CIF One-day Workshop on III-Nitride Materials, Devices, and UV Space Applications

GaN-based Ka-band Power Amplifiers for Deep-Space Telecommunications

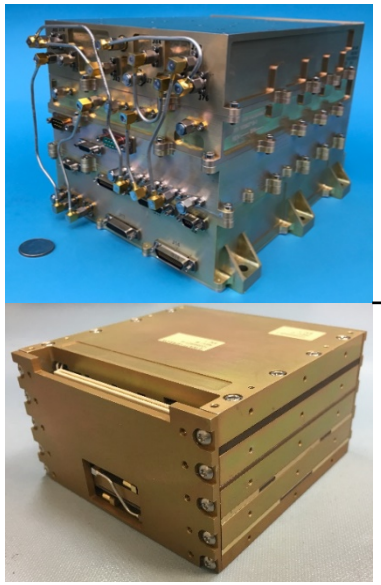
June 17, 2019

M. Michael Kobayashi, JPL 337D S/C Transmitters

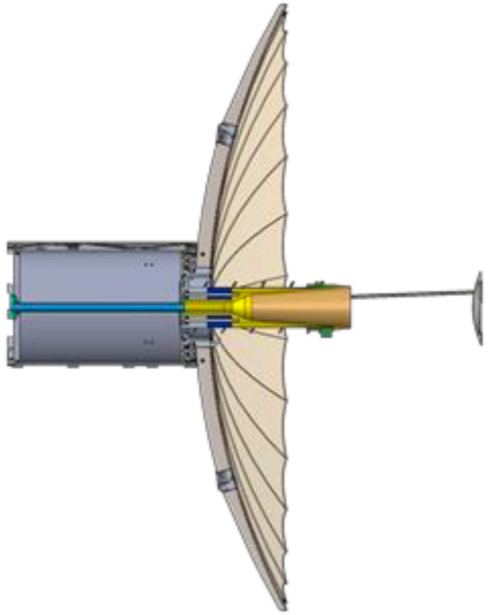
Jet Propulsion Laboratory
California Institute of Technology

GaN SSPA for Deep-Space Telecom

Fill the gap in Ka-band telecom subsystem elements



Amp



25 W + 42 dBi can provide
500 bps at 10 AU (Saturn) distances

<u>Advanced SDRs</u>
Iris Deep-Space Transponder
Universal Space Transponder

<u>Deployable Ka-band Parabolic Antenna</u>
Stowed: 1.5 U
Aperture: 0.5m, 42.6 dBi

GaN SSPA for Deep-Space Telecom

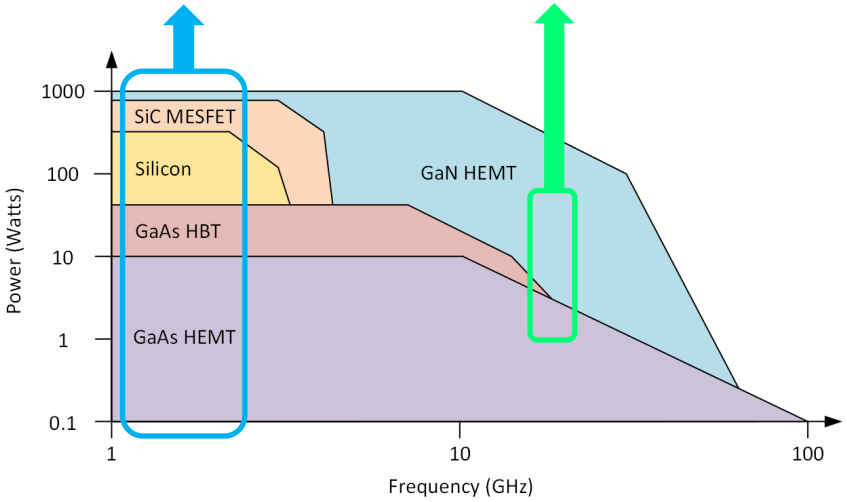
S-band is **effectively closed** due to limited bandwidth and terrestrial interference

X-band is the current workhorse for deep space communication, but **getting crowded**

