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

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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
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
$\text{Ba}_x\text{Sr}_{(1-x)}\text{TiO}_3$ – Crystal

- Perovskite-type crystal
- Ba / Sr ratio

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

- BVD model
- Mason model
Varactor Modelling (2)

Quality Factor $Q$

$U_{DC} = 0\, \text{V}$

$U_{DC} = 5\, \text{V}$

$U_{DC} = 10\, \text{V}$

$U_{DC} = 25\, \text{V}$

Frequency (GHz)
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

Gain (dB)

• Losses for minor impedance variations
**L - Matching Area**

- Excellent agreement
- Dynamically adjustable PA impedance

**Simulated** vs **Measured**

Transducer Power Loss (dB)

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Π - Matching Network

- High C value
- Suitable for low impedances
- Low IMD
• Gain for significant impedance variations
Π – Matching Area

- Excellent agreement
- Losses increase for higher impedances

Simulated Measured

Transducer Power Loss (dB)
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 significant impedance variation

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T – Matching Area

- Excellent agreement
- Higher losses for low impedances
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 significant impedance variation

![Reflection and Network Gain Diagram](image-url)
Reflection – Matching Area

- Excellent agreement
- Symmetric matching area
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

\[ \Gamma_1, \Gamma_2, \Gamma_3, \Gamma_4 \]

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L – Network IP3

- Pin=20dBm
Π – Network IP3

- \( N = 2 \)
  - \( IP_{3,\text{min}} = 35.3 \text{ dBm} \)

- \( N = 5 \)
  - \( IP_{3,\text{min}} = 43.3 \text{ dBm} \)

- \( N = 8 \)
  - \( IP_{3,\text{min}} = 47.2 \text{ dBm} \)

- \( \text{Pin} = 20 \text{ dBm} \)

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T – Linearity

\[ \Gamma_1 \]

\[ \Gamma_2 \]

\[ \Gamma_3 \]

\[ \Gamma_4 \]
T – Network IP3

- Pin = 20 dBm
Reflection MN – Linearity

\[ \Gamma_1 \]

\[ \Gamma_2 \]

\[ \Gamma_3 \]

\[ \Gamma_4 \]
Reflection MN – Network IP3

N=5

Pin=20dBm

N=10
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