Remote Wireless Power Transmission for Regenerative Fuel Cells

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Start Date = January 1, 2005
Planned Completion = March 31, 2007

Research Goals and Objectives

- To develop enabling technologies to build a novel wireless power transmission (WPT) system for NASA Space Missions
  - Investigate RF transmitter architectures that can achieve high DC-to-RF conversion efficiency.
  - Investigate GaN-based devices and circuits for high power microwave system. GaN devices have the highest power density per unit device area at frequencies from a few GHz to millimeter-wave frequency.
  - Design high-efficiency transmitter circuits including power amplifiers and power oscillators. Design high-power rectifiers.

Relevance to Current State-of-the-Art

- Power distribution using transmission lines suffers huge loss in long distance.
- Wireless power transmission has been proposed.
- Power handling capability and efficiency of device is the key
- Use GaN wide bandgap device to build high efficiency circuits.

Relevance to NASA

- With the increased interest in space exploration, WPT can be very useful in many of NASA's space missions that use regenerative fuel cells.
- Applications include unmanned spacecrafts and wireless power grid system on new planets.
- Delivering energy through focused microwave beam over a very long distance at light speed during emergency.

Budget, Schedule and Deliverables

- **Budget: $64,000 for FY04**

Phasing Plan

Q1	Q2	Q3	Q4
$5,260	$19,580	$19,580	$19,580

Project award date 9/30/04

Project started 1/1/05

Completed characterization of devices and design of rectifier 4/1/05

Q1	Q2	Q3	Q4

Completed designs of transmitter circuits including power oscillator and amplifier 7/1/05

Completed integration and testing of circuits 10/1/05

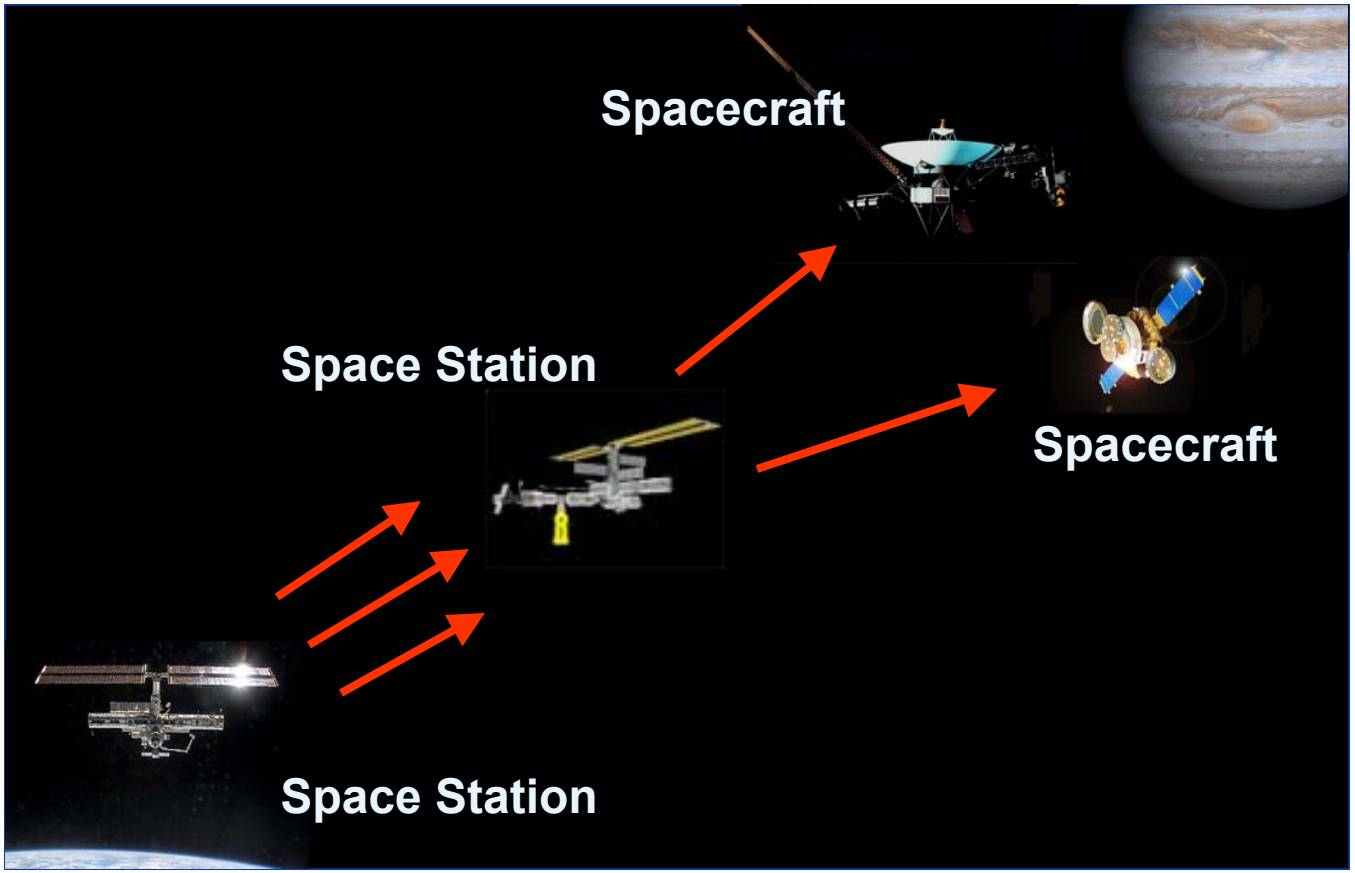
On Target

Deliverables: schematics and test results of prototype circuits

Anticipated Technology End Use

- Remote transmission of energy to charge regenerative fuel cells (RFC) for NASA space missions.
- UAV and unmanned spacecraft.
- Wireless power grid system on new planets.
- Remote powering of bio-implanted devices (low power).
- Emergency energy delivery.

