We1A-5

Investigation of Heavy-Ion Induced Single Event Effects for GaAs and GaN-based RF Amplifiers in Space Applications

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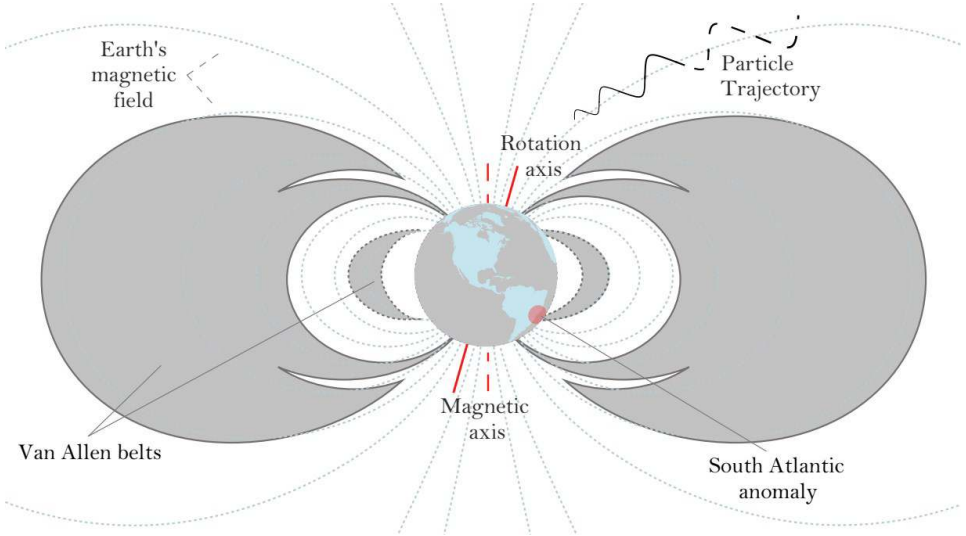
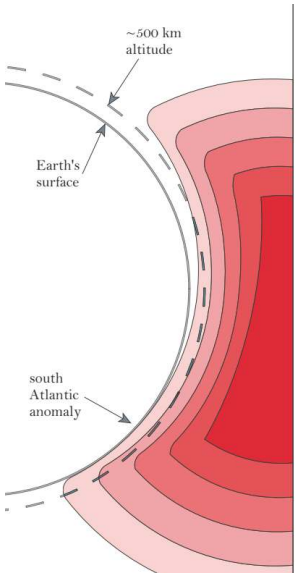
Outline

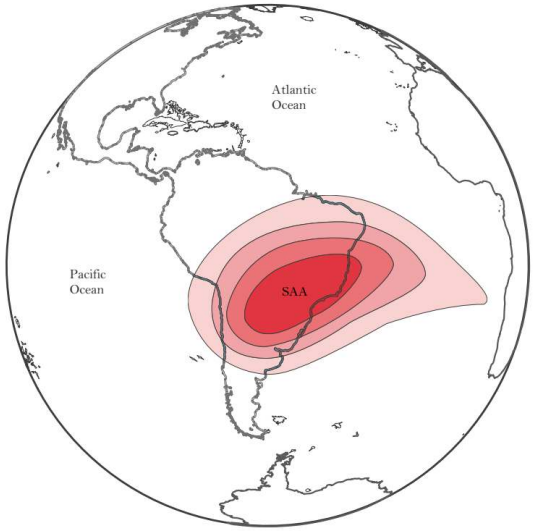
- Space Environment and Radiation Effects
- Devices Under Test
- Test Setup
- Test Results
- Conclusion

Space Environment

- Environmental conditions
  - Mechanical stress
  - Vacuum
    - Thermal issues
    - Outgassing
- Radiation
  - X-Ray
  - Gamma-Rays
  - Particles
    - Protons
    - Heavy Ions
- Radiation sources
  - Galactic cosmic rays (GCR)
  - Solar radiation
  - Radiation belts
  - South Atlantic anomaly