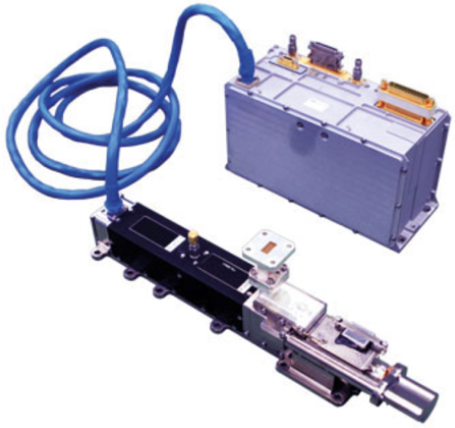
Ka-band is **largely unused**
- ~10x bandwidth capacity
- ~16x antenna gain efficiency
- ~4x radiometric precision

Multiple technology options in low-freq

Limited to GaN, maybe some GaAs



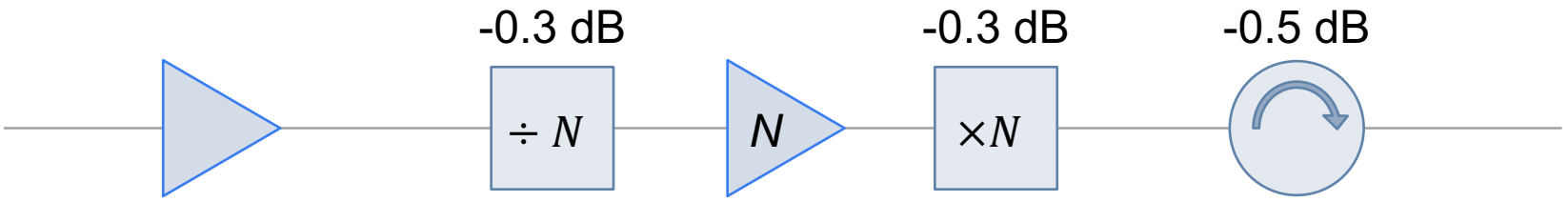
US manufacturing capability of TWTAs disappearing → GaN alternatives sought



Vacuum technology sensitive to shock/vibration – concern for high-dynamic environments that entry probes encounter

SSPA Requirements

Parameter	Requirement
Frequency	31.8 – 32.3 GHz (500 MHz BW)
Output Power	25 W (+44 dBm)
Overall Efficiency	> 40% (goal > 50%; comparable to TWTA)
Modulation Schemes	Constant envelope (BPSK / QPSK)

