National Aeronautics and Space Administration

Ka-band GaN-based SSPA for Deep-Space Telecom

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Program: Strategic Initiative

Project Objective:

The objective of this research was to investigate the path towards achieving a highly efficient Ka-band (31.8 to 32.3 GHz) solid-state power amplifier for deep-space telecommunications applications.

The goal of this 3-year task is to develop a 25-Watt power amplifier with > 40% power-added efficiency (used with the 40 dBi gain from the Ka-band Parabolic Deployable Antenna, KaPDA, can provide approximately 500 bps of telemetry downlink to the DSN at a range of 10 Astronomical Units). Such an amplifier can not only compete with traditional TWTAs, but may prove advantageous considering the inherent delicate nature, the technical expertise required, and the size/volume required for TWTAs.

Benefits to NASA and JPL:

Technical Feats

Unprecedented ~70% PAE device at Ka-band using 40-nm GaN process can ultimately provide an SSPA with ~40% overall PAE with 25 W RF.

5 W RF version can provide > 50% overall PAE now competes with vacuum-based technology in terms of efficiency.

Estimate volume for a 6-way combined SPCA is ~100-cc including the power conditioning electronics. This is >75% volume reduction compared to NISAR's 1-Watt SSPA, and >95% volume reduction compared to L3's TWTAs.

Enables

New interplanetary explorers such as SmallSats and CubeSats with constrained power and volume requirements could use a 5-Watt SPCA to achieve 100 bps from 10 AU distance (Saturn range) using a KaPDA with 40 dBi gain.

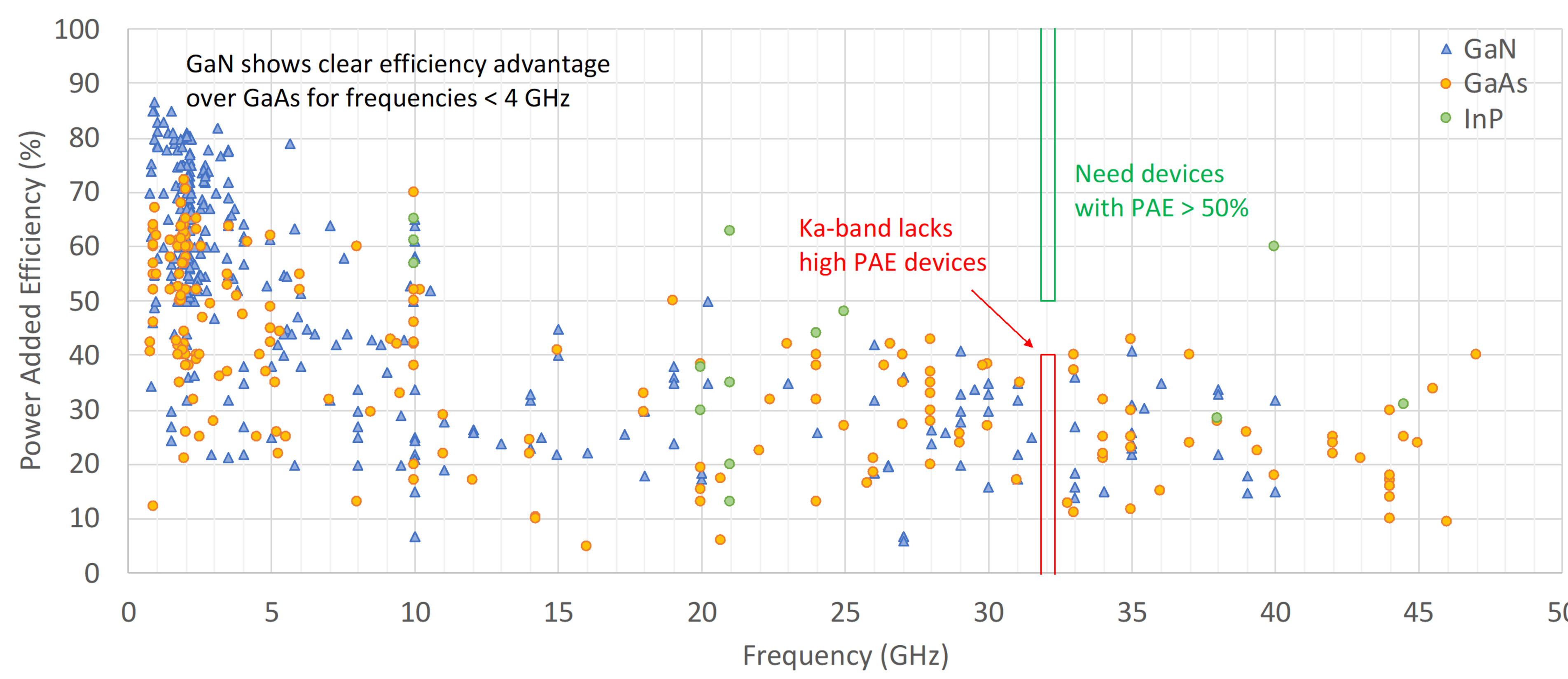
Continuous DTE telecom during high-dynamic planetary entries without intermittent drops could be achieved with solid-state technology that have higher tolerance to vibration/shock environments compared to vacuum-based technology (e.g.: TWTAs).