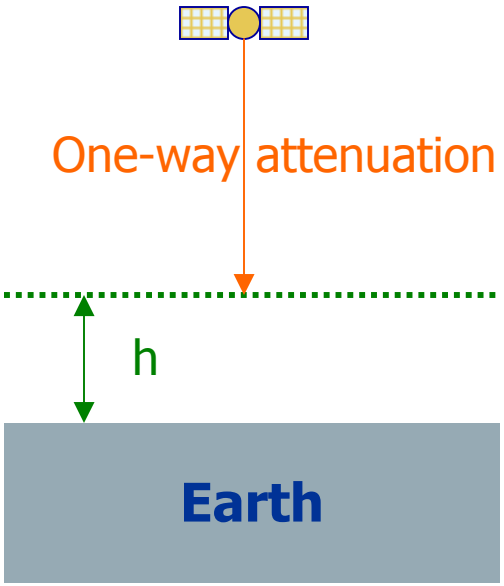
Wireless transmission of energy at light speed – using focused high power microwave beam.



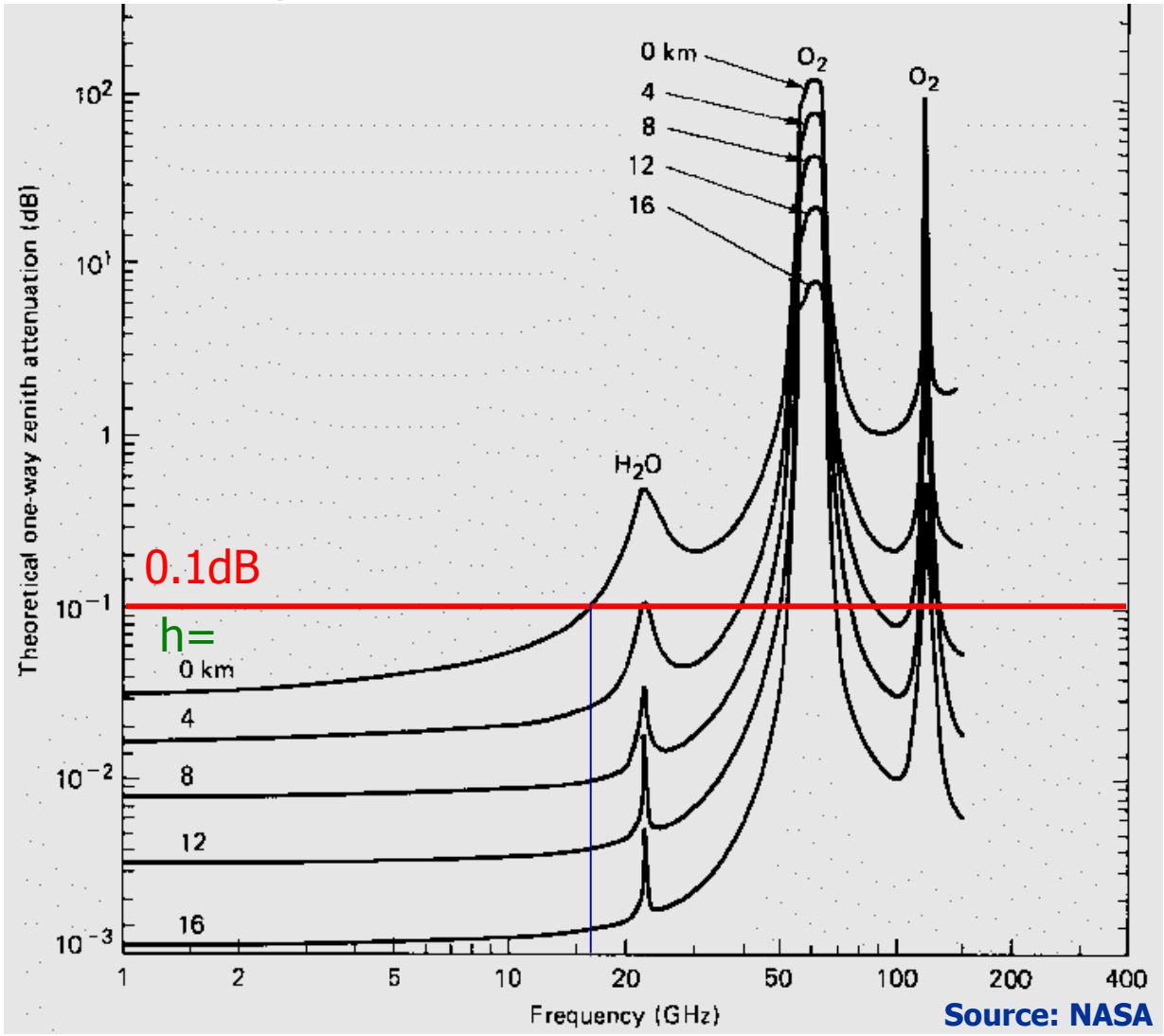
Accomplishments and Results

- Characterized GaN-based wide bandgap devices AlGaN/GaN High Electron Mobility Transistors (HEMT).
- Designed and built prototype circuits of rectifier, oscillator, and power amplifier by using AlGaN/GaN HEMT devices.
- Oscillator achieved DC-to-RF efficiency of 40%
- Power amplifier achieved Power-Added-Efficiency of 38%
- Rectifier achieved RF-to-DC efficiency of 50% (one of the two diodes is not functioning. Otherwise should achieve >70% efficiency predicted by simulation)