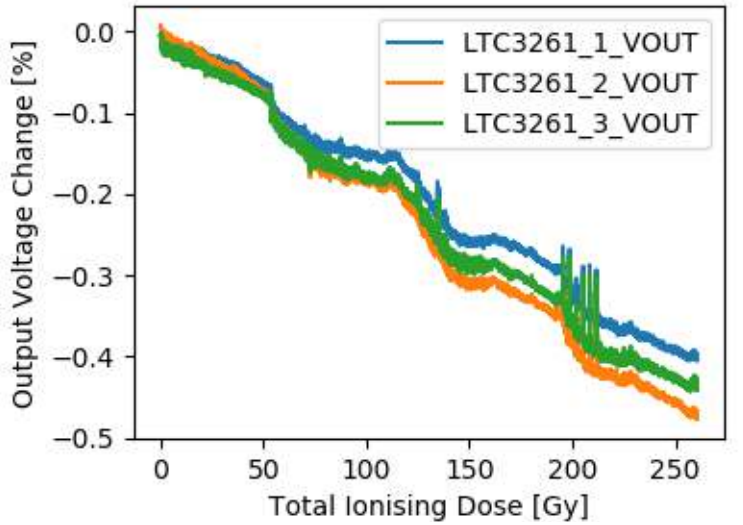


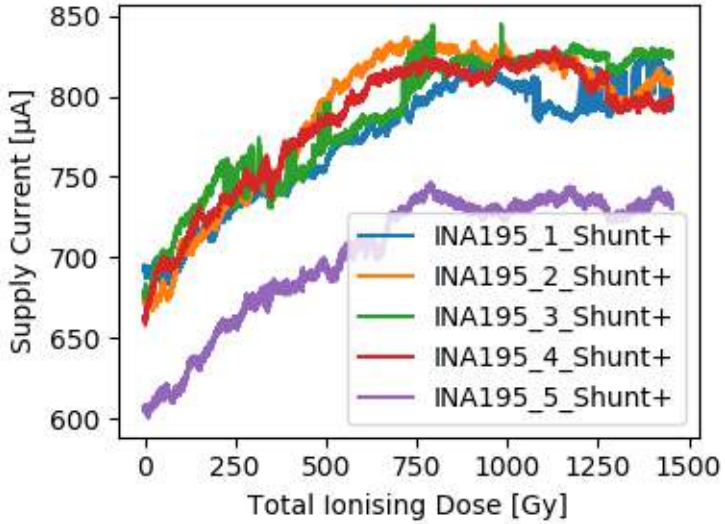




Radiation Effects (1)

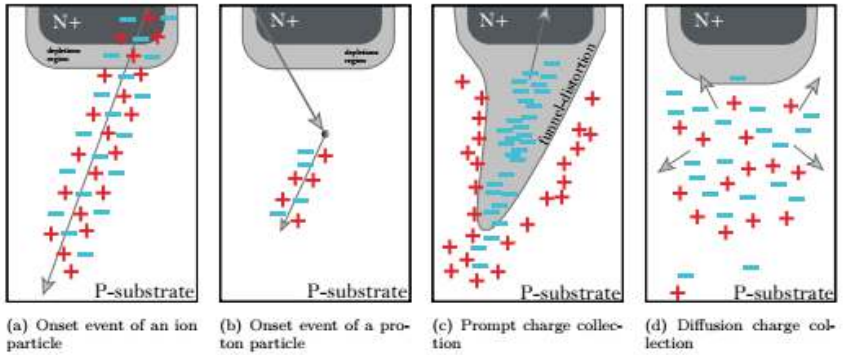
- Types of radiation effects
  - Ionizing dose effects (TID)
  - Cumulative effect
  - Generation, transport and trapping of holes in the insulation in MOS and bipolar device
  - Drift of parametric (e.g. supply current or output voltage)

