GaN LINEARIZED SSPA FOR NAVIGATIONAL SATELLITES

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TH4-E

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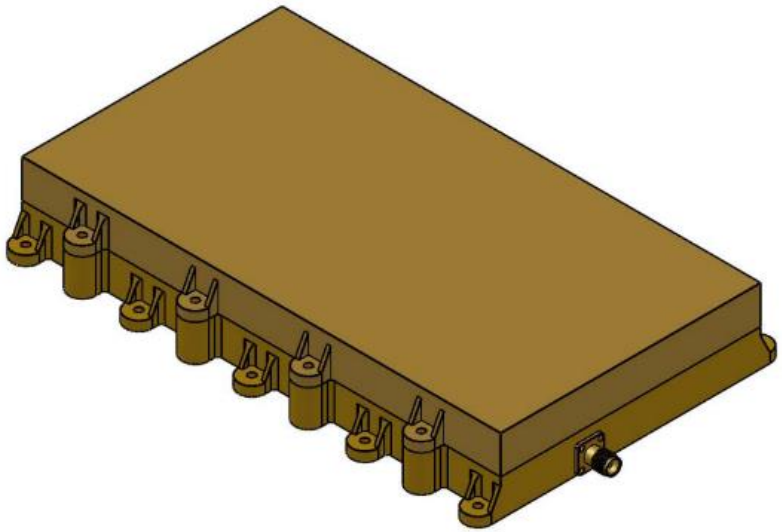


Introduction

Navigational satellites such as GPS and Galileo determine location on or near the Earth

Operate in L-band (1 – 2 GHz)

Their power amplifiers (PAs) must provide highest efficiency and meet reliability standards of space hardware

PAs of **higher power** are needed because of interference and jamming

PAs with **improved linearity** desired for new modulations

GaN SSPA

A new L-band SSPA designed for space with > 400 watts output power, improved linearity, and greater efficiency than previously reported is presented.

GaN offers > 60% PAE compared to GaAs (30%)

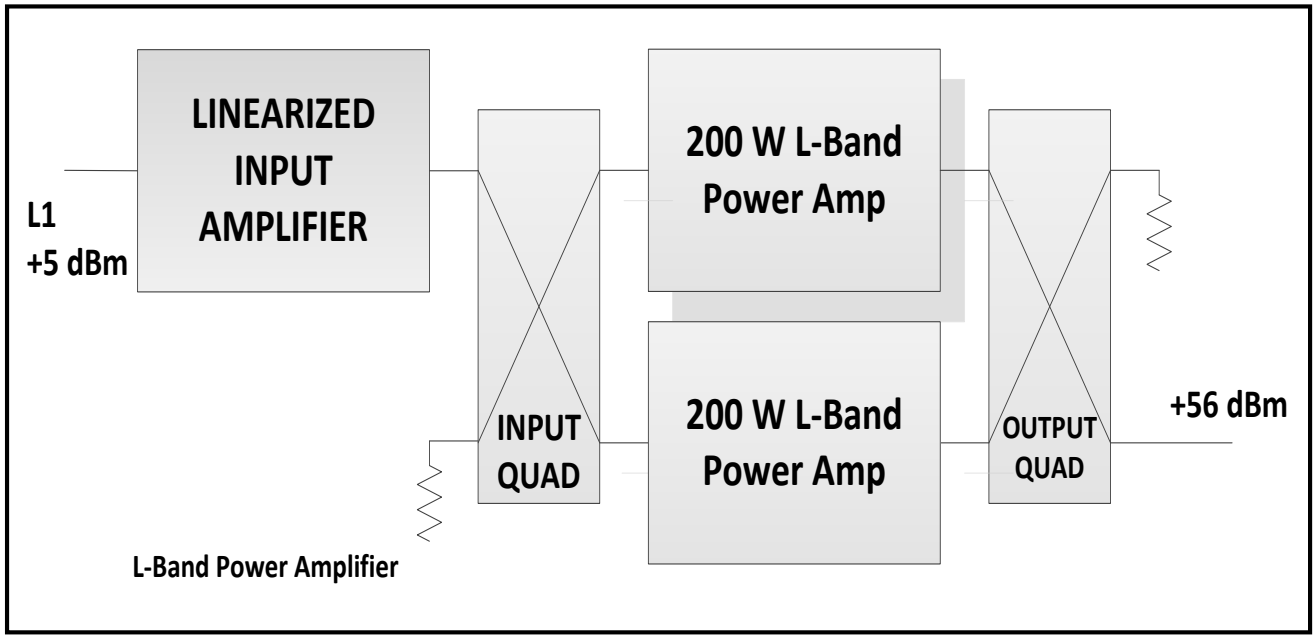
- GaN offers 150 W devices compared to GaAs (50 W)
- A linearizer is employed to achieve lower AM/PM and improved linearity

GaN Provides Higher Power at Higher Efficiency

GaN SSPA vs. TWTA in Space

- In the past **TWTAs** have been **used almost exclusively** for high power satellite PAs.
- **TWTAs** generally offered **higher power** & **PAE** than SSPAs.
- TWTA advantages increase with frequency. At **L-band**, GaN SSPAs and TWTAs have **comparable PAEs**
- Largest space qualified TWT is < 250 W. If two are combined for 400 W, metrics decisively favor SSPAs.
- The SSPA discussed in this paper besides having **> PAE**, has **a > 3-to-1 advantage** in mass and size.

