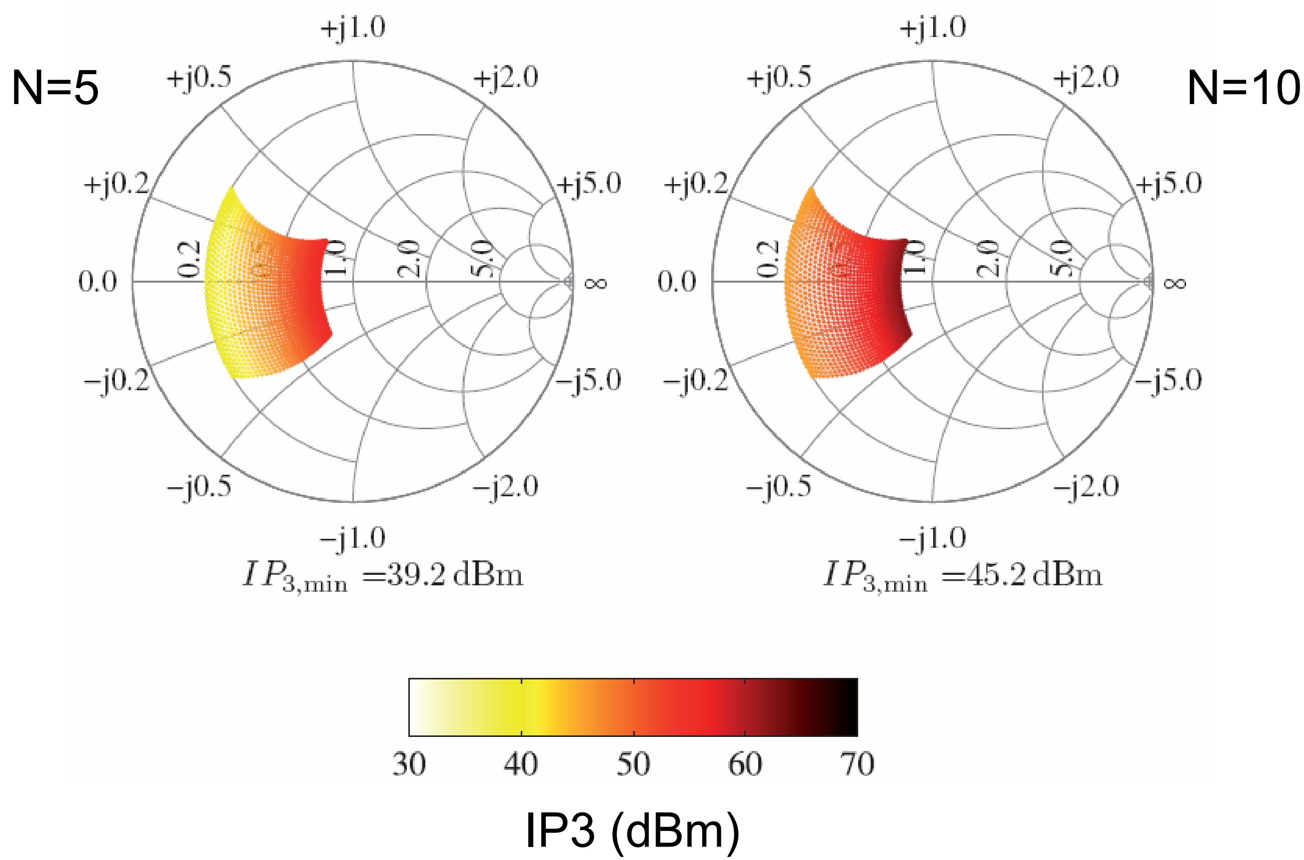
L – Network IP3



- Pin=20dBm

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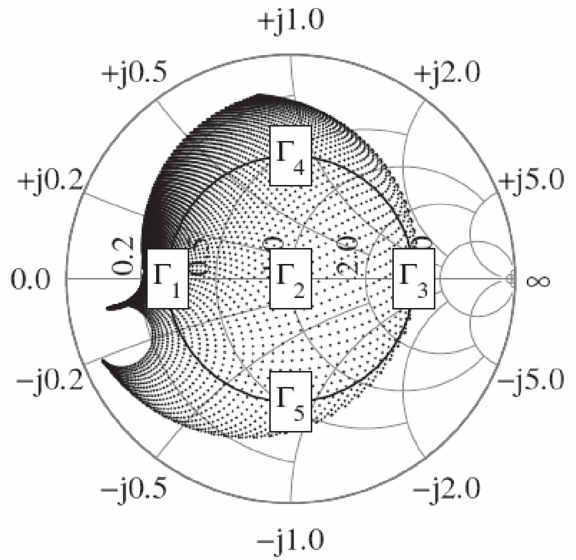
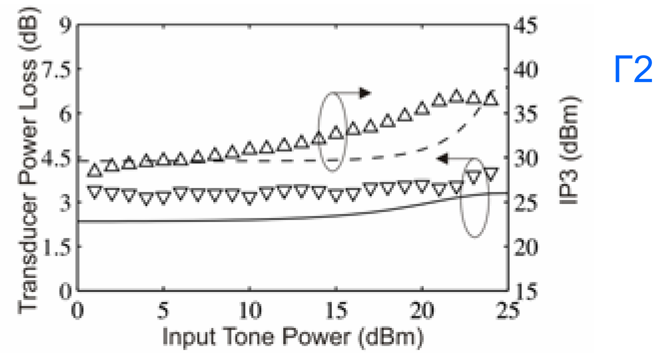
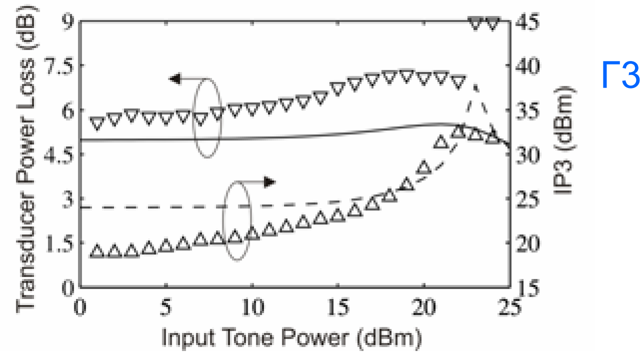