III-V Semiconductor family, especially GaN, is known to be highly radiation tolerant that could help reduce shielding mass required to explore harsh radiation environments.

FY19 Results:

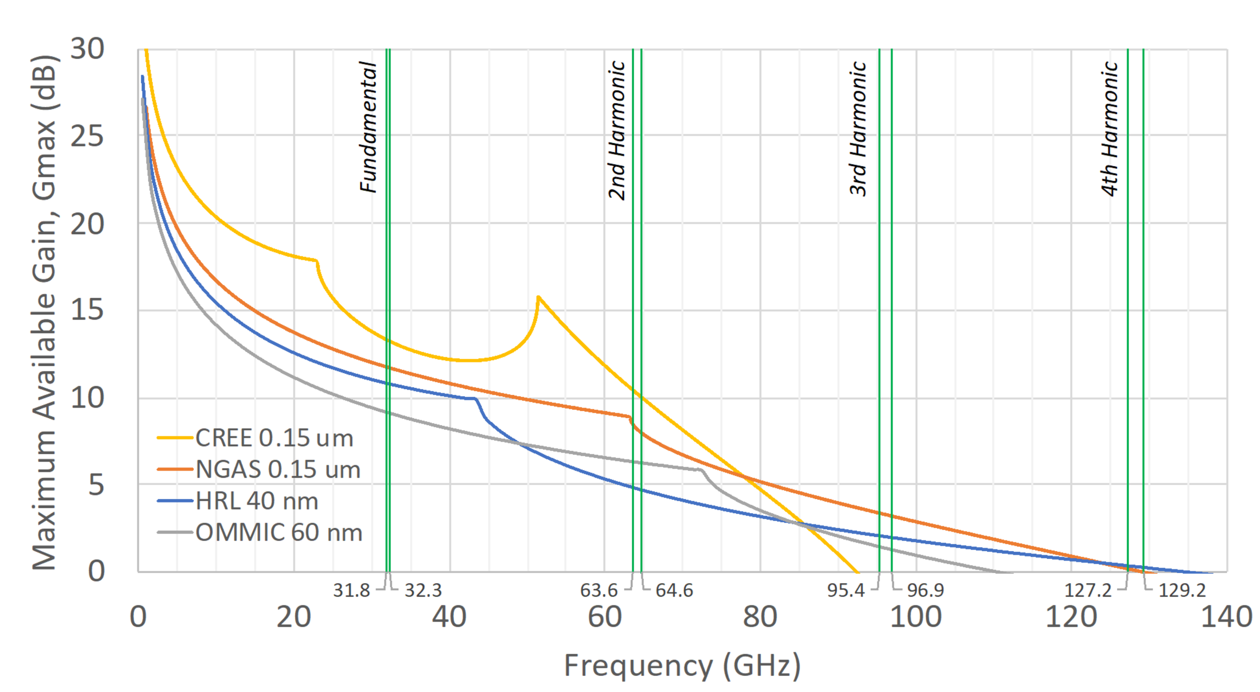
- **Survey of commercial products from vendors emerging with GaN devices**