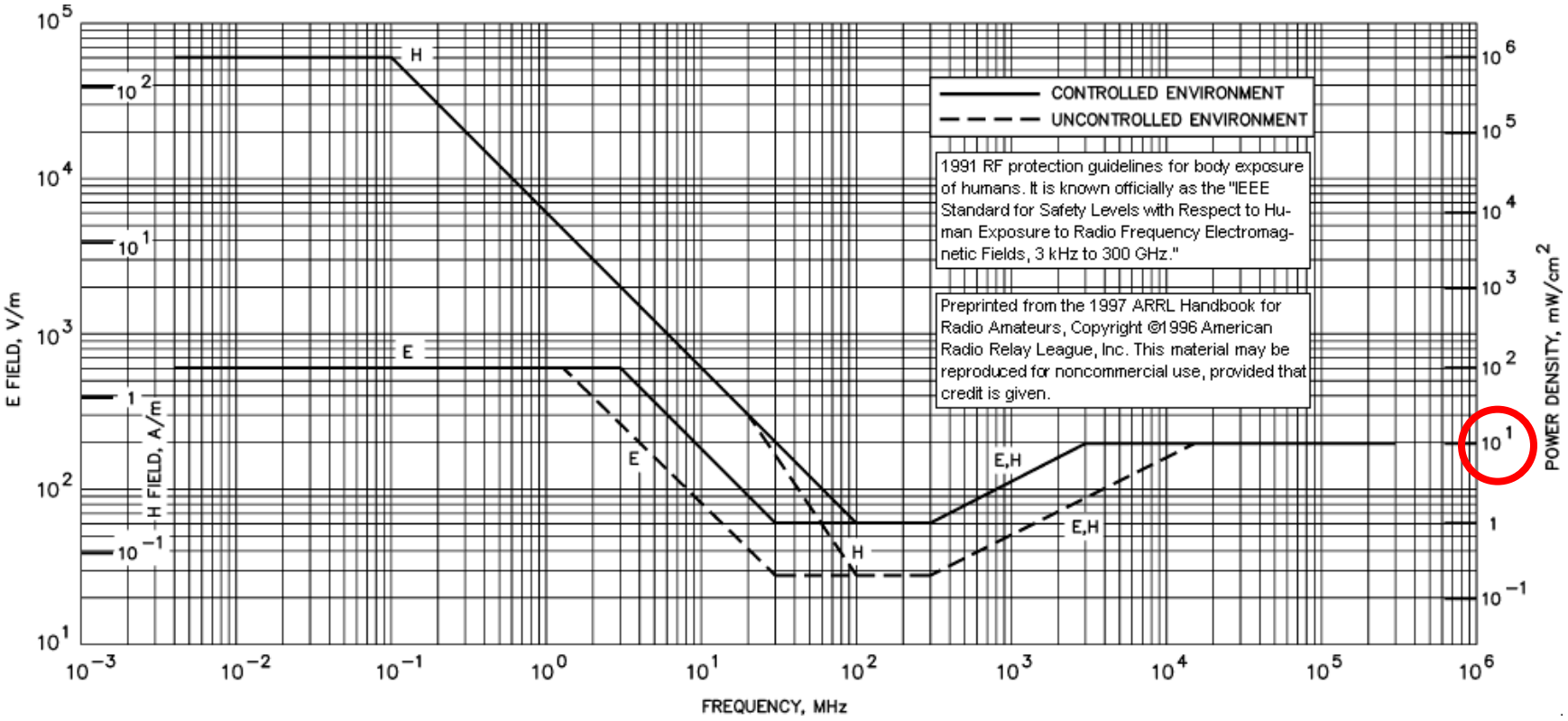
Attenuation Through Earth Atmosphere



- **One-way attenuation <0.1dB for f<16GHz**
- **In space, no attenuation**