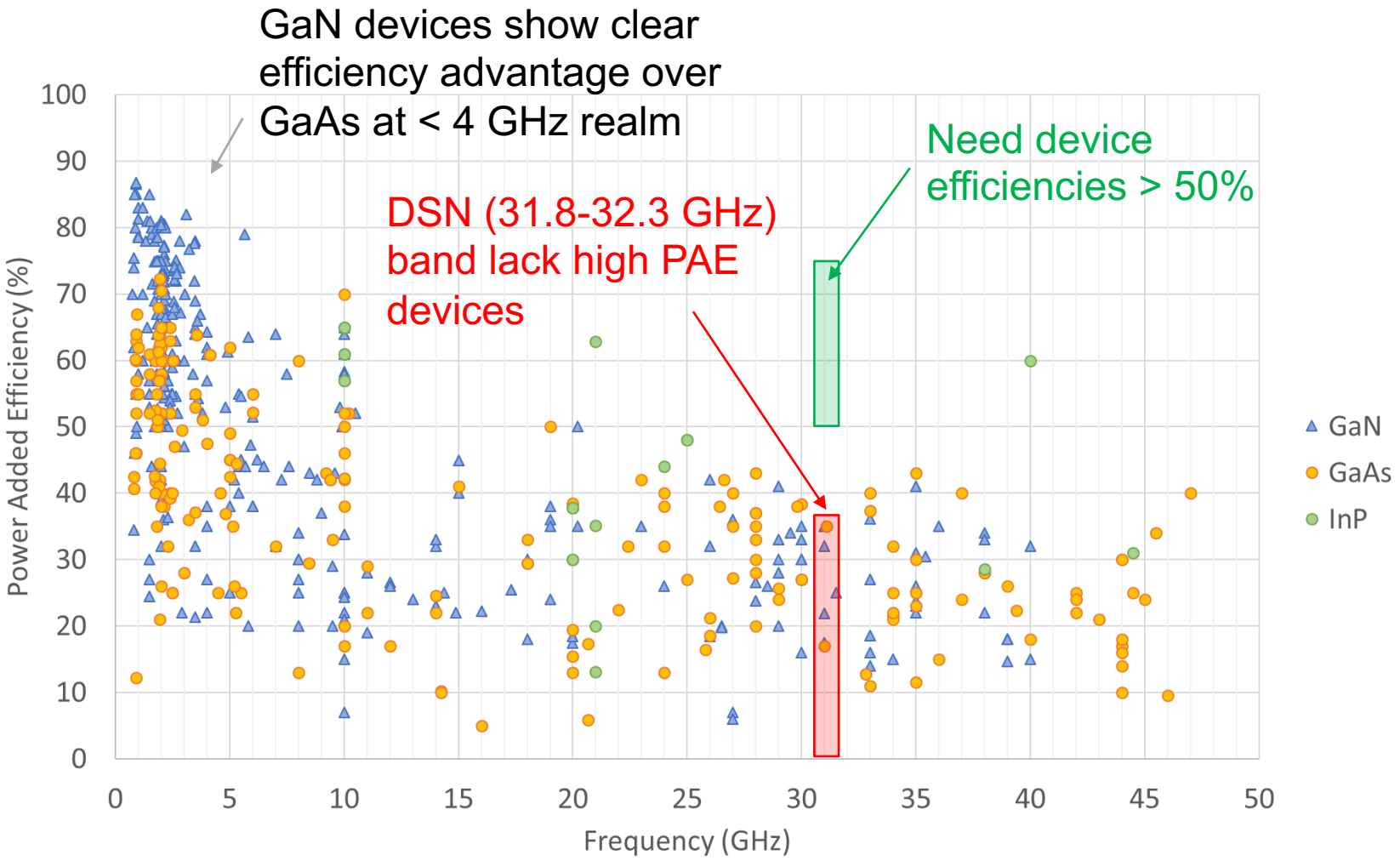


Driver Amp
30% eff.

6-way combiner/splitter
P_{device} = 5 Watts

Total Eff.	Necessary Device Eff.
40%	49.0%
50%	61.6%
60%	74.7%

III-V Semiconductor Survey



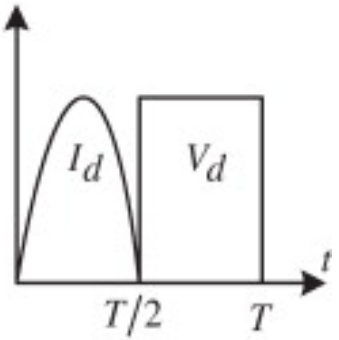
Hua Wang, Fei Wang, Huy Thong Nguyen, Sensen Li, Tzu-Yuan Huang, Amr S. Ahmed, Michael Edward Duffy Smith, Naga Sasikanth Mannem, and Jeongseok Lee, "Power Amplifiers Performance Survey 2000-Present," [Online]. Available: https://gems.ece.gatech.edu/PA_survey.html

GaN Foundry Survey

Foundry	Process	Gate (um)	Substrate	Notes
Northrop Grumman	GAN20	0.20	GaN/SiC	
Northrop Grumman	GAN15	0.15	GaN/SiC	
CREE/Wolfspeed	G28V3	0.40	GaN/SiC	Only good to ~10GHz
CREE/Wolfspeed	G28V4	0.25	GaN/SiC	Only good to ~20GHz
CREE/Wolfspeed	G28V5	0.15	GaN/SiC	Good to 40 GHz
OMMIC	D01GH/Si	0.10	GaN/Si	Thermal properties Si < SiC
OMMIC	D006GH/Si	0.06	GaN/Si	Thermal properties Si < SiC
Qorvo	Not Available	0.15	GaN/SiC	Not open to public
Qorvo	Not Available	N/A	GaN/Diamond	Confidential process; not open
UMS	GH25	0.25	GaN/SiC	$F_T \approx 30$ GHz
UMS	GH15	0.15	GaN/SiC	
HRL Labs	T3-GaN	0.04	GaN/SiC	Ultra-high $F_T > 200$ GHz
WIN Semi	NP45	0.45	GaN/SiC	
WIN Semi	NP25	0.25	GaN/SiC	
WIN Semi	NP15	0.15	GaN/SiC	Good to 35 GHz

Class-F Bias Amplifiers

- Harmonically-tuned amplifiers to “waveform engineer” the voltage/current waveforms to boost efficiency
  - Voltage waveform as perfect squarewave
  - Current waveform as half-sine wave, 180° out-of-phase with voltage waveform
  - Tuning more harmonics, the better
  - Process with high F_T desired



- Currently making progress with PDKs from foundries
- Planning to participate in Multi-Project Wafer (MPW) shared runs to save cost

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov