Reconfigurable Gallium Nitride Based Fully Solid-State Microwave Power Module for Cognitive Radio Platforms

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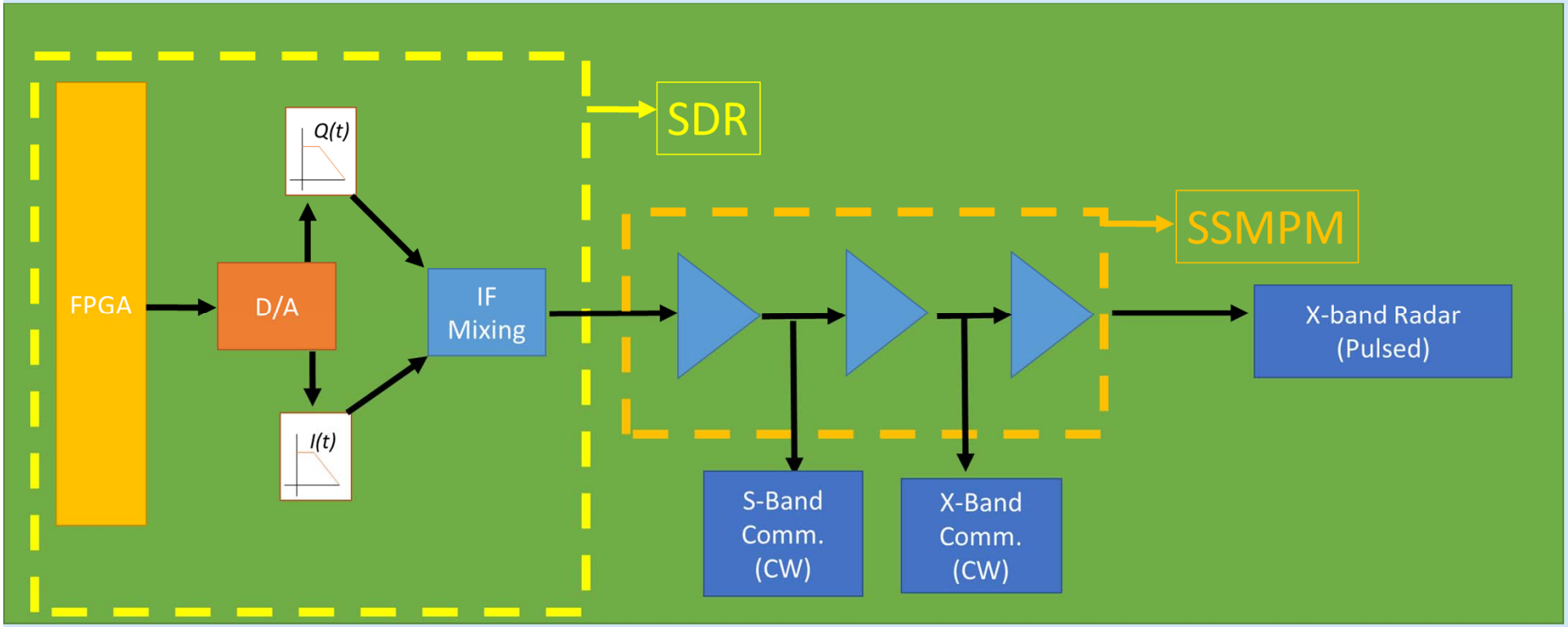
Outline

- Introduction & Motivation
- Cognitive Transmitter
- Solid-state Microwave Power Module (SSMPM)
- Efficiency & Reliability
- Transistor Field Plate (FP) Structure
- Proof-of-Concept Reconfigurable SSMPM
- Measured Results of the X-band High Power Amplifier (HPA)
- Test Results of SSMPM
- Conclusion & Discussions

Introduction

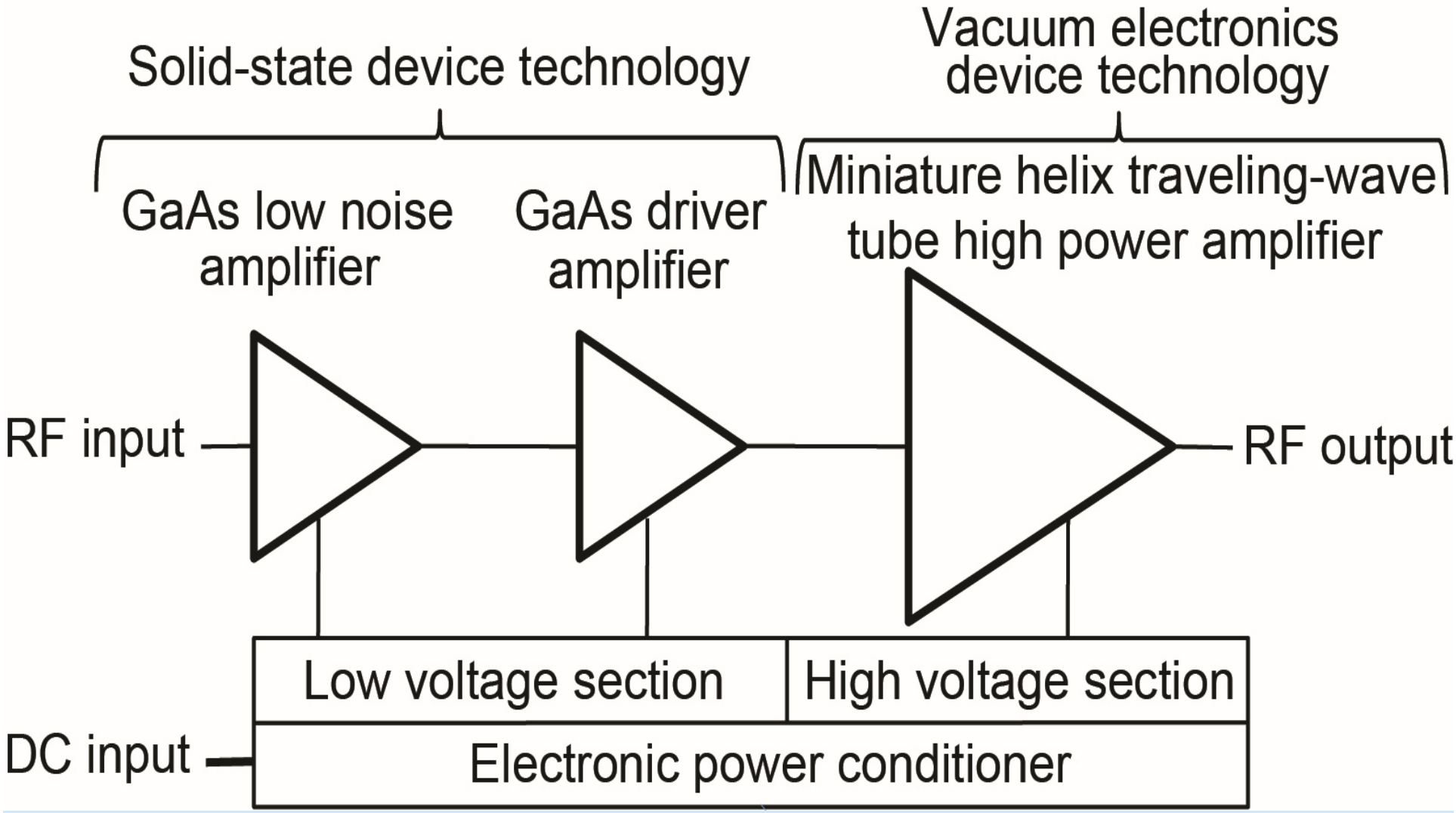
- Motivation
  - New Class of NASA Mission
    - Small Satellites, Probes for Asteroids, & Landers on Moons
- Limitation of State-of-Practice
  - Standalone multiple amplifiers used at S-Band for telemetry & command, X-Band for science data downlink, X-Band for mapping radar, etc.
- Advantages of Proposed Single Wideband, reconfigurable high-power, high-efficiency SSMPM
  - A single reconfigurable amplifier enables miniaturization of the overall RF system
  - Wide Bandwidth allows operation at multiple frequencies depending on the cognitive need at any given time
  - Can take advantage of compound semiconductor materials, devices, and circuits to enhance functionality
  - Lower cost