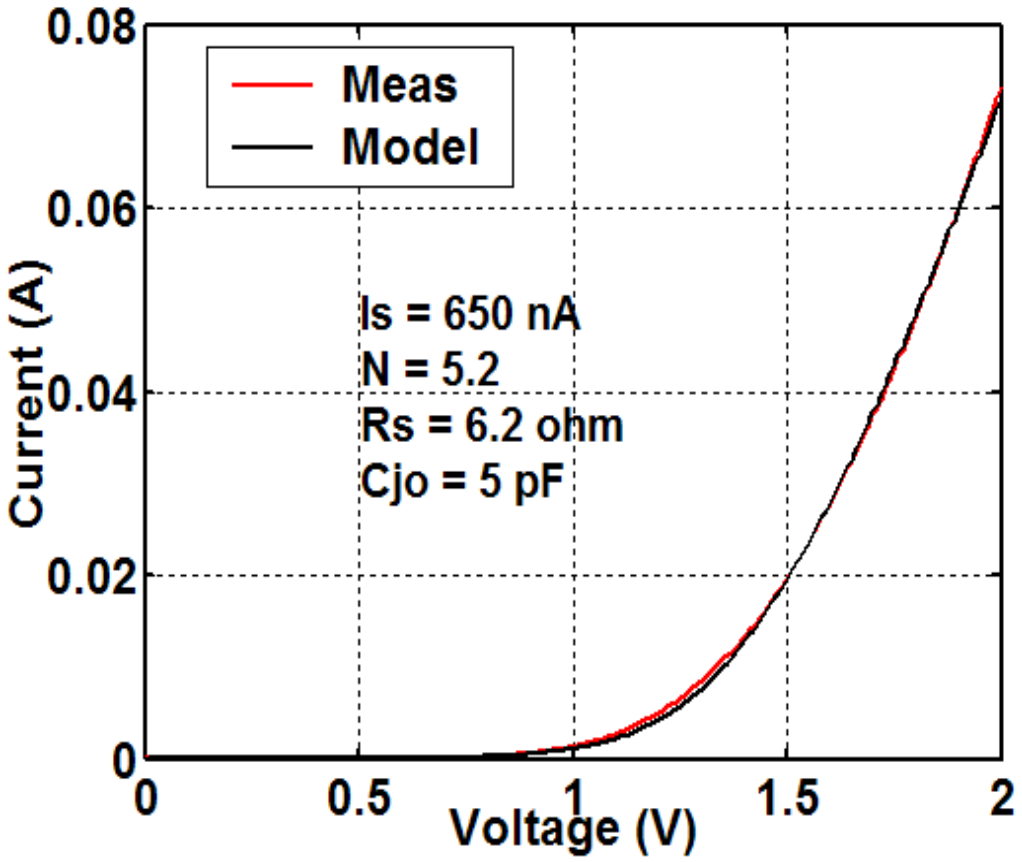
Radio Frequency Safety Guideline

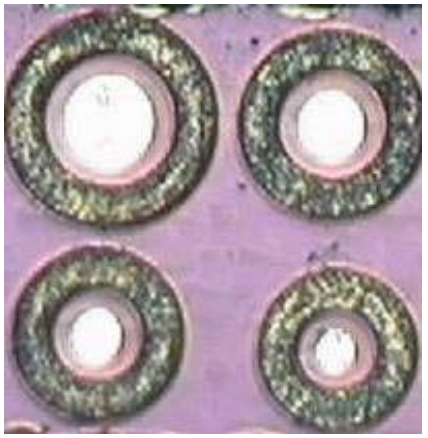


RF Safety at > 15 GHz:
10mW/cm² → 100W/m² → 10kW per (10mx10m) square!

