A high linearity, high efficiency WiMAX power amplifier using SiC MESFETs

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Outline

- WiMAX Power Amplifier requirements
- Wide Band Gap RF power devices
- Model based design of the WiMAX Power Amplifier
- Measurement Results
- Summary
WiMAX Overview

- **What is WiMAX?**
  - Next generation wireless network for data

- **Frequency Allocations**
  - 2.7GHz, 3.5GHz, 5.5GHz

- **Signal Bandwidths**
  - 1.25MHz to 20MHz per IEEE 802.16 2004

- **Modulation**
  - OFDM based with QPSK → 64QAM Bursting

- **Power Levels**
  - Subscriber units ~ 0.25W
  - Micro BTS up to 2W
WiMAX Tx Specifications

- ETSI EN 301 021 v 1.6.1, Para 5.3.3.1 For system type G
- IEEE 802.16 2004
  - RCE < -31dB
Advantages of WBG Transistors

- High Power Density
  - Smaller Devices
- High Voltage Operation
  - Higher Impedances
- Proven Long Term Reliability
  - \(2 \times 10^6\) MTTF @ 225°C
  - High Operating Temperatures
- Broad Band Performance
  - Low Output Capacitance per Peak Watt
SiC MESFETs

4H SiC Wafer (thinned to 100 µm)

Air bridges

Source Vias

Experimental SiC MESFET (J. W. Palmour et al., Tech. Dig. IEDM, pp. 385-388, 2001, Cree)
Design Goals

- Amplifier reference design using a new SiC MESFET based transistor
- Frequency band: 3.3 – 3.9GHz
- Drain Voltage: 48V
- Gain: 10dB
- Average Output Power: 1.5W
- Drain Efficiency: 17%
- RCE: < -31dB (EVM < 2.5%)
- Spectral Mask: > 2dB margin all points

- Efficiency and Linearity goals are specified at 1.5W
Model Based Design

- Design of transistor and evaluation circuit was performed using a large signal model
  - Pre-matching within the package included to peak high frequency gain
  - No output match necessary within the package due to intrinsic high output impedance
- Load pull verification of transistor model
- Measurement of s-parameters to validate the modeled package parasitics
- IM3 products were simulated to predict linearity to give faster circuit simulation
SiC MESFET Small Signal Die Model

- 1mm test FET
- CW measurements @ 25°C
- Small-signal parameters at 25% I_{DSS} compare well with model
Transistor Model

- CAP ID=C1 C= 0.012 pF
- CAP ID=C4 C= 6.006 pF
- SRL ID=R L1 R= 0.01 Ohm L= 0.4539 nH
- SRL ID=R L2 R= 0.01 Ohm L= 0.454 nH
- SRL ID=R L3 R= 0.004 Ohm L= 0.03327 nH
- SRL ID=RL4 R= 0.01 Ohm L= 0.2792 nH
- SiC d10r3 ID=sic10d1 TN OM= 25
- MSUB Er= 9.8 H=20 mil T =1 mil Rho= 1 T and= 0.0005 ErN om= 9.8 Name= SUB1
- MLIN ID= TL1 W= 150 mil L= 30 mil
- MLIN ID= TL2 W= 150 mil L= 30 mil
- PORT P=1 Z=50 Ohm
- PORT P=2 Z=60 Ohm

CREE

Creating technologies that create.
Simulated Source and Load-Pull Data

Load Pull Data Contour Graph

- LPCS(7,0,0.5)
  Source Pull at 3850 MHz
- LPCS(38,28,0.75)
  Load Pull at 3850 MHz
- LPCSMAX()
  Load Pull at 3850 MHz
- LPCSMAX()
  Source Pull at 3850 MHz
Circuit Model

Input Match

Output Match
CRF35010 Evaluation Test Board
Measured Results

- The CRF35010 was characterized using the following tests
  - Small Signal s-parameters
  - CW Gain, Power and Efficiency
  - WiMAX linearity
    - Spectral Mask
    - RCE
- All power measurements were made vs. frequency and over the required 15dB dynamic range
Small Signal S-Parameters

Frequency (GHz)

<table>
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<th>S(1,1) Simulation</th>
<th>S(1,1) Measurement</th>
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CW Power, Gain and Efficiency

![Graph showing CW Power, Gain and Efficiency](source)

- **Pin (dBm)**
- **Gain (dB)**
- **Pout (dBm)** & Drain Efficiency (%)
- Measured Gain
- Simulated Gain
- Measured Power
- Simulated Power
- Measured Efficiency
- Simulated Efficiency
WiMAX – Signal Generation
WiMAX – Demodulated Signal
WiMAX – Spectral Mask

D Offset is as defined in ETSI EN 301 021 v 1.6.1, Para 5.3.3.1 for type G system
WiMAX – RCE and Efficiency

RCE vs Output Power from 3.4GHz to 3.8GHz

Average Output Power (dBm)

RCE (dB)

Drain Efficiency (%)
Summary

- Introduced the new WiMAX system
- Showed advantages of using wide band gap semiconductors
- Compared measured and modeled data
- Met most design goals with first pass success
Acknowledgements

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