Cognitive Transmitter

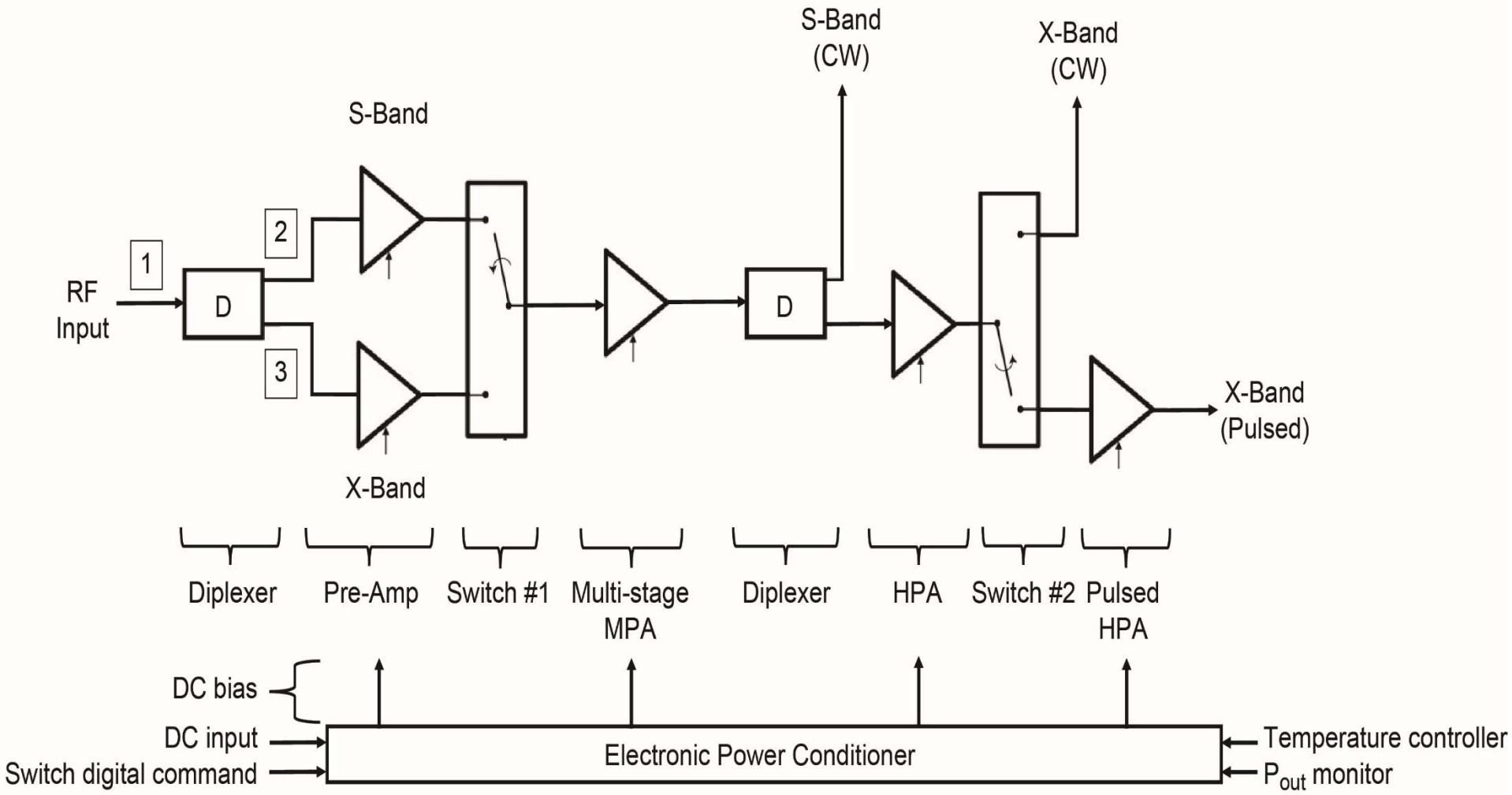


- A Cognitive Transmitter is expected to perform transmit-power control and dynamic spectrum management
- Additional knowledge for the cognitive processor is gained through proximity sensing with X-band Radar
  - This helps determine impact of interference with EM surfaces

Conventional Microwave Power Module (MPM)



Fully Solid-State Microwave Power Module (SSMPM)