Π – Linearity



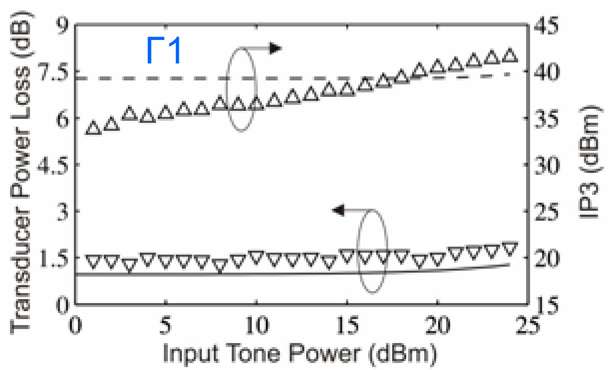
+j1.0
+j0.5
+j2.0
+j0.2
+j5.0
0.0
∞
−j0.2
−j5.0
−j0.5
−j2.0
−j1.0
Γ1
Γ2
Γ3
Γ4
Γ5



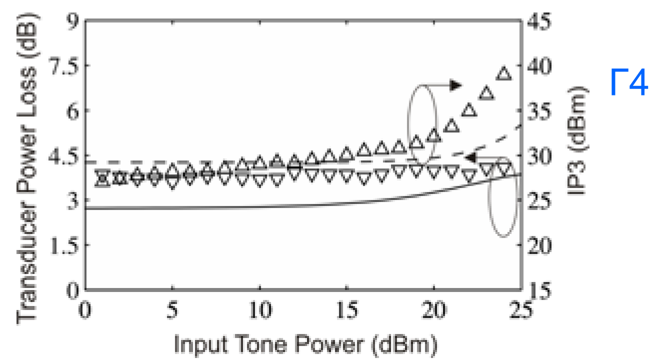
Γ2
Transducer Power Loss (dB)
IP3 (dBm)
Input Tone Power (dBm)



