Ka-Band Wide-Bandgap Solid-State Power Amplifier Technology

Jet Propulsion Laboratory

Mid-Year Review

Pasadena, California

January 27, 2004
Agenda

- Welcome
- Task Overview
- JPL Design Task
  - Requirements
  - Architectures
  - Detailed Analyses
- Break
- Discussion
- GRC Design Task
  - Overview
  - Notional Architectures
  - Thermal/MMIC Analysis
- Feedback & Wrap-Up
Welcome

- JPL welcomes partner contractors, sponsors, interested parties and guests.
- Purpose & Goals
  - Communicate task status
  - Describe key accomplishments
  - Define future plans
- JPL is a partner contractor for WBG SSPA Study
  - Partner Contractors
    - HRL
    - NGST
  - NASA Glenn is the JPL Managing Organization
    - Also plays a technical role
A Key Accomplishment
First Panoramic Look

Meridiani Planum, Mars

January 27, 2004
TASK OVERVIEW
Program Objective

To determine the feasibility of a WBG semiconductor based 120–150 W Ka-band SSPA as an alternative for space TWTAs with an engineering model build in 3–5 years leading to a flight model build in 7–8 years.

**Target SSPA**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
<th>NOTE</th>
<th>35 W TWTA</th>
<th>100 W TWTA</th>
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<tbody>
<tr>
<td>1 Power Output</td>
<td>120 to 150 Watts</td>
<td></td>
<td>35 Watts</td>
<td>100 Watts</td>
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<tr>
<td>2 Power Added Efficiency</td>
<td>40%</td>
<td>@P1dB</td>
<td>52% (46% w/EPC)</td>
<td>60%</td>
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<tr>
<td>3 Band of Operation</td>
<td>31 to 36 GHz</td>
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<td>31.8-32.3 GHz</td>
<td>31.8-32.3 GHz</td>
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<tr>
<td>4 Bandwidth</td>
<td>10%</td>
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<tr>
<td>5 Gain</td>
<td>50 dB</td>
<td></td>
<td>51 dB</td>
<td>50 dB</td>
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<tr>
<td>6 Noise Figure</td>
<td>&lt;20dB</td>
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<td>&lt;4°/dB</td>
<td>&lt;4°/dB</td>
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<tr>
<td>7 AM/PM Conversion</td>
<td>&lt;2°/dB</td>
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<tr>
<td>8 Phase Ripple</td>
<td>&lt;3° peak to peak</td>
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<td>28 V±4 V</td>
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<tr>
<td>9 Input Bus voltage</td>
<td>50 Volts±5 Volts</td>
<td>DC</td>
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<tr>
<td>10 Mass</td>
<td>&lt;4 kg</td>
<td>incl. EPC</td>
<td>2.5 kg</td>
<td>2.5 kg</td>
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<tr>
<td>11 Environment</td>
<td>GEO or Deep Space</td>
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Additional architecture-dependent requirements include redundancy, graceful degradation, and adequate thermal management.

Noise figure, AM/PM conversion, bus voltage and radiation tolerance are primarily MMIC/semiconductor technology driven.
SOW TASK 1: Architecture Identification
- Reviewed over 100 published articles relevant to millimeter-wave power combining and have begun focusing on three general architectures for further detailed study
- Delivered report of findings to sponsor (11/7/03)

SOW TASK 2a: Detailed Architecture Considerations
- Defined sub-system requirements and trade space
- Currently evaluating electrical performance of architectures identified in task 1 at component and system levels (80% complete)
- Have started to evaluate mechanical and thermal performance

SOW TASK 2b: MMIC Considerations
- Established subcontract with Rock Systems LLC to evaluate WBG reliability status and identify critical path/develop roadmap for insertion into high-reliability applications
GaN Reliability Subcontract

- Contract established with Rock Systems LLC, December, 2003
  - S. Kayali (JPL), G. Ponchak (GRC), R. Shaw (Rock Systems), “GaAs MMIC Reliability Assurance Guideline for Space Applications”
  - Reliability Lead – Roland Shaw, Rock Systems LLC
- 6 month study of WBG device reliability status and roadmap

- Phase I results due 2/3/04
  - Current reliability status of GaN broad state-of-the art devices and comparison with GaAs technology
  - Critical path for GaN insertion in space and high-reliability applications

- Phase II results due 7/10/04
  - Recommendation for core reliability guideline for WBG RF semiconductors
  - Possible failure mechanisms
  - Accelerated life test methodology requirements
  - Critical development roadmap required for 3-5 year technology insertion

- Phase I results will be included in NASA interim report #2
Progress Summary

- We have examined promising architectures and believe we can meet requirements outlined for the program
  - Low combiner losses (approximately < 1.0 dB total)
  - Projected GaN MMIC performance (not outside the realm of possibility)
    - Advances still required
    - Challenges still ahead
- PAE is what may differentiate WBG technologies at Ka-band to be competitive with the tube
  - A lower power MMIC (3W) but high PAE (greater than 40%) may afford a reasonable compromise in terms of thermal footprint and graceful degradation
  - May be the most viable approach consistent with the customer timeline
- Important next steps in the current phase are key component proof of concept hardware demonstrators and modeling for high efficiency
  - Combining circuits
  - Thermal studies
Phase I Schedule

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<th>Tasks</th>
<th>Months after start of contract</th>
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<td>AUG</td>
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<td>1. Architecture Identification</td>
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<td>2. Detailed Analysis</td>
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<td>3. Hardware Validation</td>
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<td>4. Technology Roadmap</td>
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- **Task Start:** August 4, 2003
- **Task 1 – Architecture identification, completed**
  - Interim Report #1 delivered November 7, 2003
- **Task 2a – Detailed analyses of selected architectures currently underway**
- **Task 2b – WBG technology review**
  - Reliability study subcontract established
- **Interim report #2 on detailed analysis due March 2004**
## SSPA Roadmap

### JPL Task Plans

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### WBG SSPA Roadmap

January 27, 2004

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Mid-Year Technical Review

January 27, 2003
Pasadena, California

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