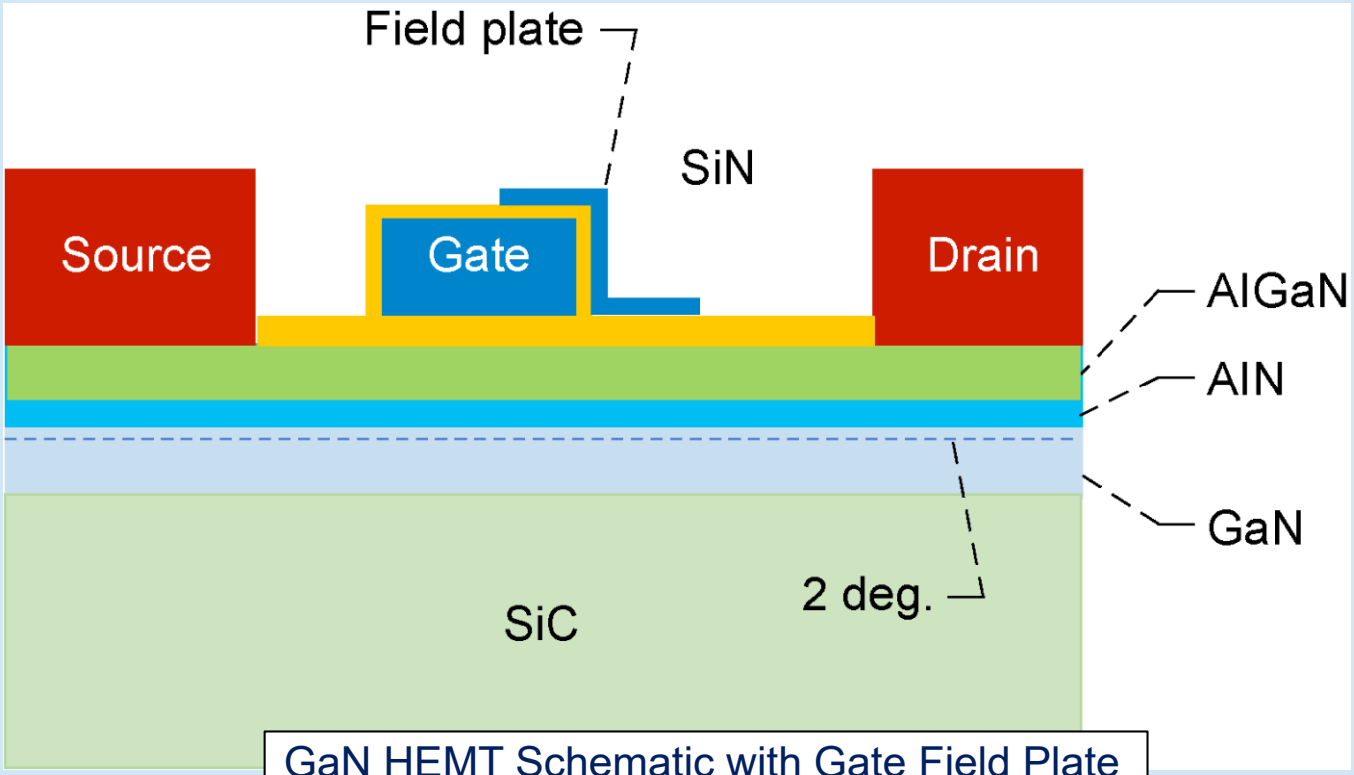


Efficiency & Reliability

- The Importance of efficiency
  - The power amplifier can consume 80-90% of the space craft bus [1] [2]
    - Increase in efficiency = lowered heat sink mass + Increase in device lifetime

- GaN is an improvement in reliability
  - GaN HEMTs contain a 2-D gas layer that help to recombine scattered carriers induced by radiation
    - This makes GaN 8-10x more radiation hardened than GaAs [3]

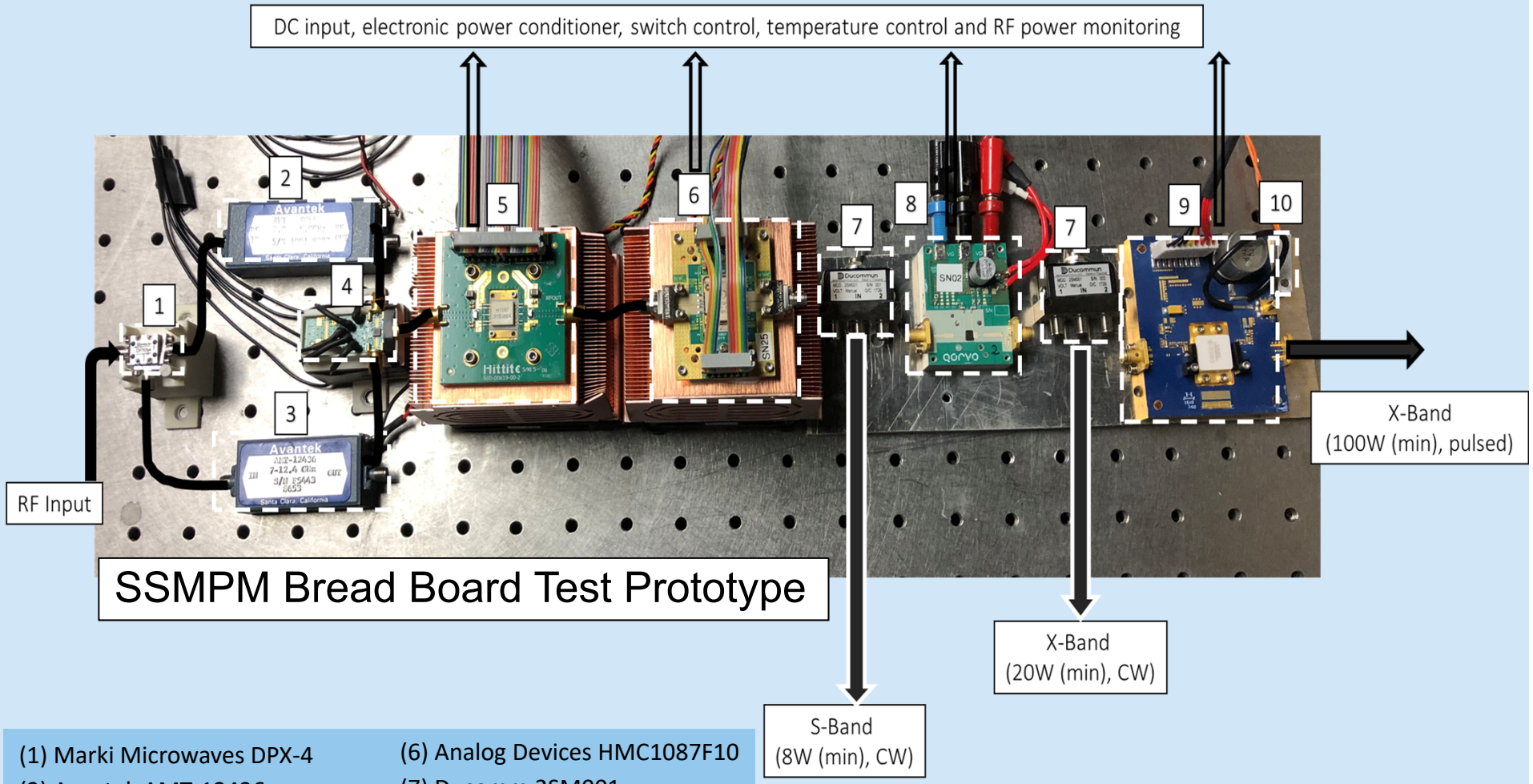
Advanced Field Plate Structure



GaN HEMT Schematic with Gate Field Plate

- An FP redistributes the electric field to suppress transport carriers away from the conducting channel surface
  - Enabling higher breakdown voltages and operating drain voltage
    - Increased power, PAE and linearity performance
    - Results in an increase in device lifetime and reliability
- The trade-off
  - an increase in C_{GD}

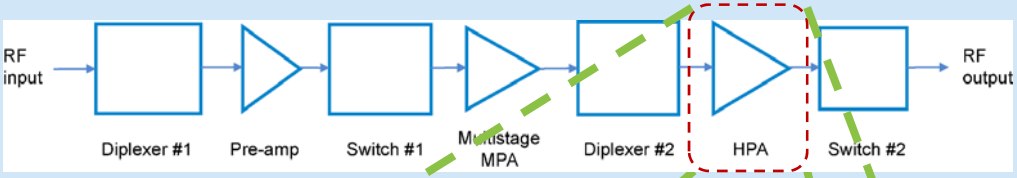
Bread Board Version of the Fully SSMPM



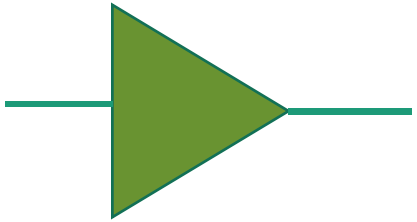
(1) Marki Microwaves DPX-4
(2) Avantek AMT-12436
(3) Avantek AWT-6035
(4) Analog Devices HMC1118 SPDT
(5) Qorvo TGA2214-CP
(6) Analog Devices HMC1087F10
(7) Ducomm 2SM001
(8) Qorvo TGF2978-SM
(9) Cree CGHV96100F2
(10) Thermocouple