Γ3
Transducer Power Loss (dB)
IP3 (dBm)
Input Tone Power (dBm)

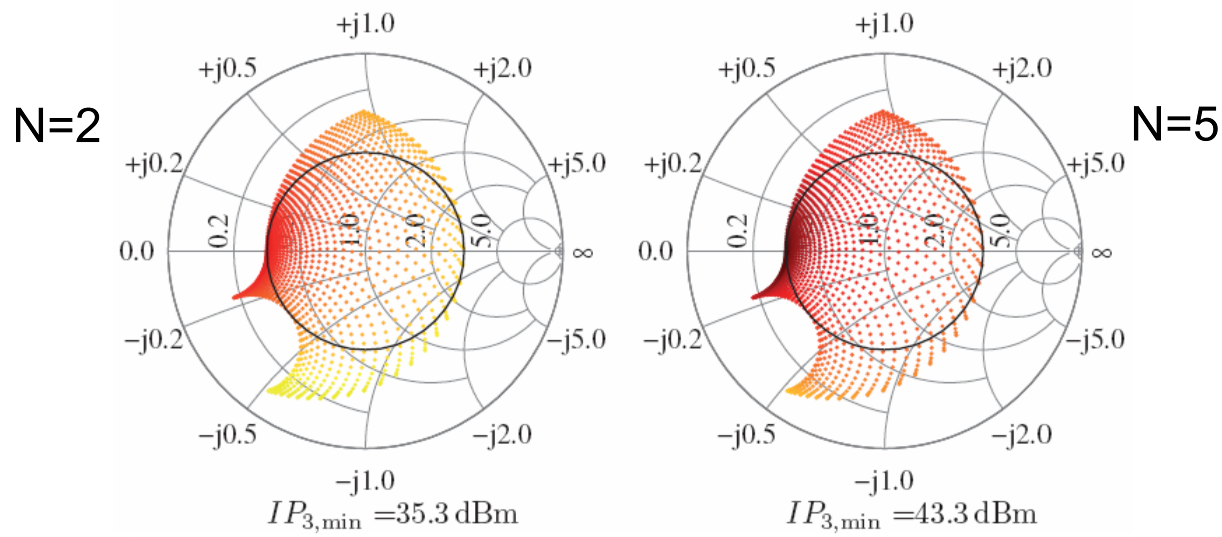


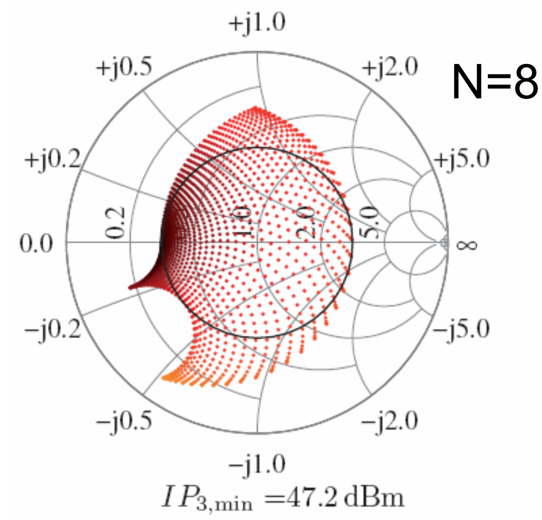
Γ1
Transducer Power Loss (dB)
IP3 (dBm)
Input Tone Power (dBm)