> 400 W SSPA Architecture



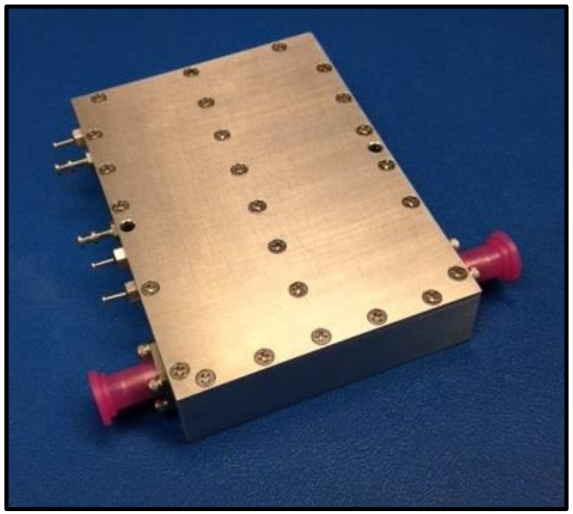
The SSPA consists of the LIA and HPA composed of 2 quadrature-combined > 200 W PA modules.

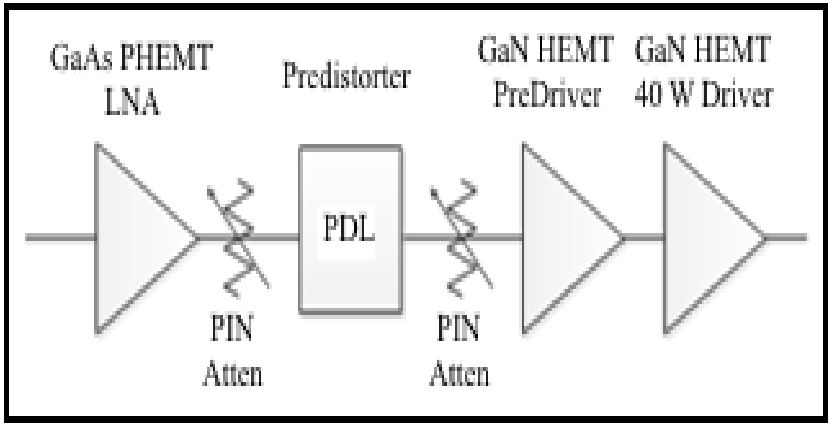
- Uses all Space Qualified Devices
- Achieved > 450 W with PAE > 65% over 50 MHz BW

LIA

The Linearized Input Amplifier (LIA) provides small signal gain, predistortion linearization, and up to 46 dBm RF drive to the HPA section