GaN CW HPA With Advanced Field Plate

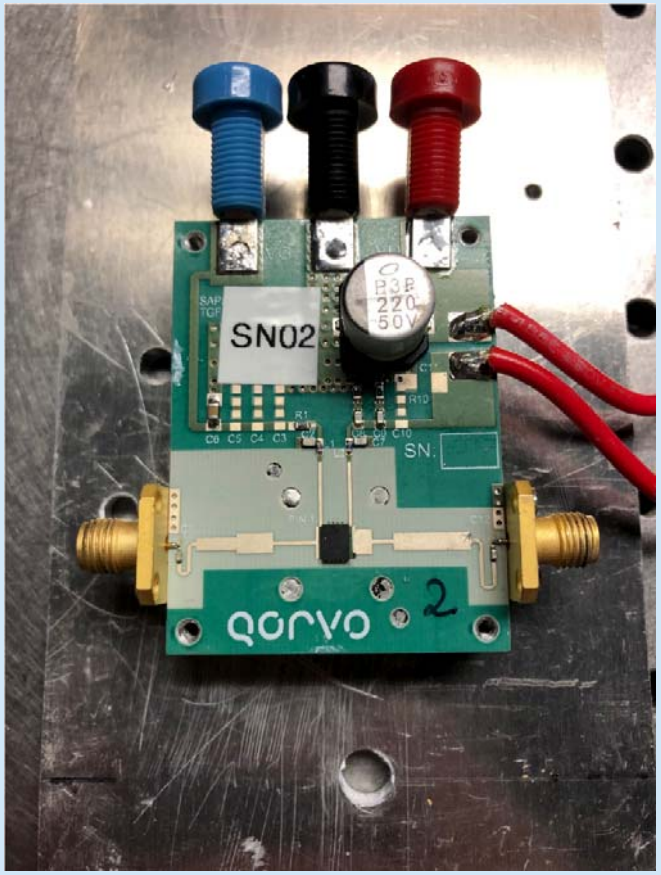
X-band CW Signal Path



HPA Configuration

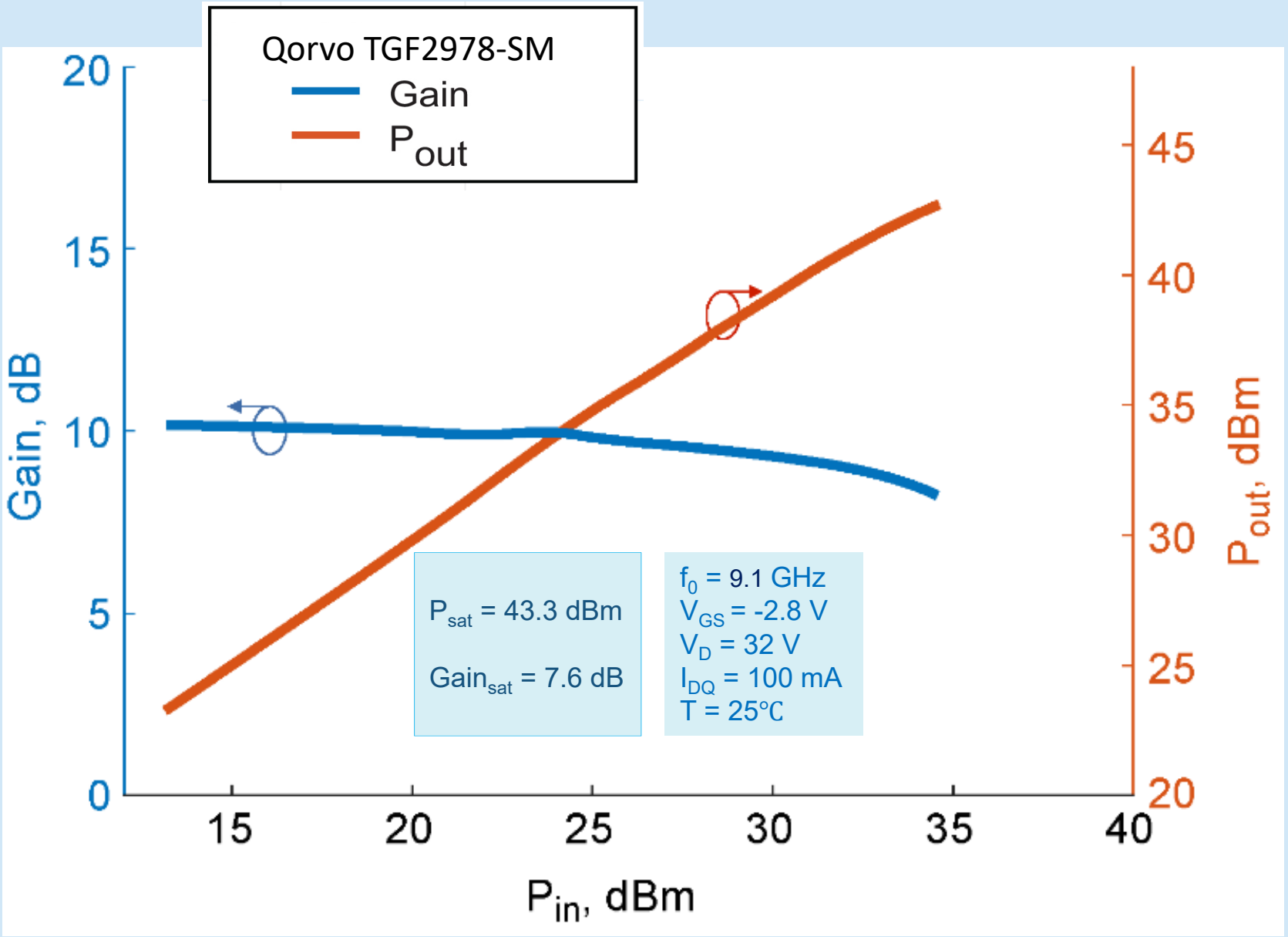


@ X-band:
- Psat = 43.5 dBm
- Gain = 7.9 dB
- PAE = 46.6%

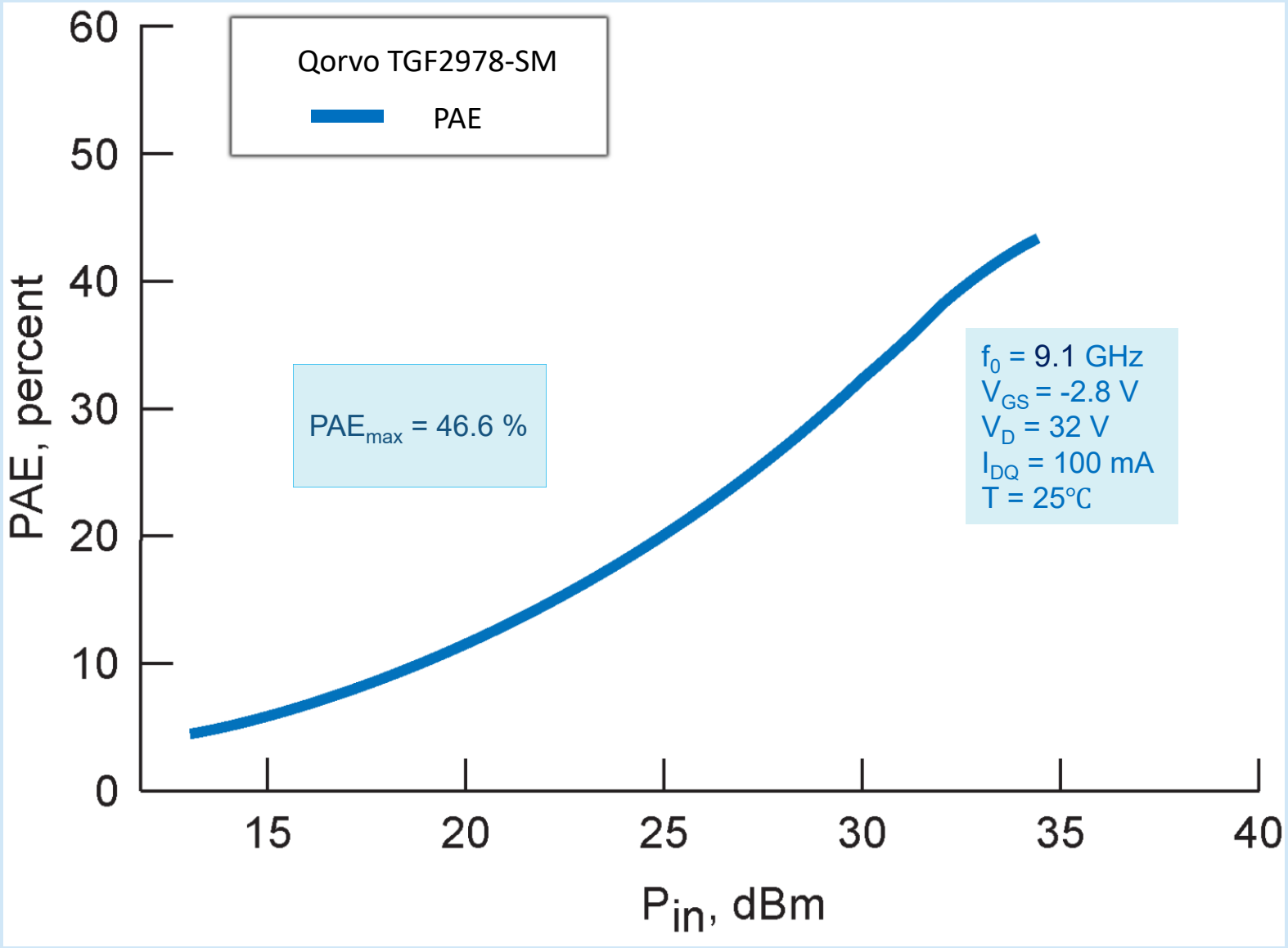