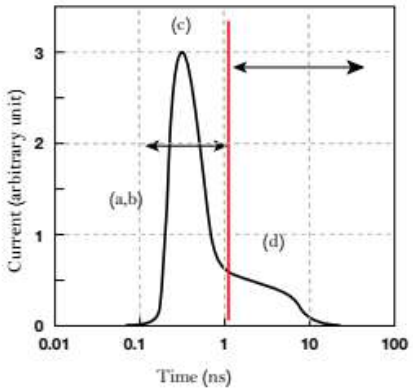




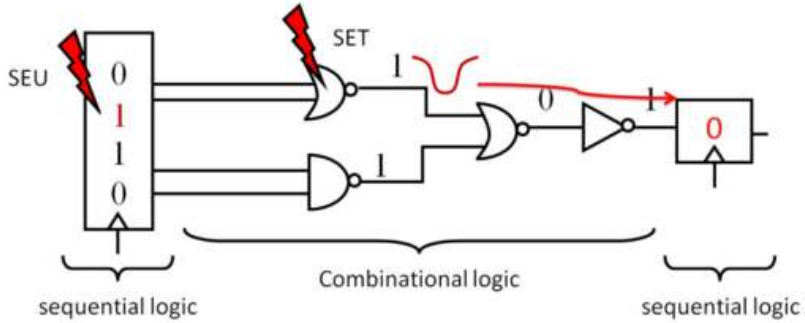
Radiation Effects (2)

- Single event effects (SEE)
  - Particle interaction with matter
  - Destructive effects
    - Single event latchup (SEL)
    - Single event burnout (SEB)
    - …
  - Non-Destructive effects
    - Single event upset (SEU)
    - Single event transient (SET)
    - Single event functional interrupt (SEFI)
    - …
- Displacement damages (DD)





(e) Transient charge vs. time



Devices Under Test

- HMC788A
  - 0.01 – 10 GHz GaAs pHEMT gain block
  - 14 dB gain
  - Single 5 VDC supply voltage
  - Darlington pair amplifier
  - Internally matched to 50 Ohms

INTERFACE SCHEMATICS

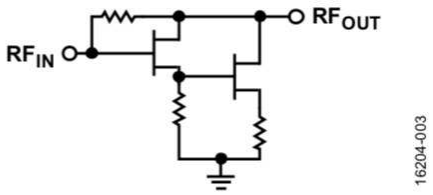
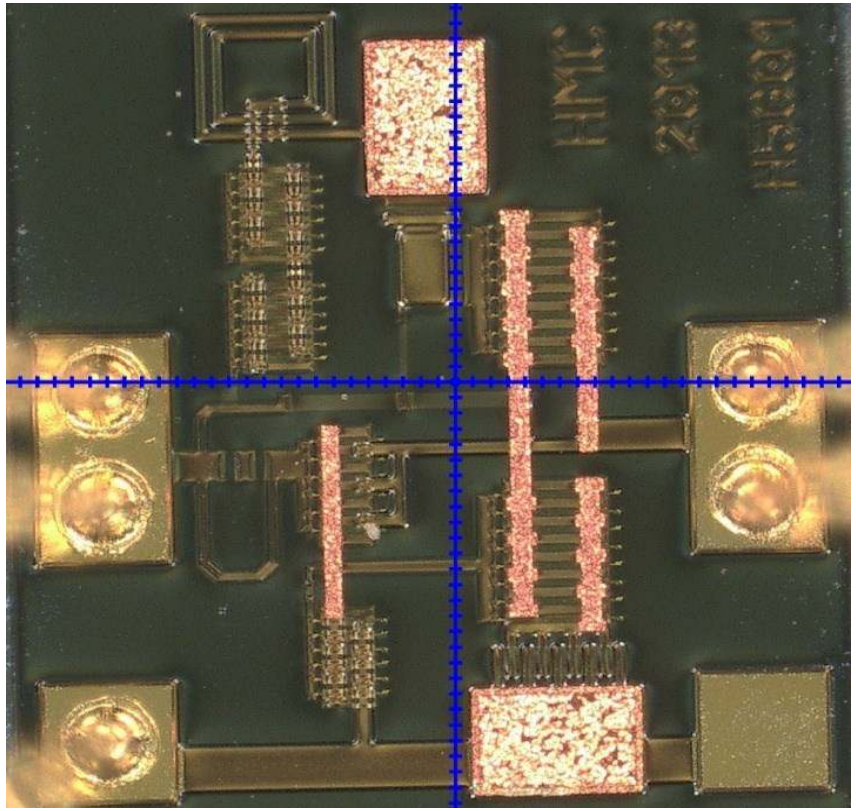
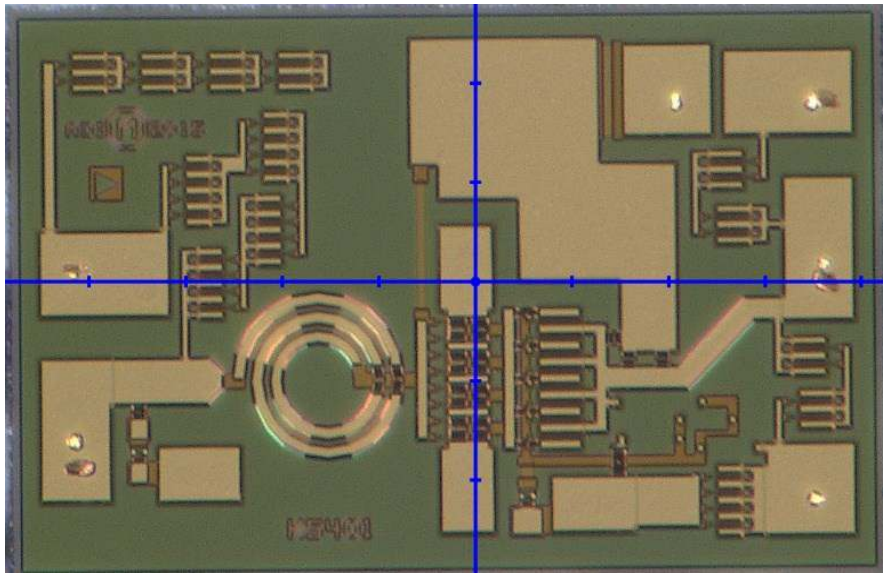