LIA Linearized Input Amplifier

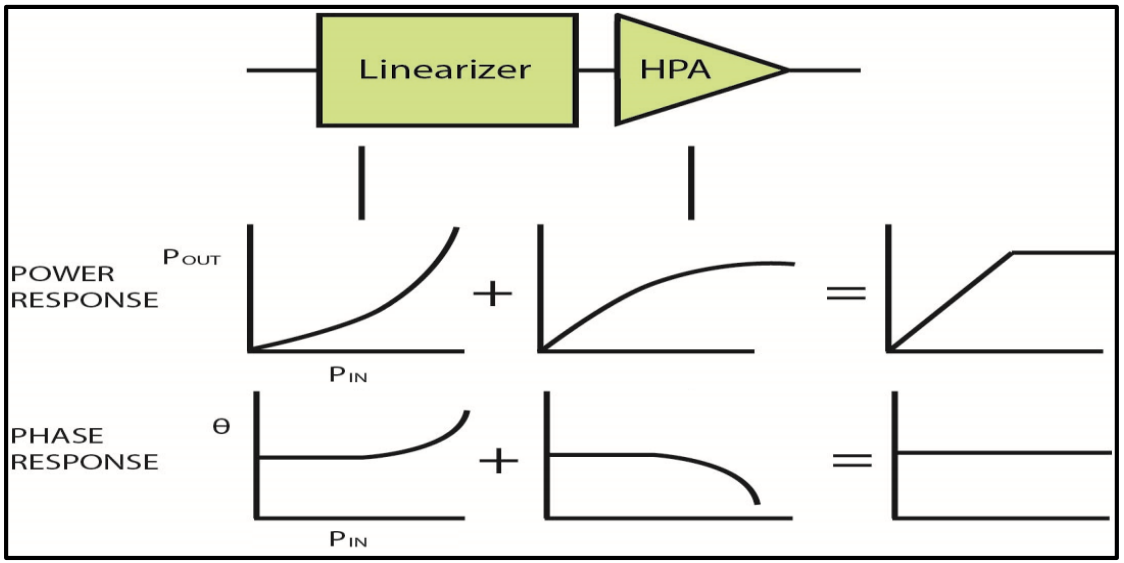




Linearizer

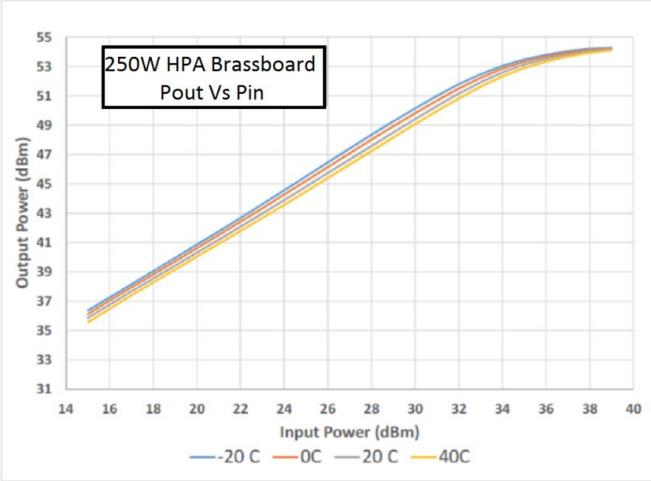
Allows HPA to operate closer to saturation and thus operate at higher efficiency

Provides a magnitude and phase transfer response that is opposite to that introduced by the power amplifier

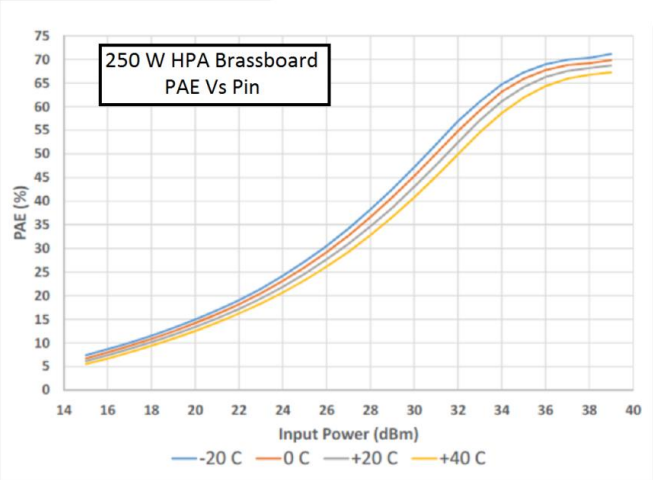


> 200 W Power Model

- The modules use 2 quadrature-combined 150 W GaN devices.
- The matching uses soft substrate and low loss (<0.15 dB) 3 dB hybrids

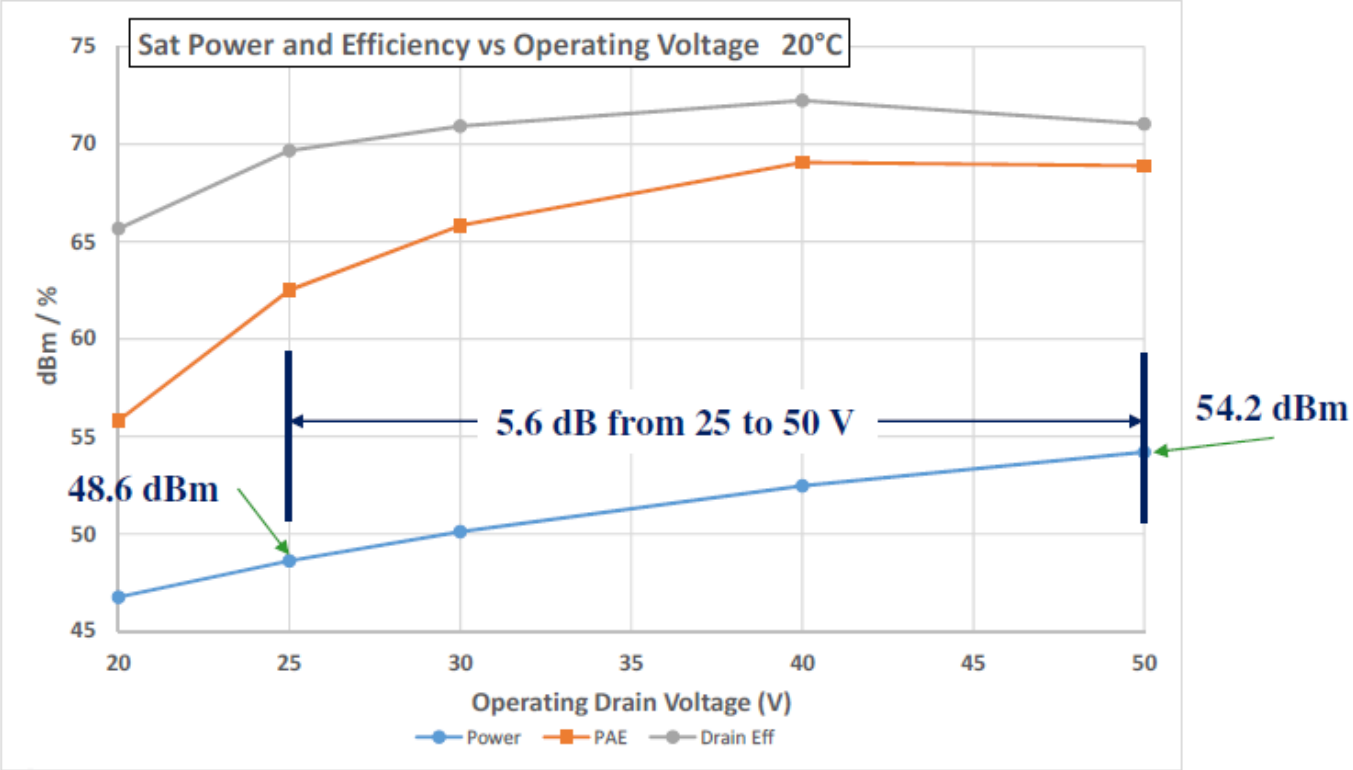


50 V	Sat Power	Sat Power
°C	dBm	Watts
-20	54.28	267.9
0	54.23	264.9
20	54.19	262.4
40	54.11	257.6
Pushing:	-0.00283 dB/°C	