Qorvo Model TGF2978-SM
- GaN-on-SiC substrate
- Utilizes Gate Field Plate
- Internally Matched to 50 **Ω**
- Evaluation Board f_0 = *9.1 GHz*

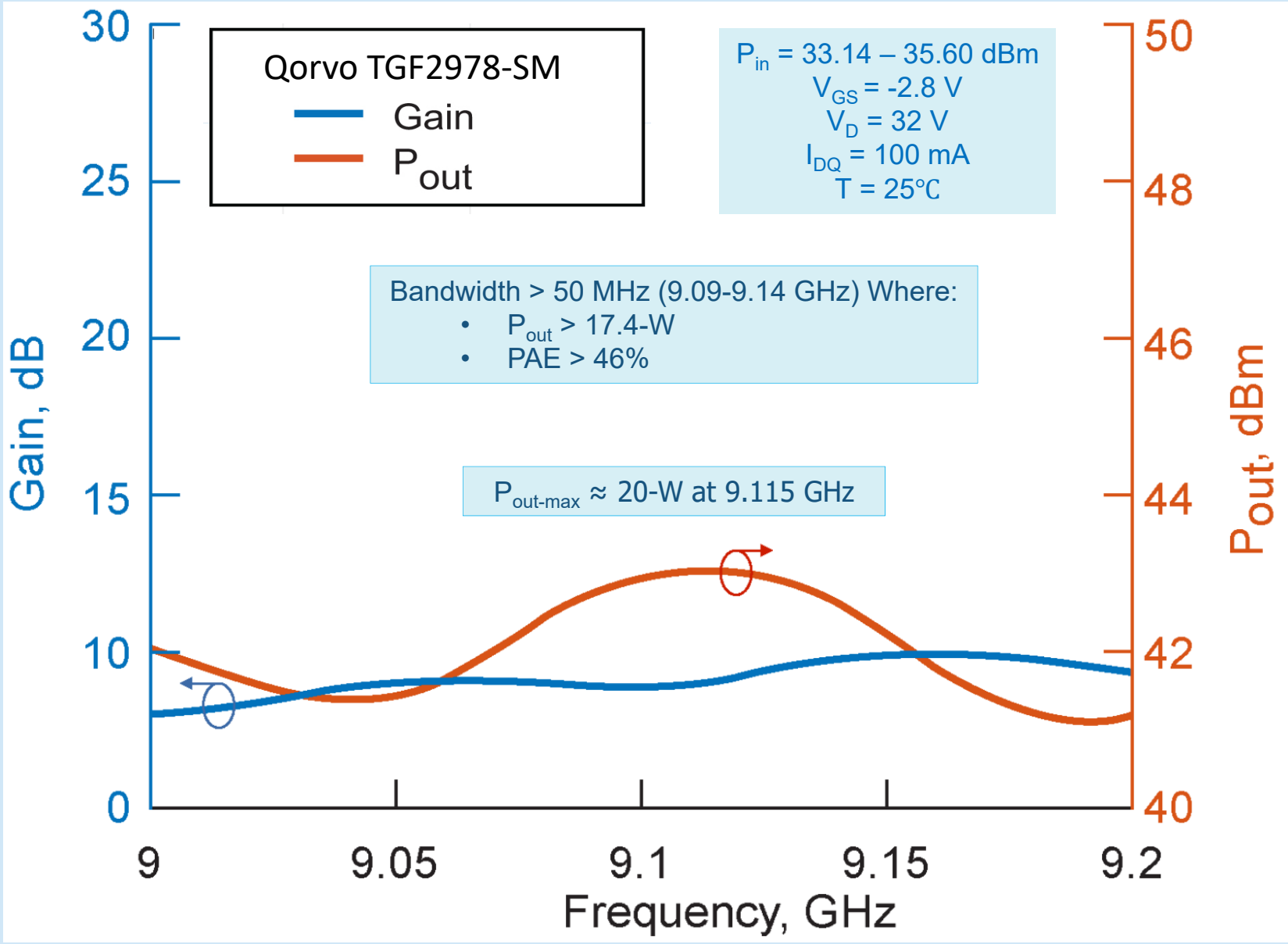
High Power CW Measured Output Power & Gain