Compared to: High voltage electric line with safety distance > 15m

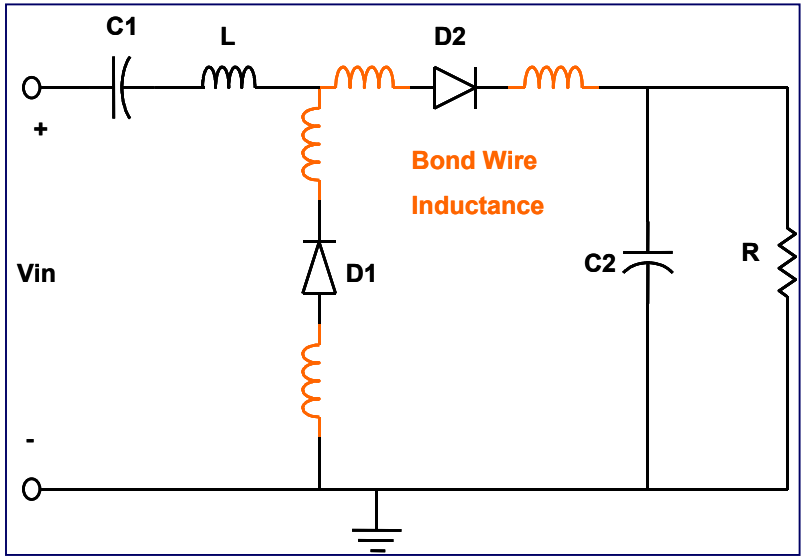
Device Modeling



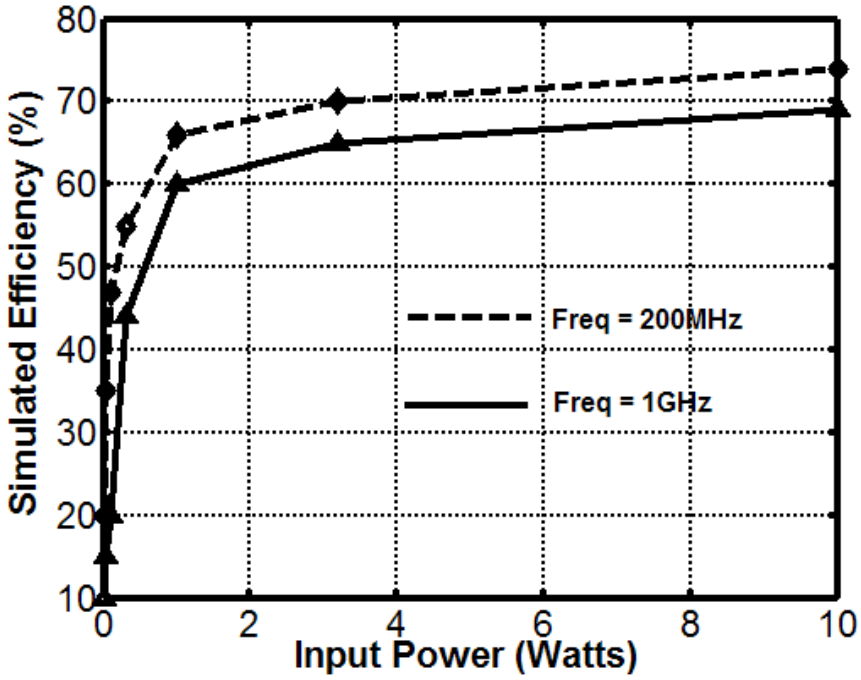


Simulated Rectifier Efficiency

Circuit Schematic

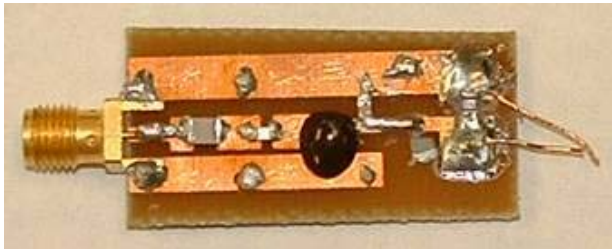