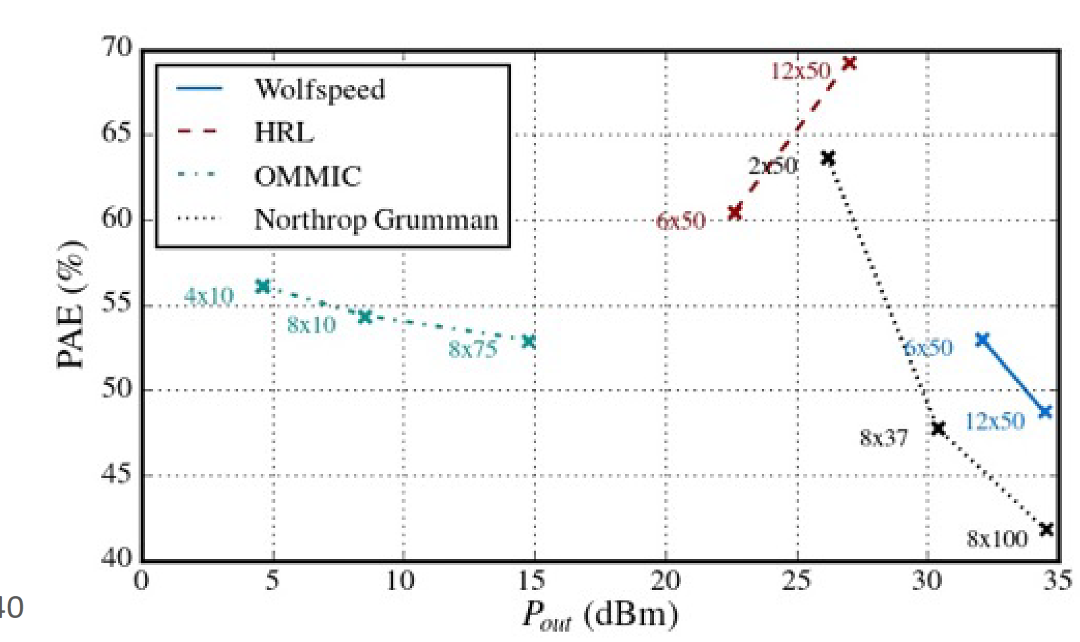
Best device: Qorvo's TGA2594 (0.15 um GaN/SiC, 27-31 GHz, 5-Watt output, 30% PAE)
Determined industry focuses on:
- Wideband multi-GHz applications and sacrifice efficiency
- 5G Wireless products that require high linearity to support high-order modulation like 256QAM