Figure 3. RF_{IN}, RF_{OUT} Interface Schematic



Devices Under Test

- HMC8410
  - 0.01 – 10 GHz GaAs low noise amplifier
  - 19.5 db gain
  - 5 VDC Drain Supply voltage
  - Negative bias voltage required
  - Internally matched to 50 Ohms



Interface schematics

Figure 3. GND Interface Schematic

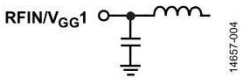


Figure 4. RFIN/V_{GG}1 Interface Schematic

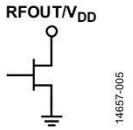
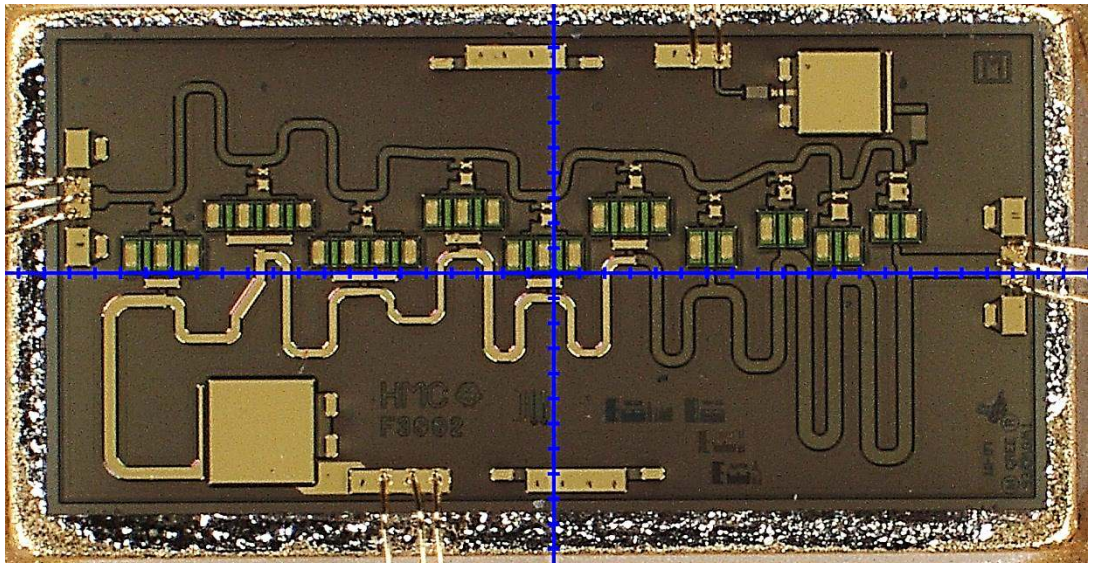
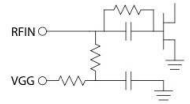
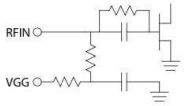
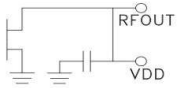
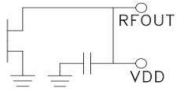