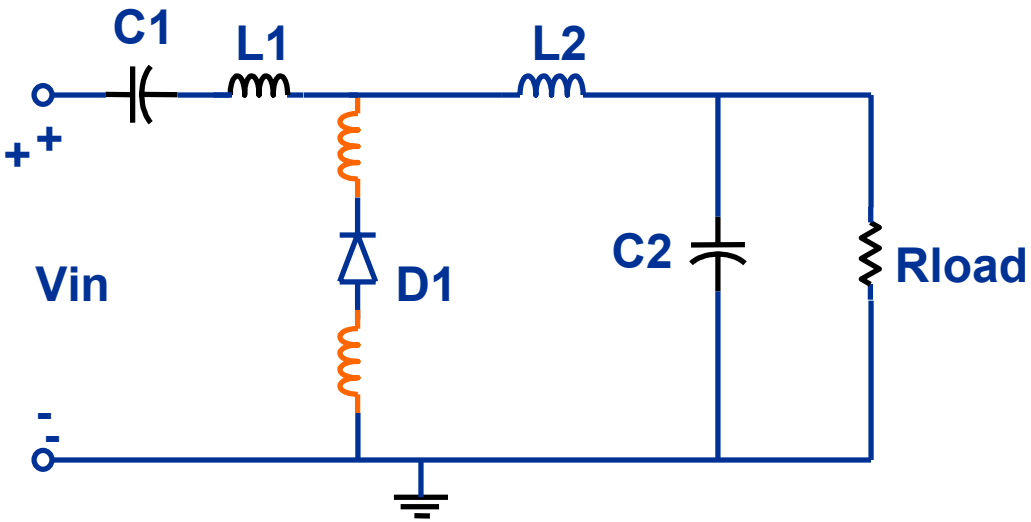
Simulated Efficiency



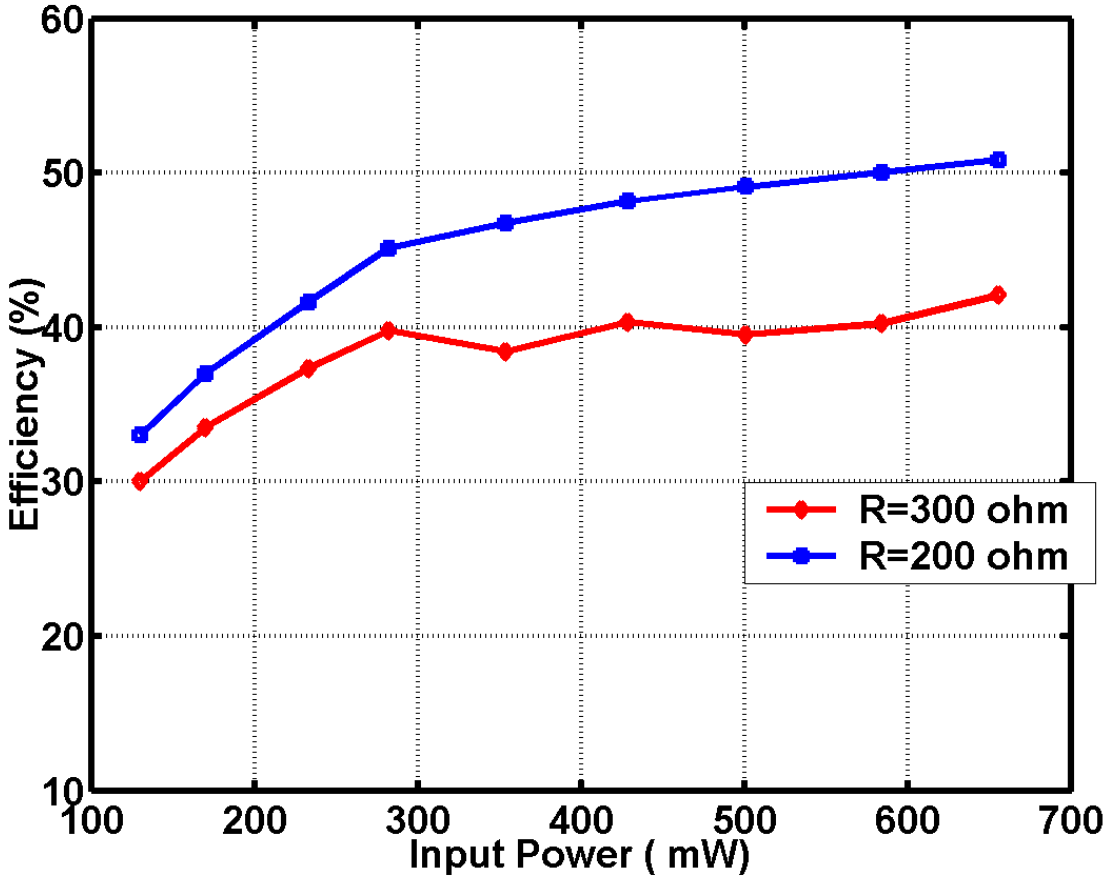
Higher Power → Higher Efficiency

Rectifier prototype and actual schematic (one diode is shorted)



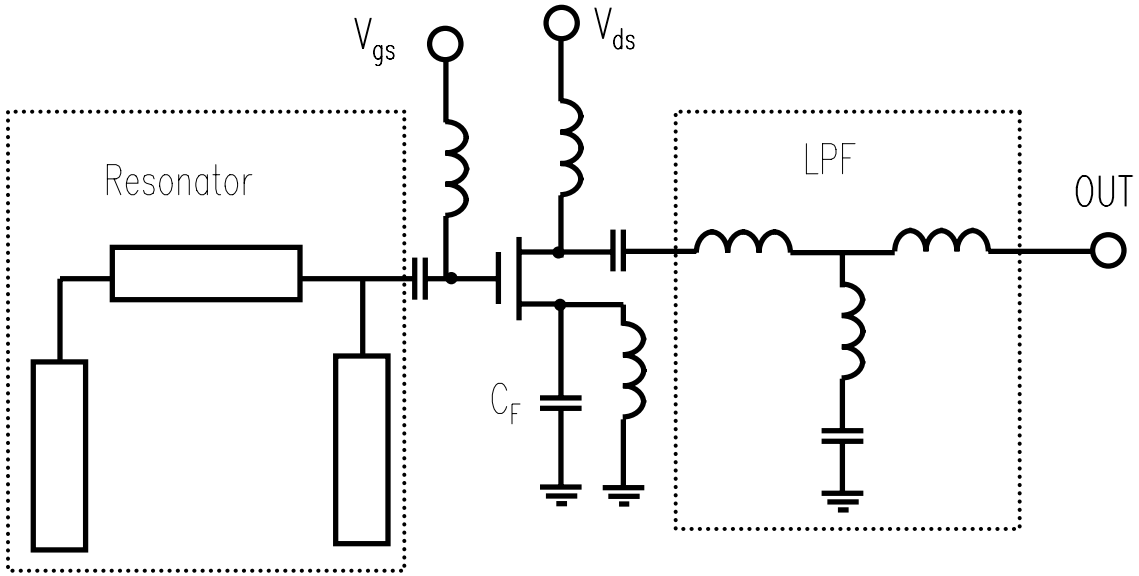


Measured Result (with only one diode working)