50 V	Sat PAE	Sat Drain η
°C	%	%
-20	71.2	73.4
0	69.9	72.0
20	68.7	70.9
40	67.3	69.4
Pushing:	-0.065 %/°C	-0.066 %/°C

Power Module Performance vs. Drain Voltage

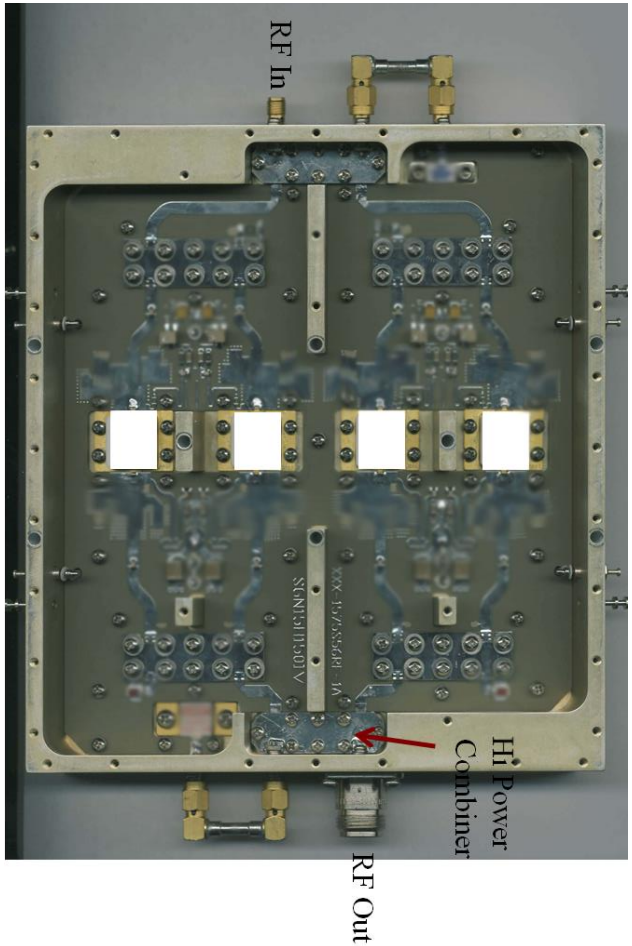


Provides wide output power range (5 dB) over 25 V to 50 V

Maintains high efficiency over the wide output power range

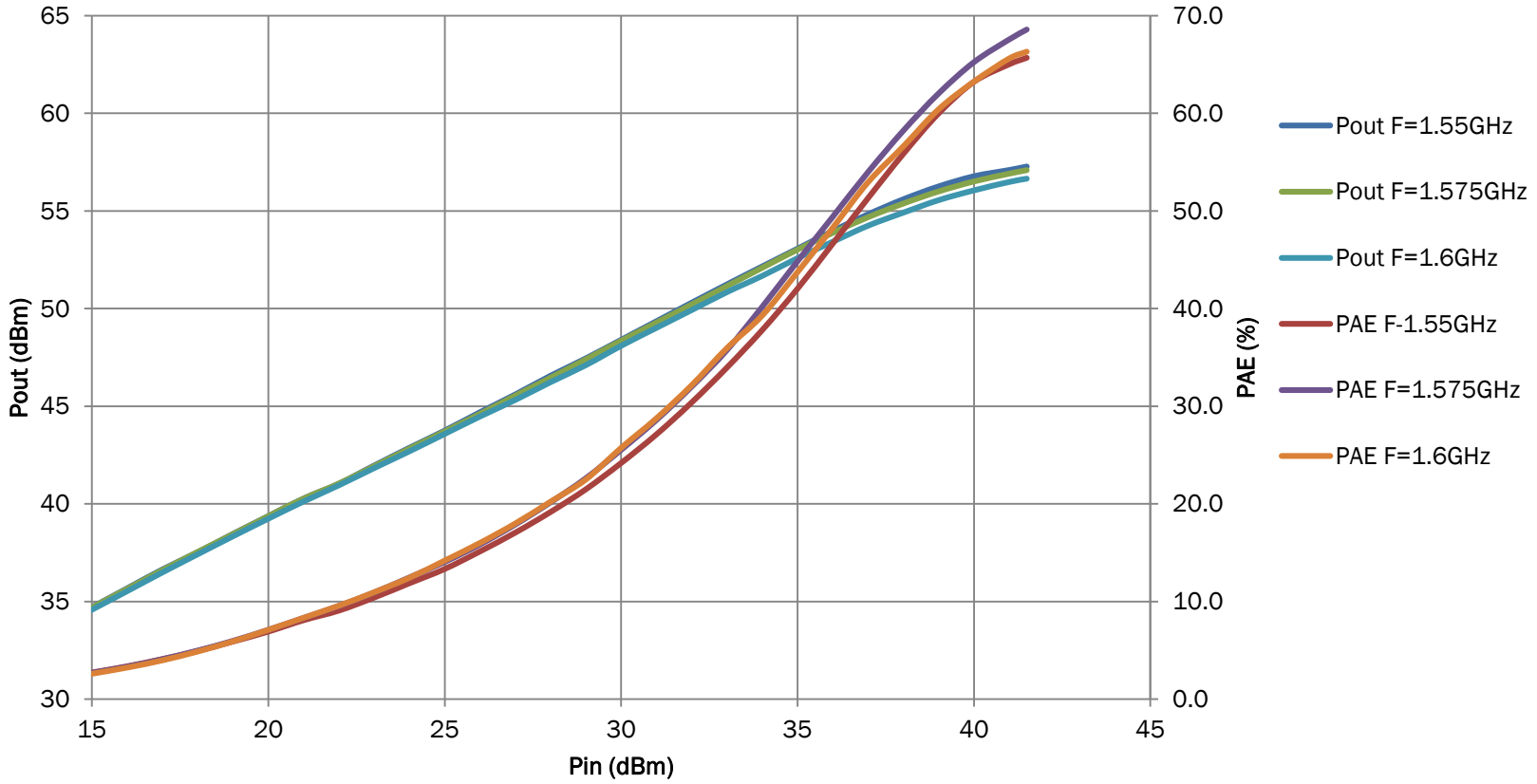
> 400 Watt HPA

- Consists of 4 x 150 W GaN devices combined to produce up to 500 W of RF output power
- The input to the devices is split four ways
- The device outputs are combined using 3 quadrature hybrid combiners
- The devices are matched to the hybrids using low-loss transmission line reactive matching techniques