Figure 5. RFOUT/V_{DD} Interface Sc

Devices Under Test

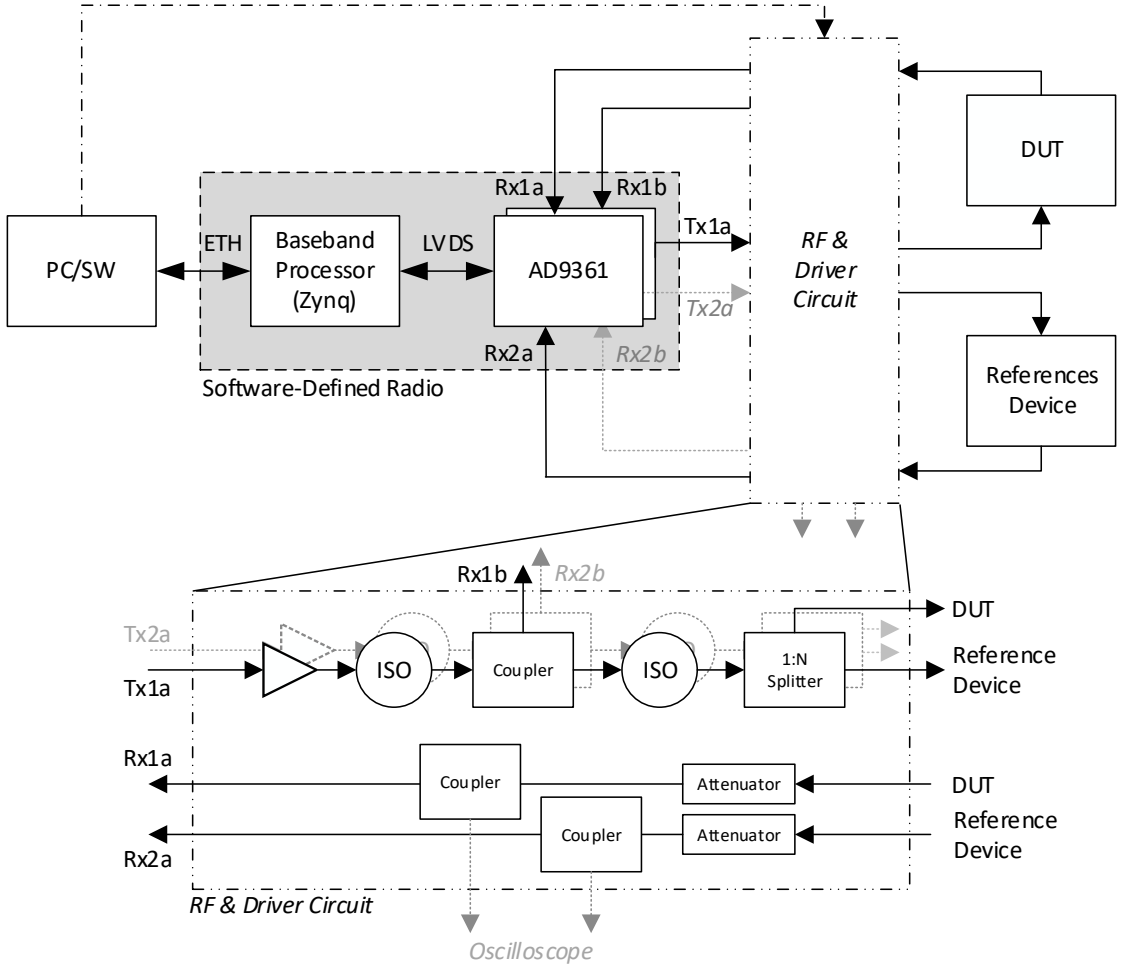
- HMC1087
  - 2 – 20 GHz GaN power amplifier
  - 8 W RF output
  - 11dB (small signal) and 5.5 dB gain
  - 28 VDC drain supply voltage
  - Negative bias voltage required
  - Internally matched to 50 Ohms
  - Consist of 10 FET structures that are parallel organized and forms a traveling wave amplifier