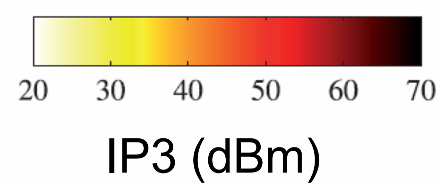


Γ4
Transducer Power Loss (dB)
IP3 (dBm)
Input Tone Power (dBm)

Π – Network IP3







- Pin = 20 dBm

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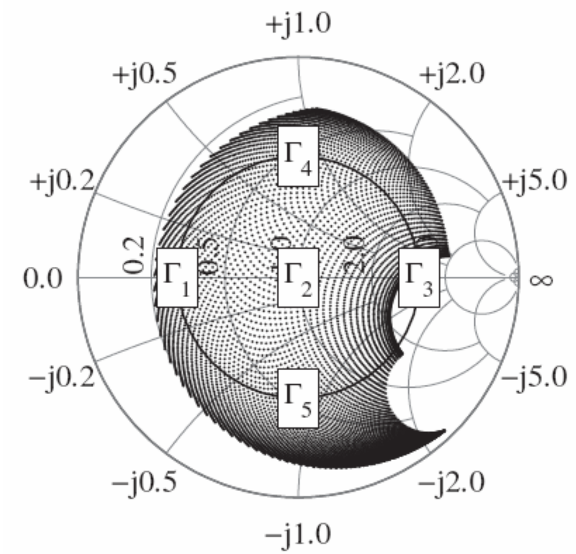
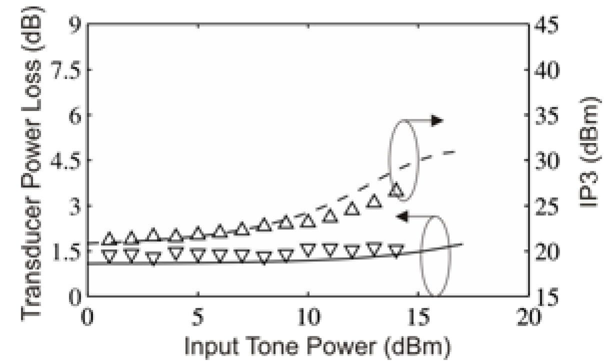
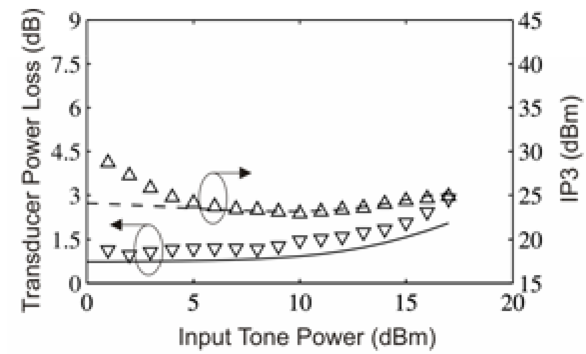
T – Linearity