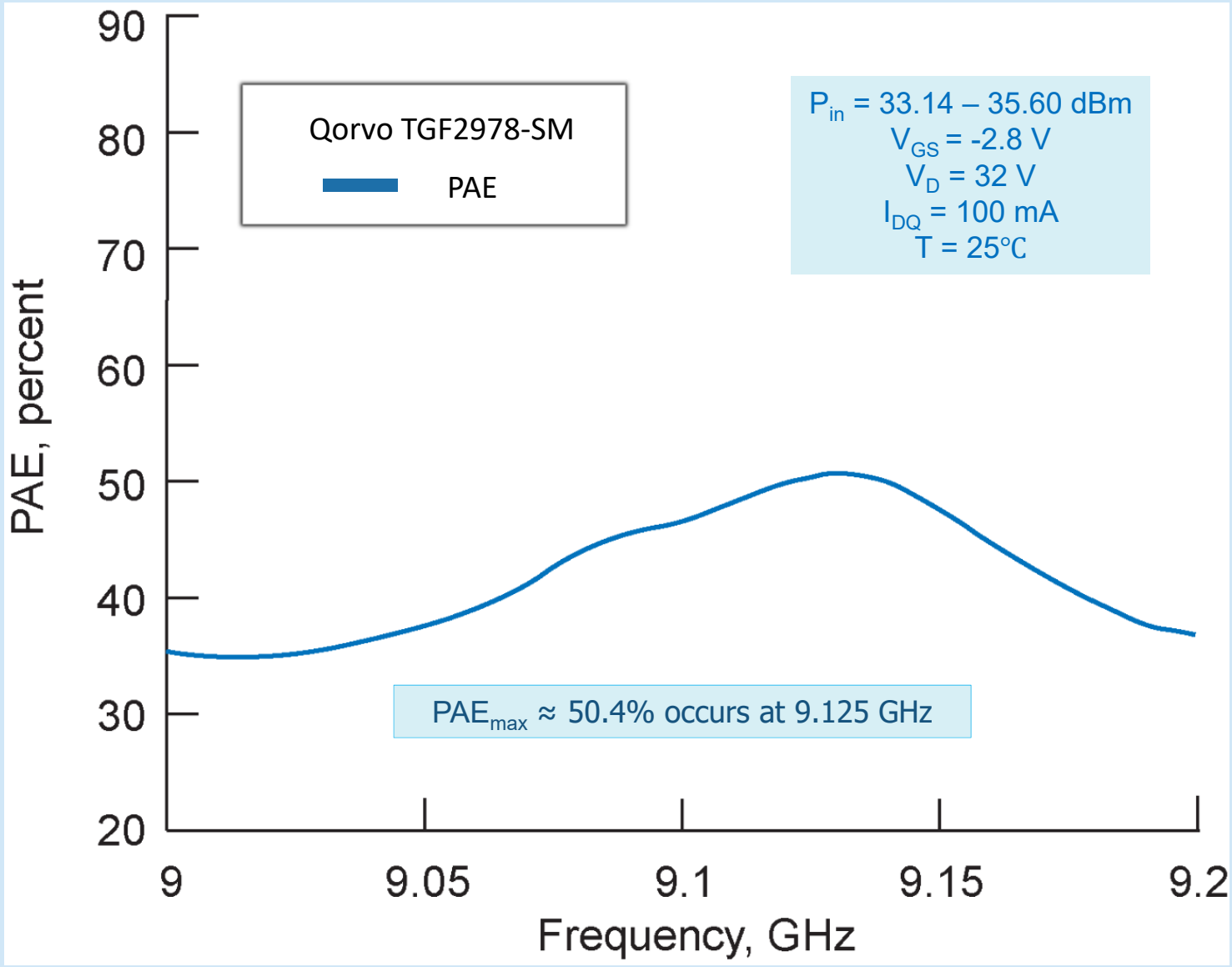
High Power CW Amplifier Measured PAE



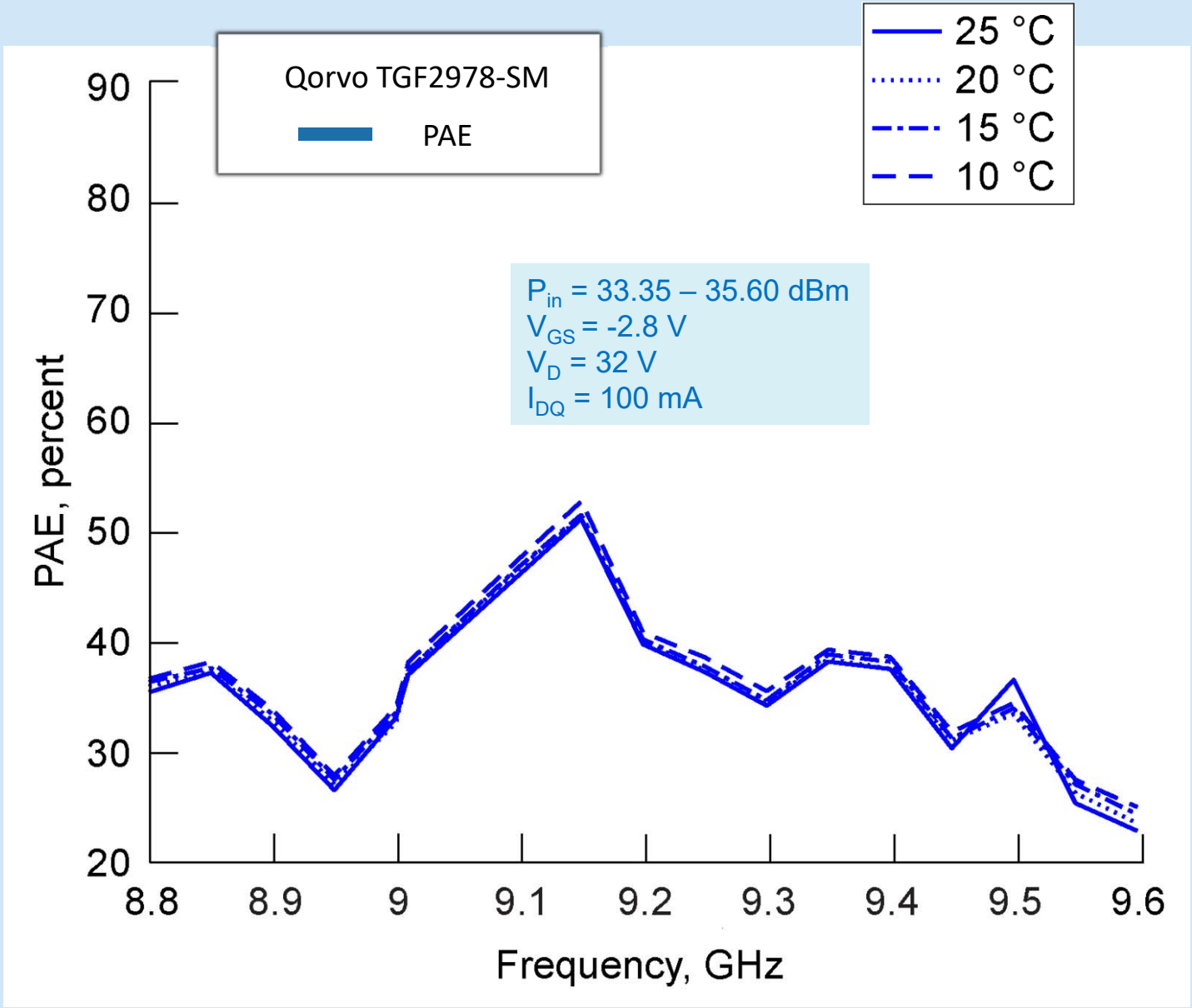
High Power CW Amplifier Measured P_{out} and Gain vs Frequency