Pin Number	Function	Description	Interface Schematic
1	Vgg	Gate Control Voltage.	
2, 4, 5, 7, 9, 10	NC	These pins are not connected internally, however all data shown was measured with these pins connected to RF/ DC ground externally.	
3	RFIN	This pad is DC coupled and is matched to 50 Ohms. External blocking capacitor is required.	
6	Vdd	Drain bias.	
8	RFOUT	This pad is DC coupled and is matched to 50 Ohms. External blocking capacitor is required.	

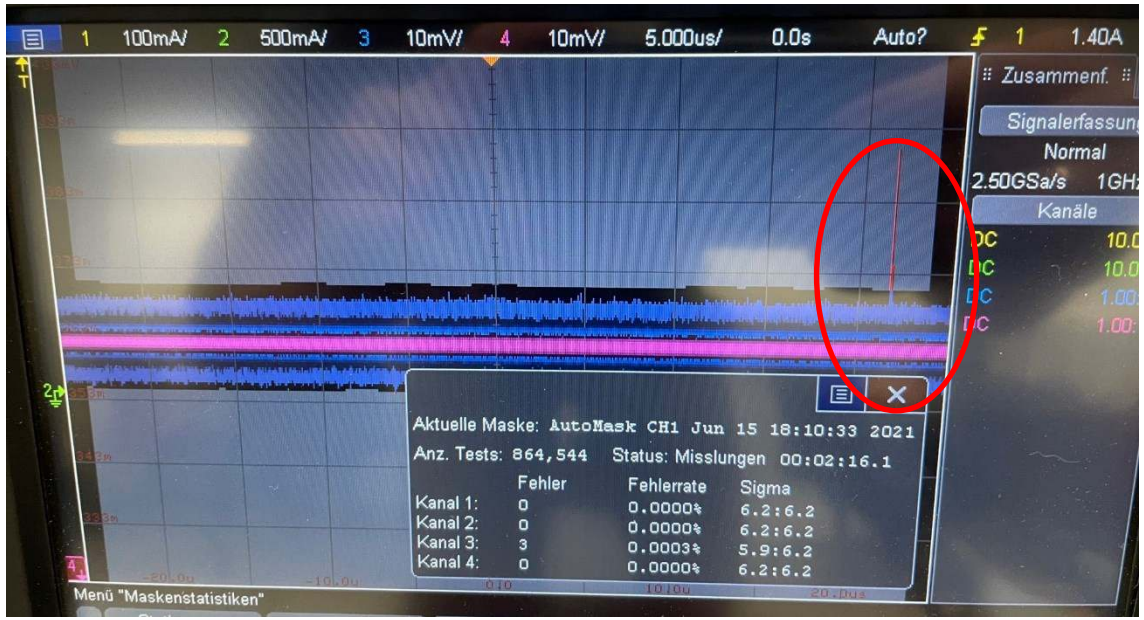
Test Setup

- Test Setup
  - SDR-driven test setup
  - Current probes to SET detection on power supply (drain and gate)
  - Oscilloscope to detect fast transients on the RF output (not captured by SDR)
  - Fully automated setup
  - DUTs operated at 4 GHz RF input (sinewave tone)
  - DUTs operated close to saturation
  - Nominal and max. supply voltages applied
  - Two samples each tested



Test Results

- Test Results
  - All DUTs remain nominal under radiation
  - No destructive failures observed
  - Even at maximum rating the DUTs did not failed
  - Likely that the rating conditions are beyond actual FETs ratings
  - Only once, a SET on the supply voltage (drain) of the HMC1087 was observed



Conclusion

- Successfully tested three different RF amplifier for Single Event Effects under Heavy-Ion irradiation
- Use of an (partially) SDR-based test setup
- Only one sample showed a single transient at its supply voltage input (drain)
- No destructive events observed at all tested DUTs and samples under nominal and max. rating conditions
- Likely that the FETs are capable to handle higher drain voltages

Thank you for your attention

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