- **Evaluation of GaN foundries for custom MMIC development**

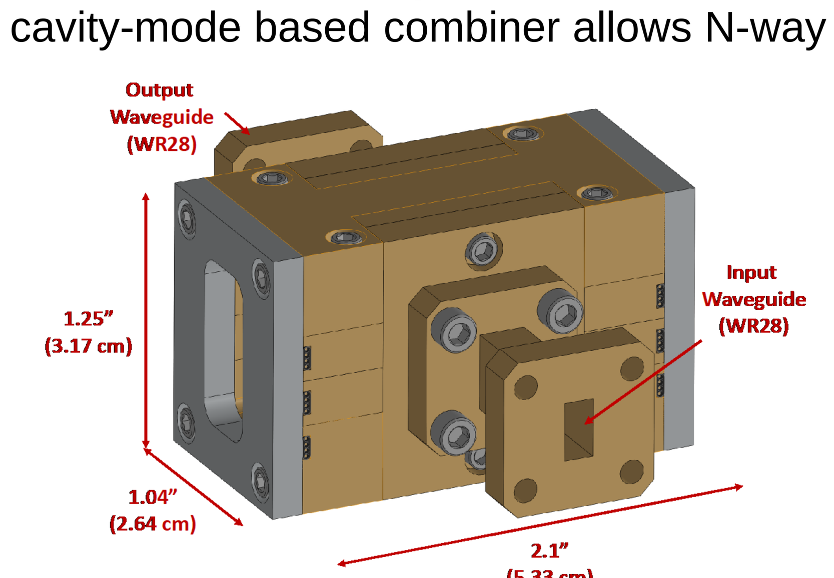
New 0.15-um GaN process emerging with lower parasitic capacitance that supports higher frequency operation
Developmental 60-nm and 40-nm GaN process pushes f_T to > 200 GHz
Source/Load-pull simulations for inverse Class-F bias achieves devices w PAE > 50%

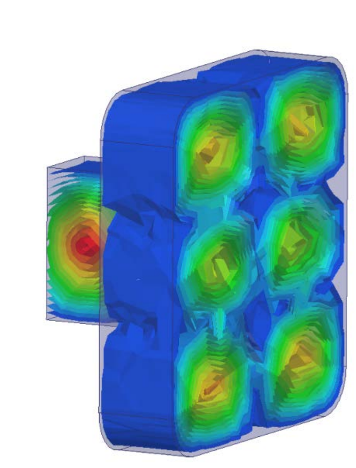




- **Spatial Power Combining Amplifier (SPCA) Design**

Low-loss cavity-mode based combiner allows N-way combination (6-way designed)





TM310 Mode E-field Plot

Level	Parameter	HRL 12x50um	NGAS 2x50um	HRL 6x50um	CREE 6x50um	CREE 12x50um	NGAS 8x37um	NGAS 8x100um
Device	**Power Added Efficiency**	**69.3%**	**63.7%**	**60.5%**	**53.0%**	**48.8%**	**47.8%**	**41.8%**
Device	Output Power, Poa (W)	0.5	0.4	0.2	1.6	2.8	1.1	2.8
MMIC	No of Stages, K	3	3	5	1	1	2	1
MMIC	Combiner Loss, L_a (dB)	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
MMIC	**Output Power, Po (W)**	**3.5**	**2.9**	**4.7**	**3.1**	**5.3**	**4.0**	**5.4**
MMIC	Preamp stages, n	2	2	2	1	2	1	1
MMIC	No of total amps, N	14	14	56	3	4	6	3
MMIC	Drive Level (dBm)	6.54	11.36	9.73	13.58	9.64	15.76	16.87
MMIC	Power Gain, Gm (dB)	28.92	23.25	26.97	21.33	27.61	20.26	20.45
MMIC	**Power Added Efficiency**	**40.9%**	**41.7%**	**33.1%**	**37.9%**	**28.5%**	**32.9%**	**30.3%**
SSPA	No of Combination Stages, S	8	8	6	8	4	6	4
SSPA	Combiner Loss, L_o (dB)	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
SSPA	**Output Power, Po (W)**	**26.9**	**22.1**	**26.7**	**23.6**	**20.3**	**22.9**	**20.6**
SSPA	Input Drive (dBm)	15.77	20.59	17.71	22.81	15.86	23.74	23.09
SSPA	Power Gain, Gt (dB)	28.52	22.85	26.57	20.93	27.21	19.86	20.05
SSPA	**Power Added Efficiency**	**39.0%**	**39.8%**	**31.6%**	**36.2%**	**27.2%**	**31.4%**	**28.9%**
SSPA	Efficiency Degradation	30.3	23.9	28.9	16.8	21.5	16.4	12.9

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Poster No. RPC-251