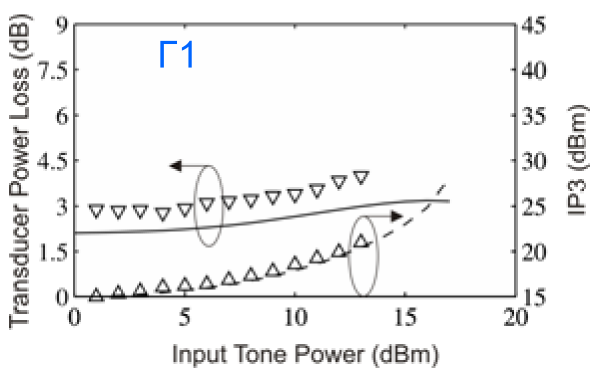
Γ2



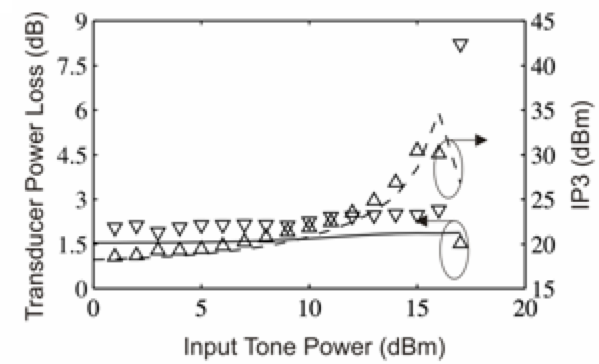
Γ3



Γ1

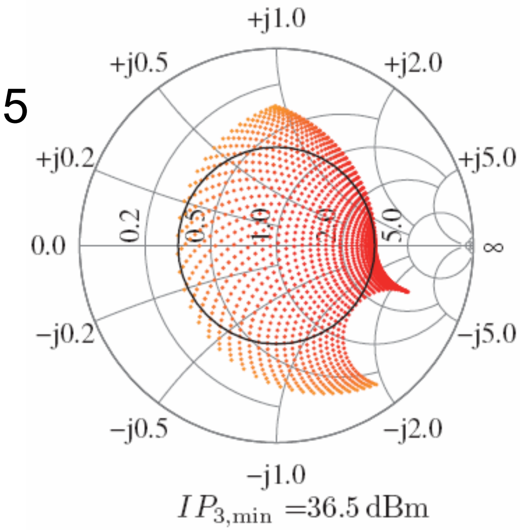


Γ4

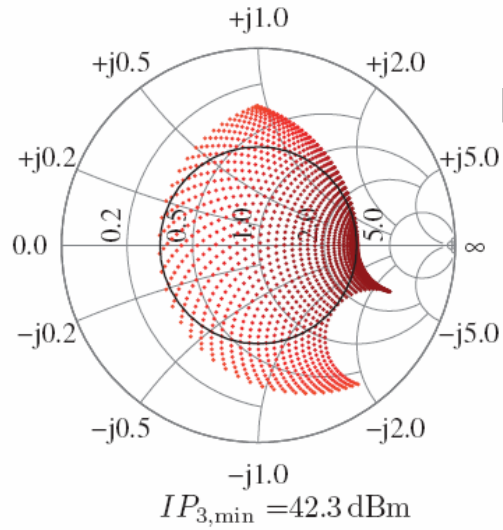


T – Network IP3