400 Watt HPA

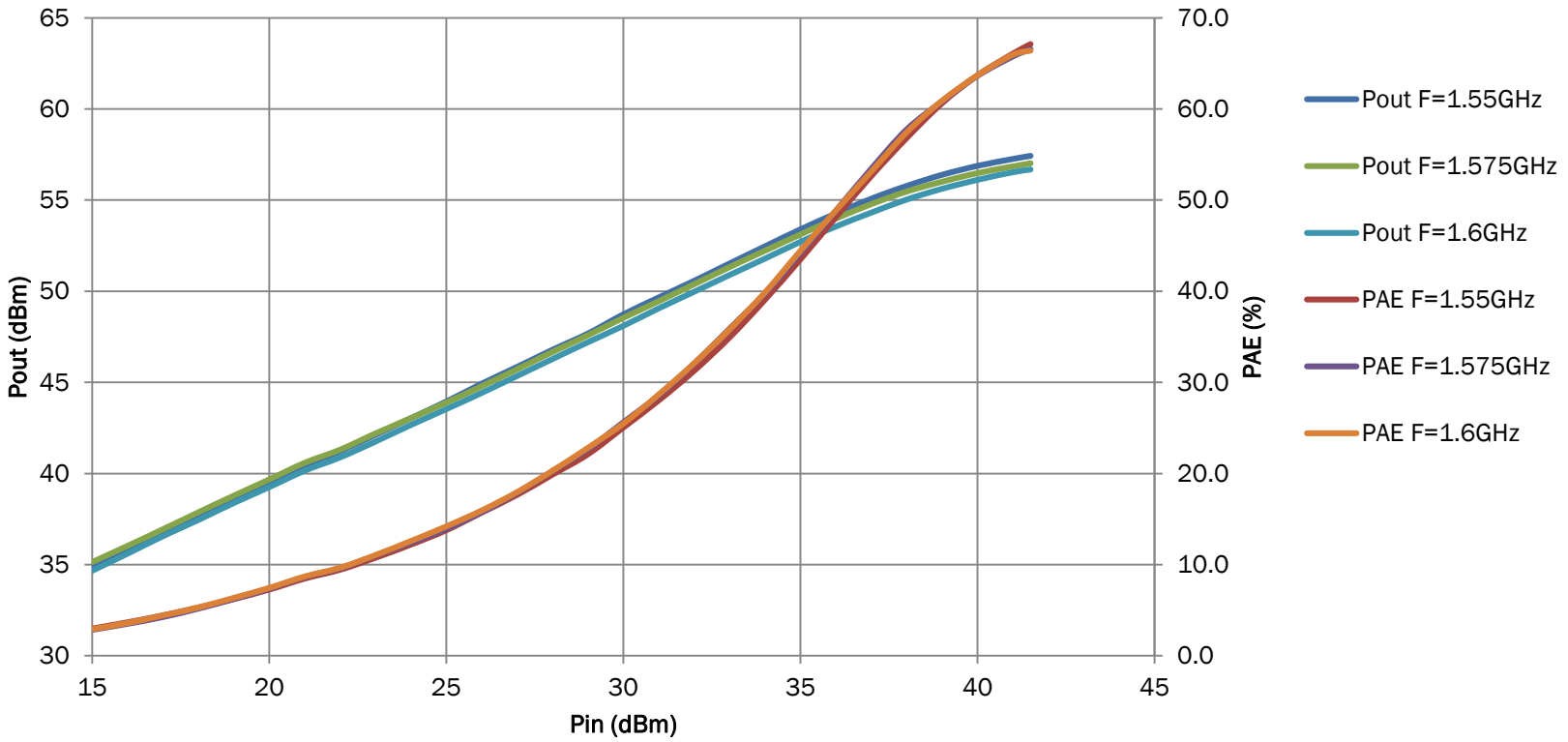
>400 W HPA @ 40°C Over 50 MHz BW



High Pout and PAE Achieved at WC Hot Temperature

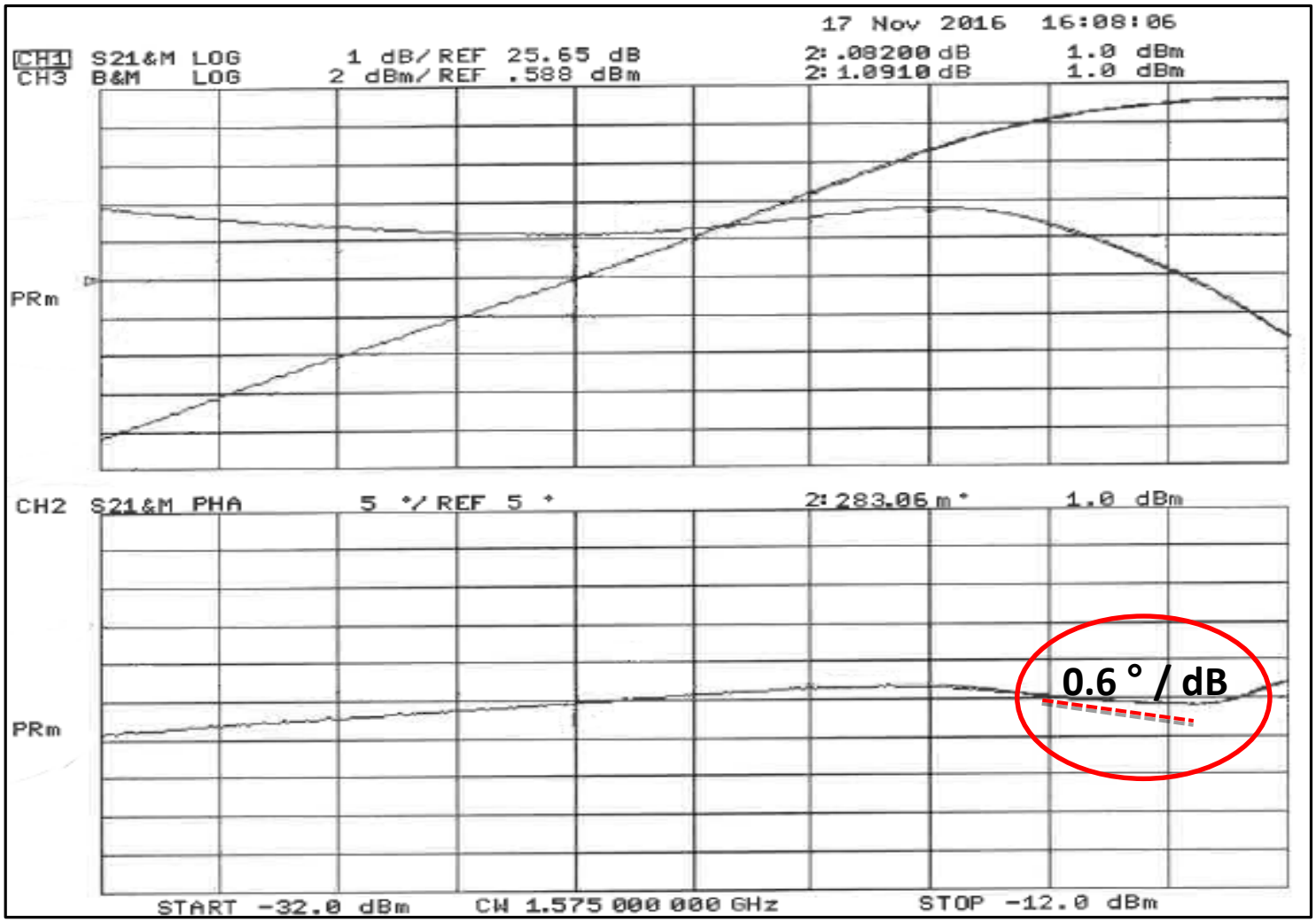
400 Watt HPA

400 W HPA @ 25°C and Over 50 MHz BW

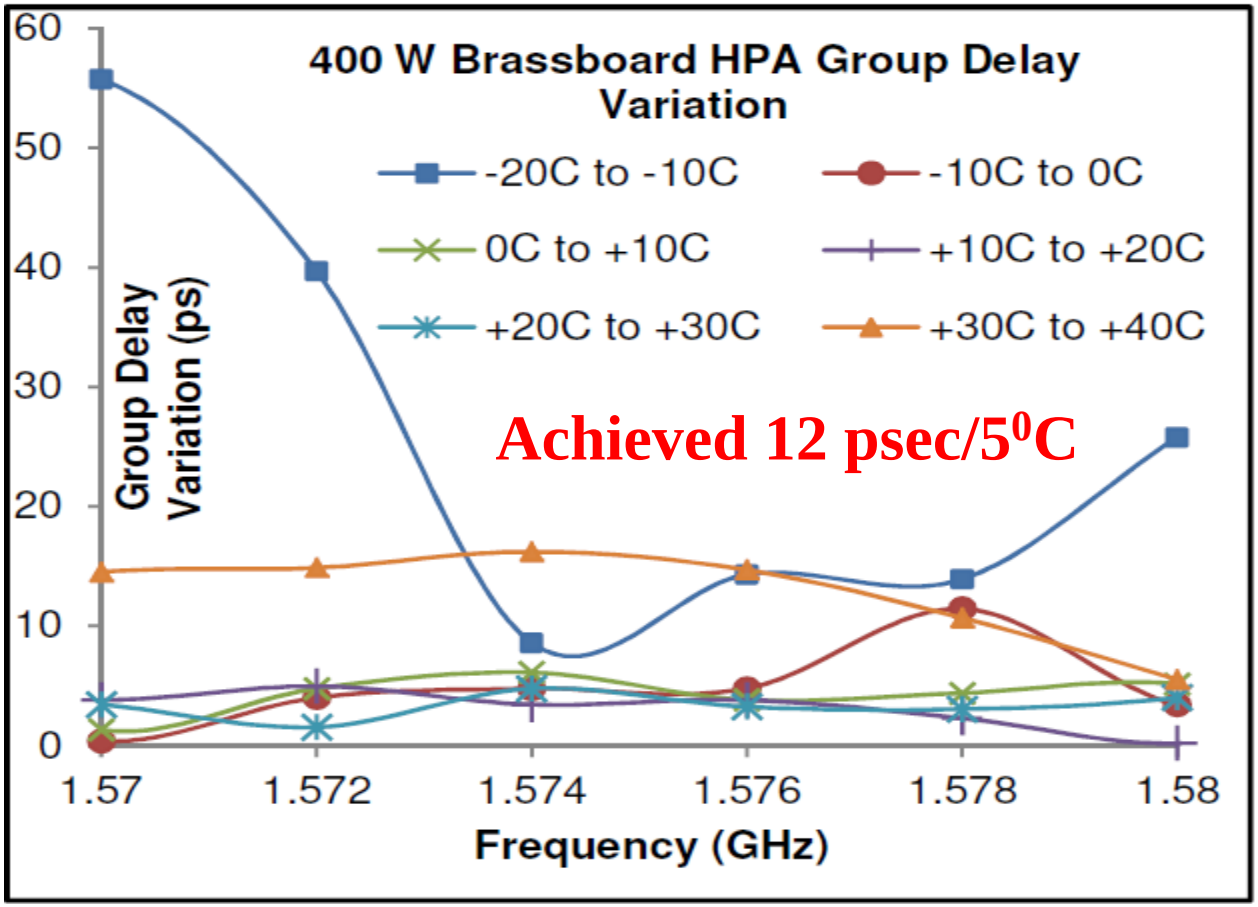


Output Power & PAE

400 Watt SSPA AM/PM



Group Delay of 400 Watt HPA