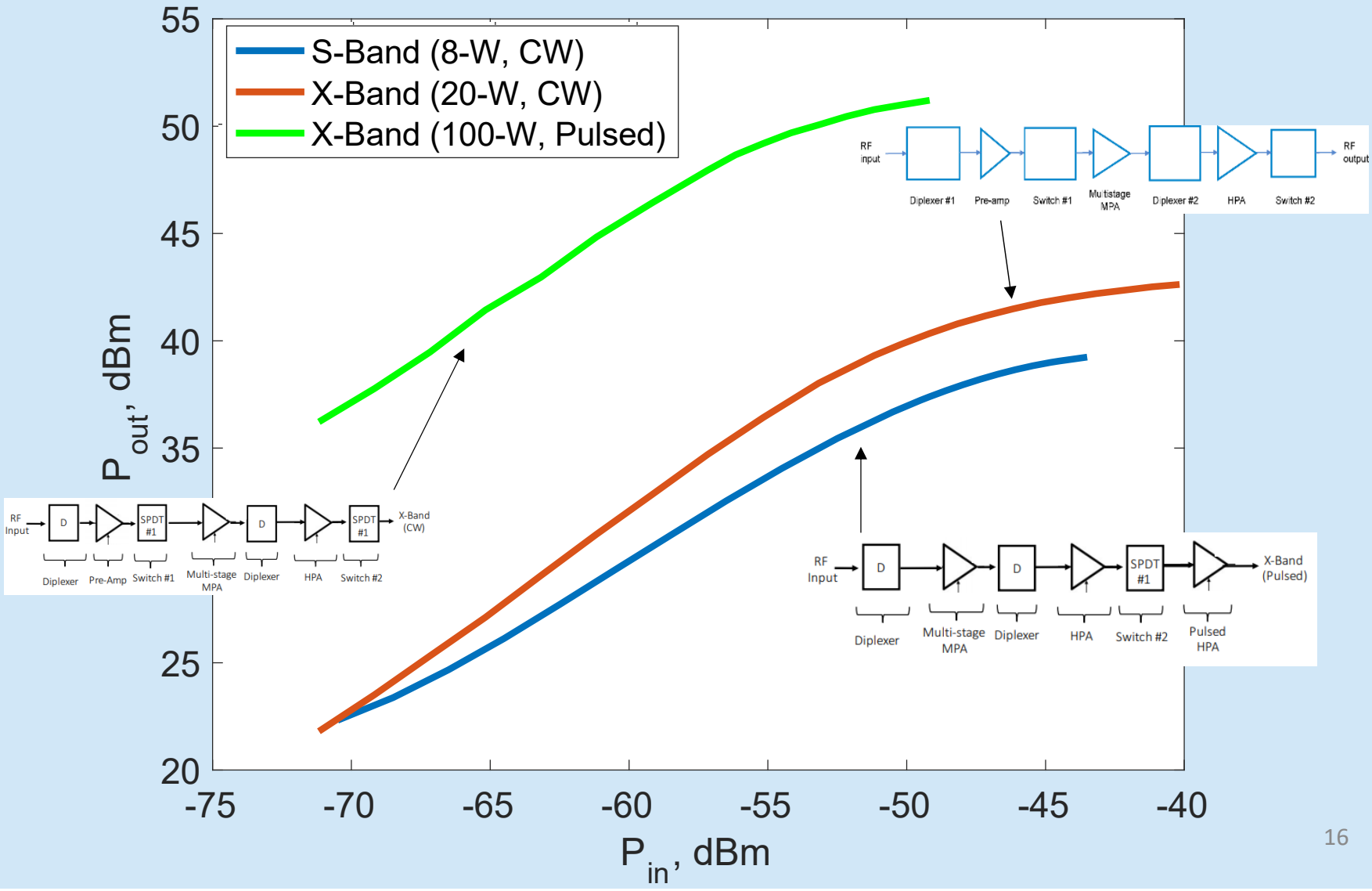
High Power CW Amplifier Measured PAE vs Frequency



High Power CW Amplifier Measured PAE vs Frequency for Various Temperatures



Measured Output Power at S-Band (CW), X-Band (CW) and X-Band (Pulsed)



Conclusions & Discussions

- The paper presents as a proof-of-concept the design, integration, and performance of a novel reconfigurable, S-/X-band GaN MMIC based, fully solid-state microwave power module (SSMPM)
- Results indicate that the S-band CW chain can deliver P_{sat} of 39 dBm (8 W) for TT&C, the X-band CW chain can deliver P_{sat} of 43 dBm (20 W) for telecommunications, and the X-band pulsed chain can deliver P_{sat} of >50 dBm (>100 W) for radar applications
- This dynamic reconfigurability provides the necessary functionality to enable a cognitive transmitter, and with the addition of proximity sensing to assist with mapping of the surrounding environment
- The addition of a field plate to a GaN HEMT increases device reliability and efficiency
- Leveraging upon compound semiconductor devices and novel materials will enable the monolithic heterogeneous integration of GaN plus CMOS for realization of a compact SSMPM in the future

Questions

References

[1] E. Illokken, “TWT Reliability in Space”, Aerospace and Electronic Systems Magazine, IEEE, 2(7), 22-24. 1987.