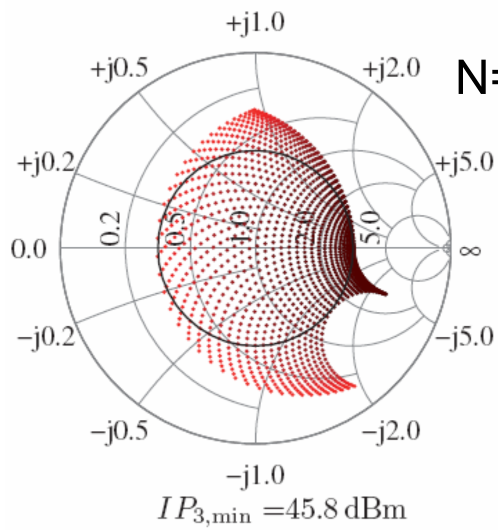
N=5

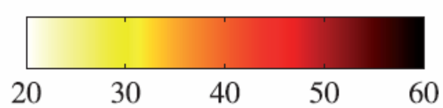


N=10



N=15

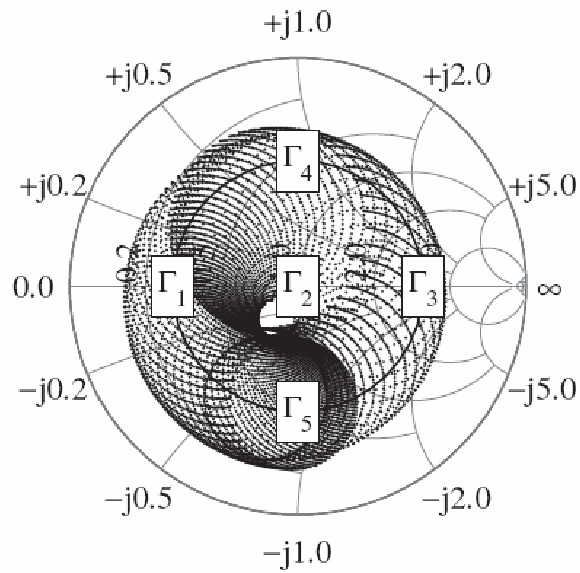


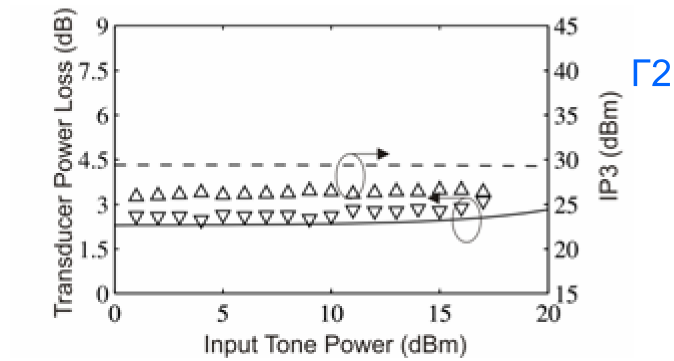


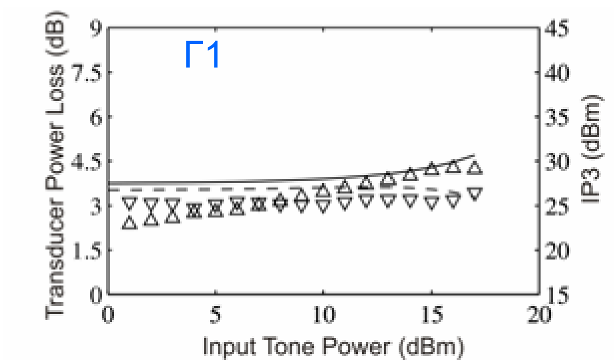
IP3 (dBm)