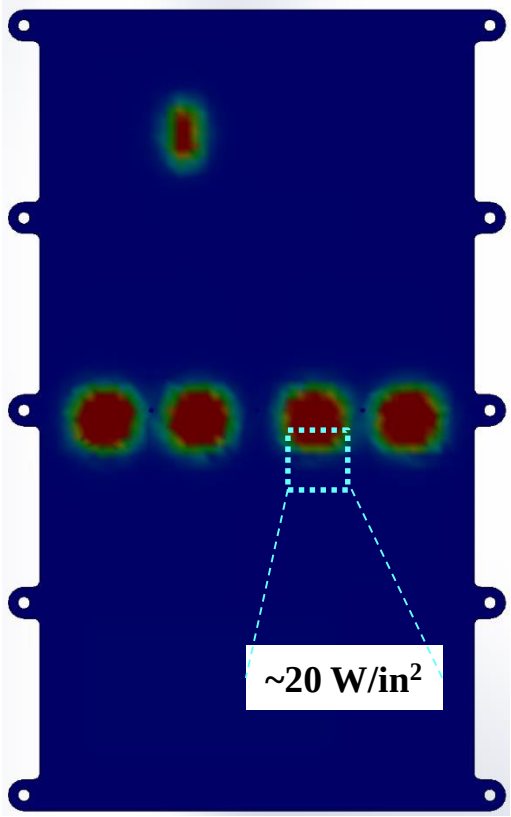


Low HPA GD Variation Achieved Across Band

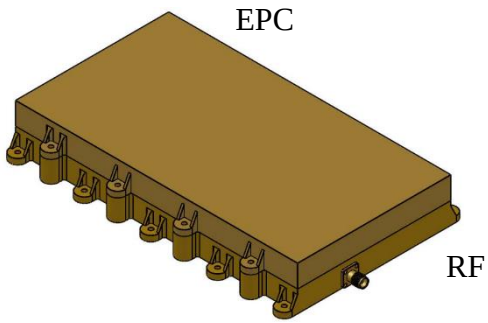
Multipaction

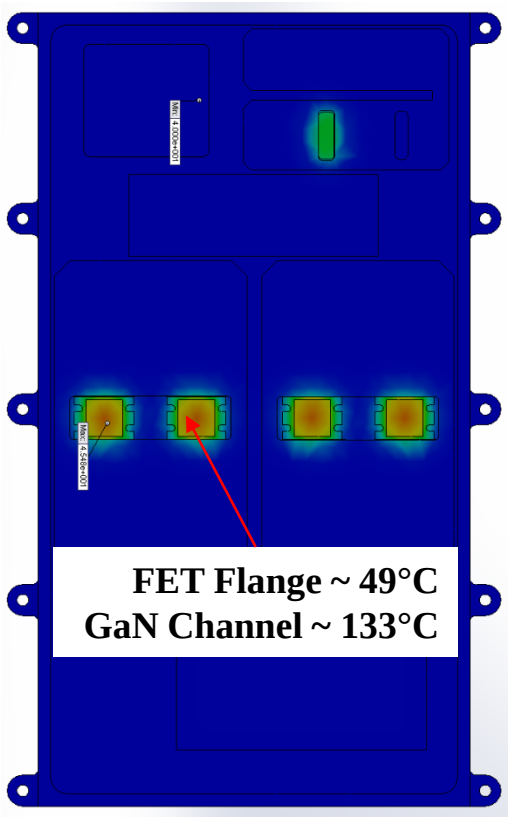
- Multipaction in vacuum is a critical concern for HPAs
- Major consideration during design of 400 W SSPA
- Analysis performed using ESA program for minimum gap at power levels to > 450 W
- Analysis shows that gaps < 6.8 mils are allowable

Effective Thermal Design



Housing at 40°C Baseplate
Al Post under each FET
Bottom view showing Heat Flux

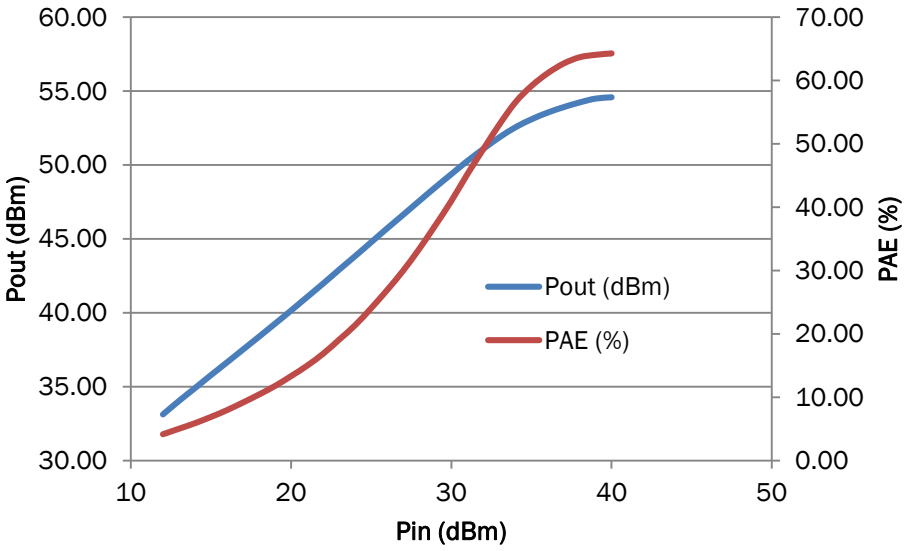




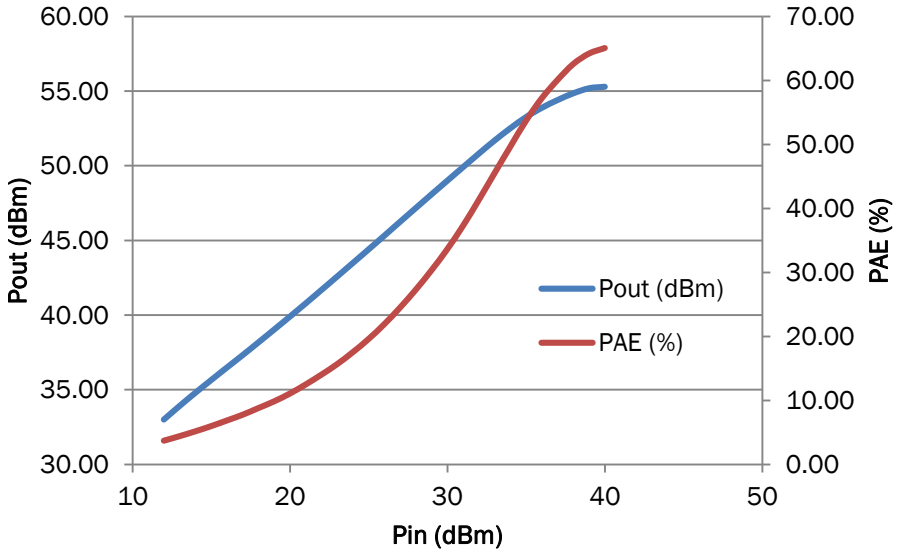
Housing at 40°C Baseplate
Al Post under each FET
Top view showing Temperature

Low Band @ 50 V

F = 1227.60 MHz



F = 1176.45 MHz



Conclusion

- Developed high power (450 W to 150 W) & PAE (> 65%) GaN SSPA for navigational satellites
- Used linearizer to improve AM/PM slope and PAE
- Developed low loss hybrid couplers for higher efficiency and RF output power
- Showed a thermal flux of < 20 W/in^2 can be met
- Special attention paid to producibility and affordability