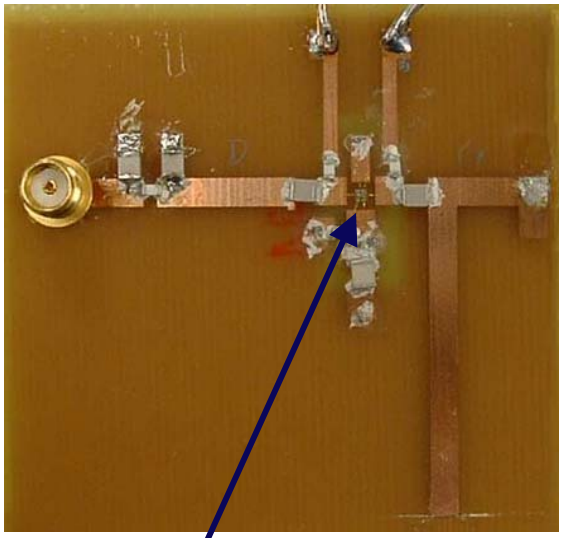


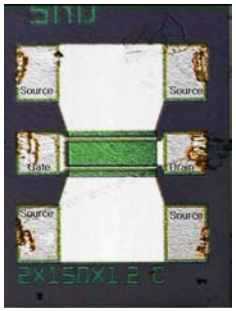
High Efficiency Oscillator

Circuit Schematic



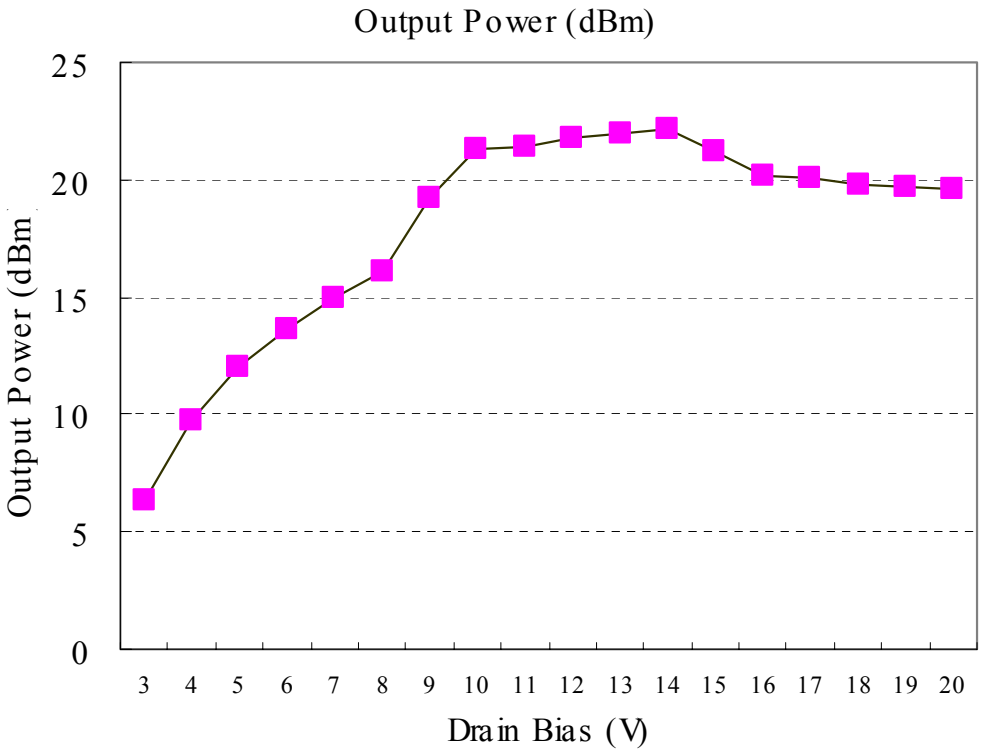
Fabricated Test Board





AlGaN/GaN HEMT 300µmx1.2µm

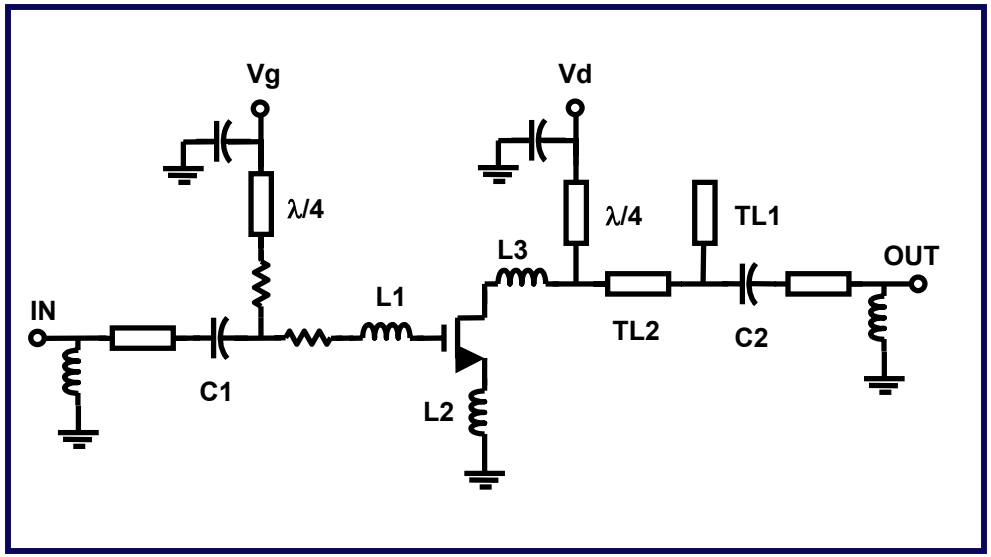
High-Efficiency Oscillator



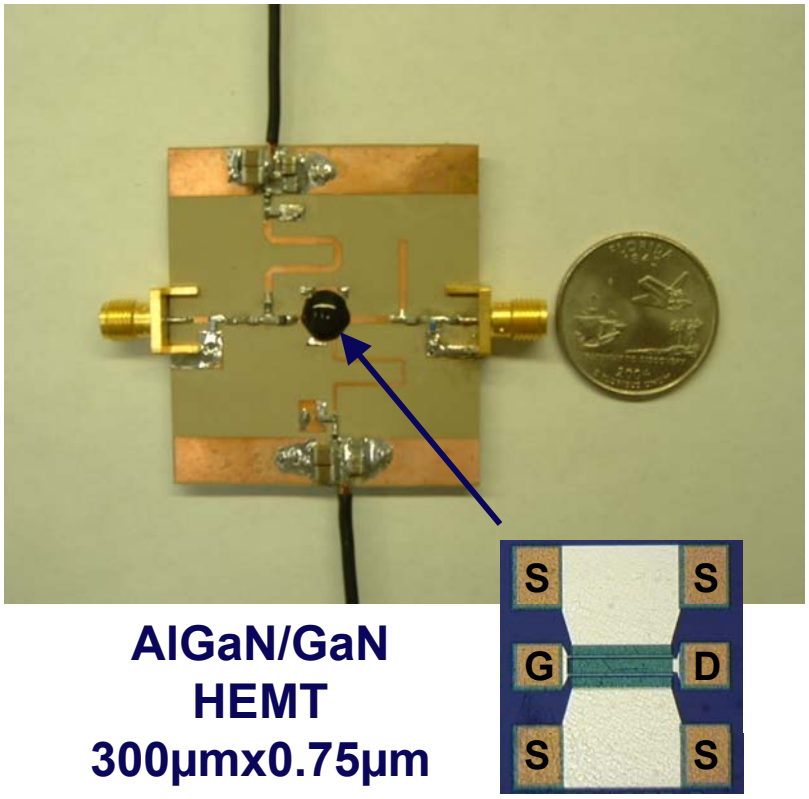
- Convert DC power to RF transmission at 1.3 GHz
- High voltage and high power
- Max. power = 22.5 dBm
- DC-to-RF conversion efficiency = 40%

High-Efficiency Amplifier

Circuit Schematic

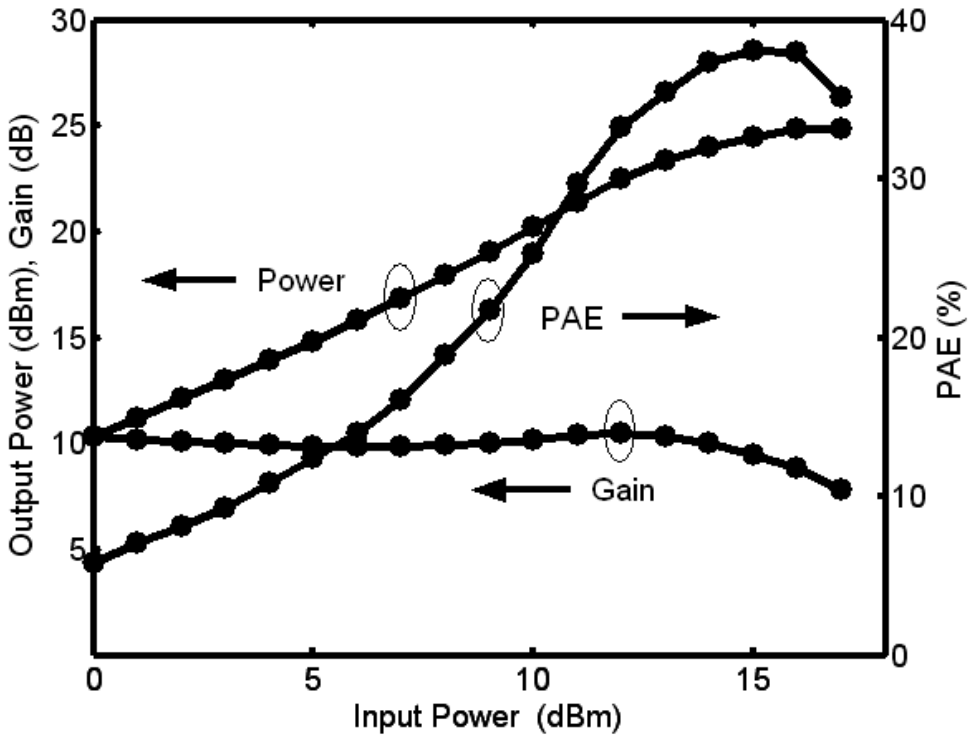


Fabricated Test Board



AlGaN/GaN HEMT 300μmx0.75μm

High-Efficiency Amplifier



- Generate high RF power from small signal input
- Max. power = 25 dBm
- Power Added Efficiency (PAE) = 38%
- Efficiency is similar to oscillator
- Large device or array of circuits will achieve much higher power.

Future Plans

- Redesign circuits to improve efficiency.
- Incorporate new devices from Dr. Pearton and Dr. Ren.
- Integrate with antenna to test transmission.
- Spatial power combining of array structure.
- System design to study overall efficiency.
- Collaborate with NASA GRC to fine tune the design for future missions.