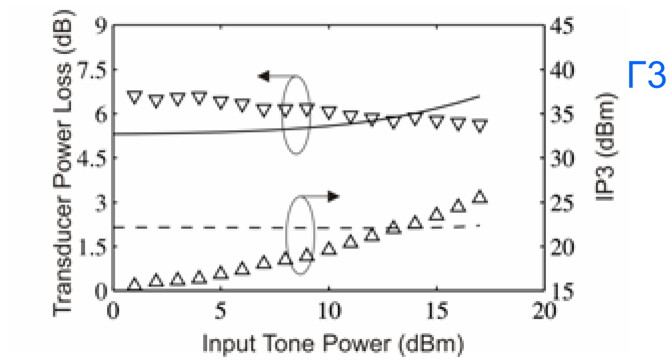
- Pin = 20 dBm

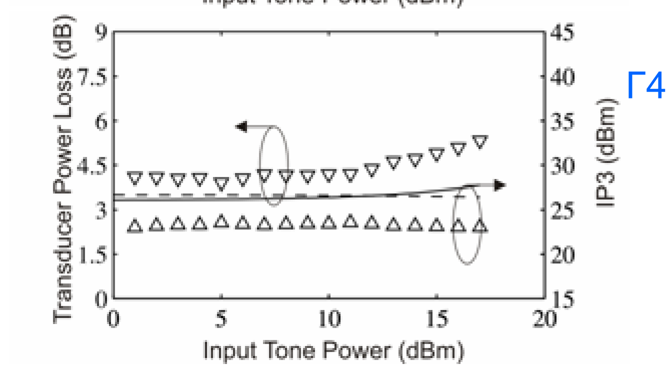
Reflection MN – Linearity



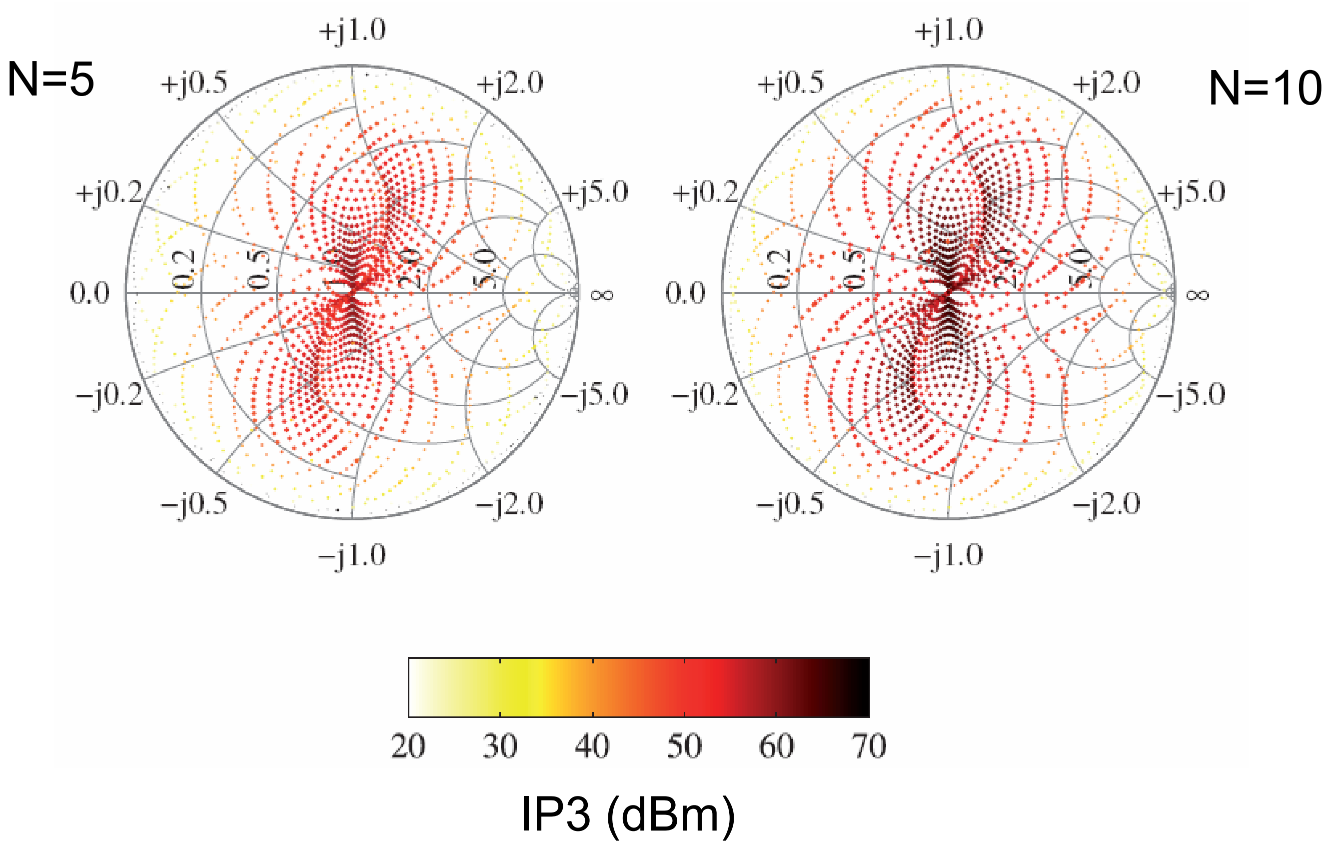








Reflection MN – Network IP3



- Pin=20dBm

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Summary

- BST thin-film varactors & modelling
- Matching networks
  - L-topology
  - Π-topology
  - T-topology
  - Reflection-type
- Linear and nonlinear investigation
- Measurements

Thank you for your attention