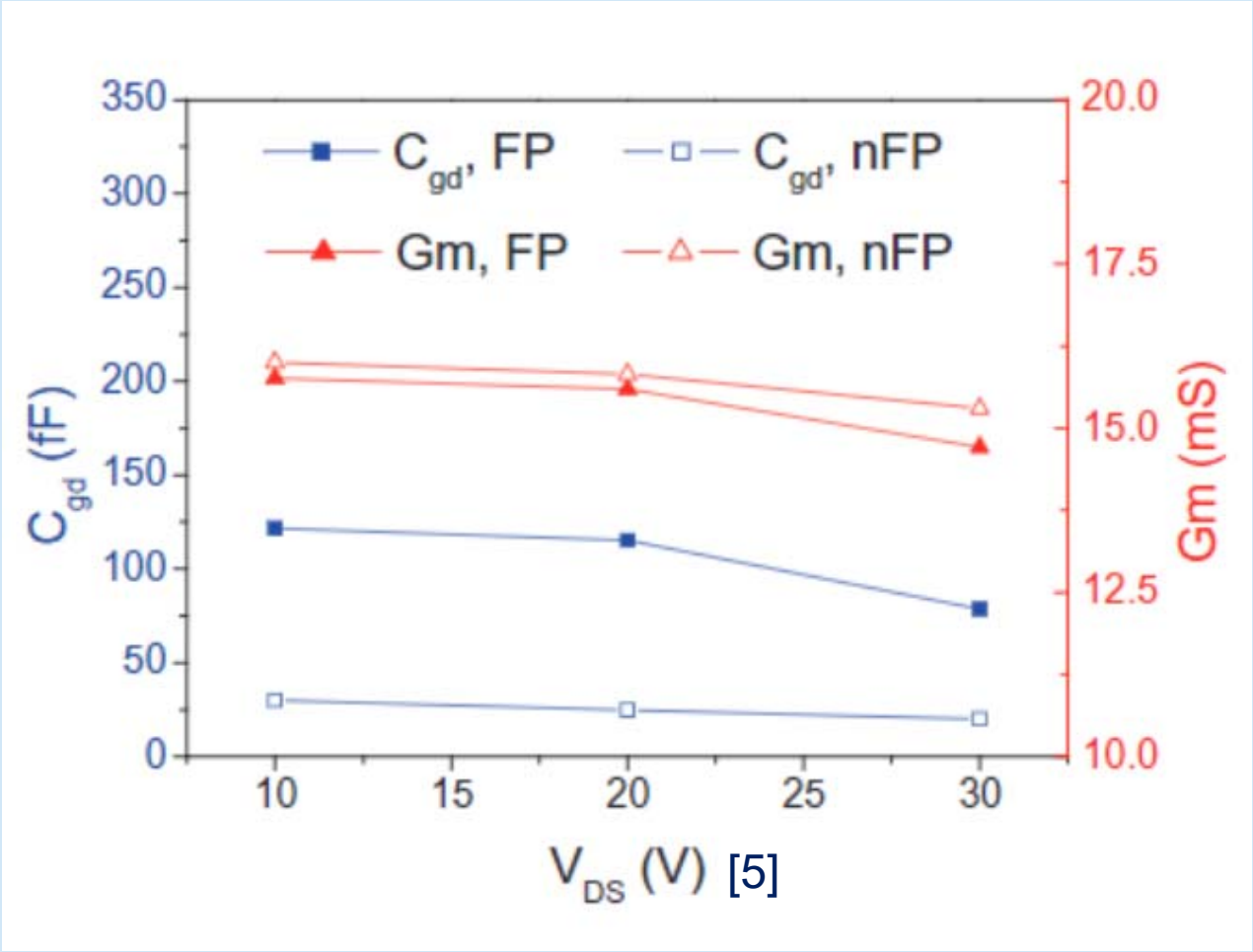
[2] R. Strauss, “Orbital Performance of Communication Satellite Microwave Power Amplifiers”, International Journal of Satellite Communications, 11, 279-285. 1993.

[3] B. D. Weaver et al, “On the Radiation Tolerance of AlGaN/GaN HEMTs“, ECS Journal of Solid State Science and Technology, vol. 5, June 28, 2016.

[4] Che-Yang Chiang, Heng-Tung Hsu, Edward Yi Chang, "Effect of Field Plate on the RF Performance of AlGaN/GaN HEMT Devices," Physics Procedia, Volume 25, 2012, Pages 86-91

Addendum

Plot of C_{GD} and G_m vs V_{DS} for Field Plate and Non-filed Plate

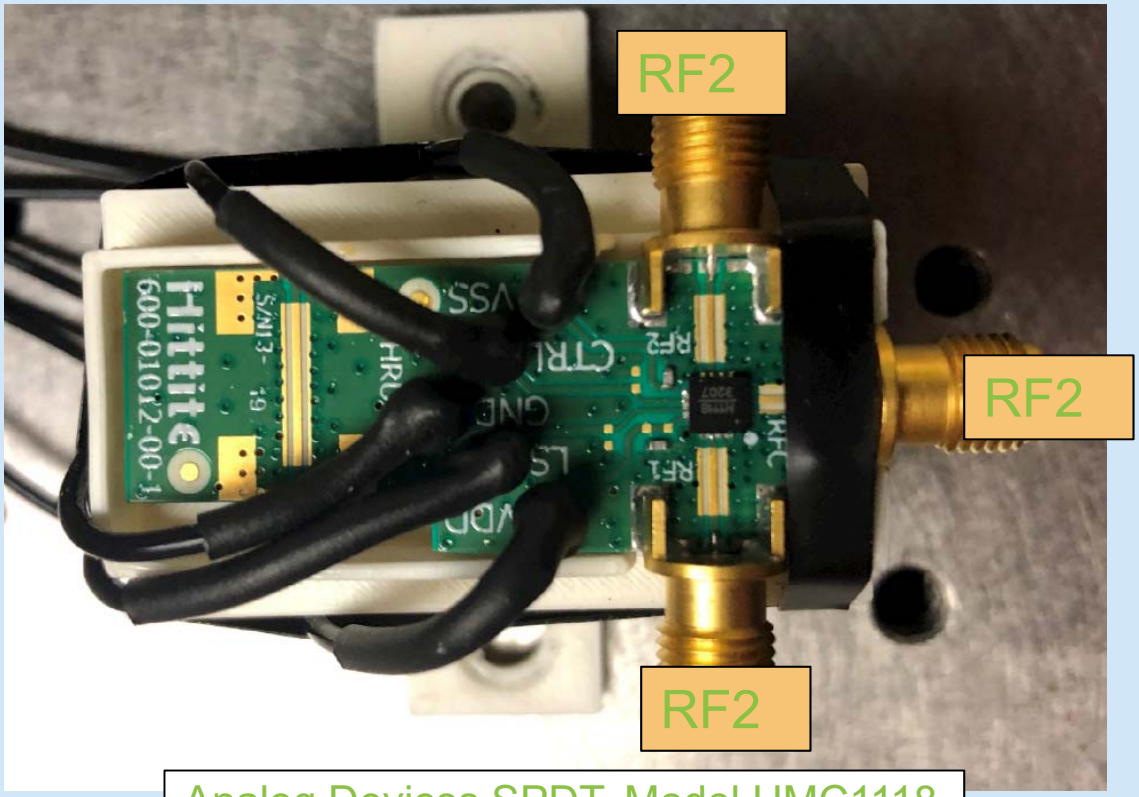


With FP:

- Increase in C_{GD}
  - Results in a decrease in f_T*
- Slight Decrease in G_m

*If $f_T > f_0$ then no adverse effect on efficiency

Non-Reflective SPDT Switch Measured Characteristics



Analog Devices SPDT, Model HMC1118

- Bandwidth: 9 KHz -13 GHz
- Internally matched to 50 Ω
- IL is 0.6 dB @ 2.15 GHz and 1.4 dB @ 8.475 GHz
- Isolation is > 50 dB @ 2.15 GHz and > 40 dB @ 8.475 GHz

High Power CW Amplifier Measured P_{out} and Gain for Various Temperatures