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Predicted High-Frequency and High-Power Performance of AlGaN-Channel HEMTs for Radio-Frequency Applications

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Abstract

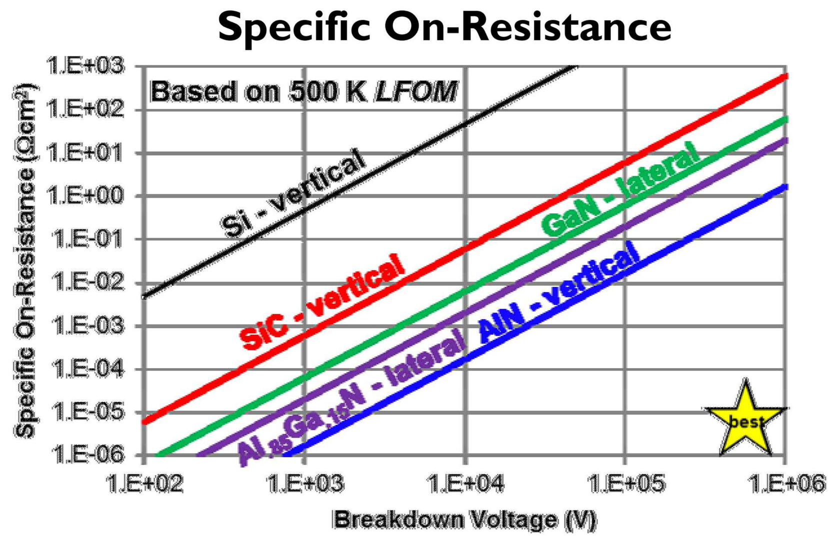
Performance prediction, especially linearity, for a novel high-power RF device technology at the early stages of development is challenging, chiefly because performance parameters are design-dependent and are function of bias and power level. This paper presents a method for high-power RF performance calculation, which was applied to Aluminum Gallium Nitride (AlGaN) channel High Electron Mobility Transistors (HEMTs) to obtain an estimate for power and linearity performance. The emerging Al-rich AlGaN-channel HEMTs have the potential to greatly exceed the power handling capability of today's AlGaN/GaN HEMTs. To assess the high-power RF performance, a combination of TCAD simulations and a MATLAB-based algorithm was used. The simulation results indicate that a saturated power density of 18 W/mm with 55% PAE and OIP3 over 40 dBm can be achieved for this class of device. Furthermore, this method provides a way to refine the device design, and can be applicable to other novel high-frequency, high-power technologies.

Motivation

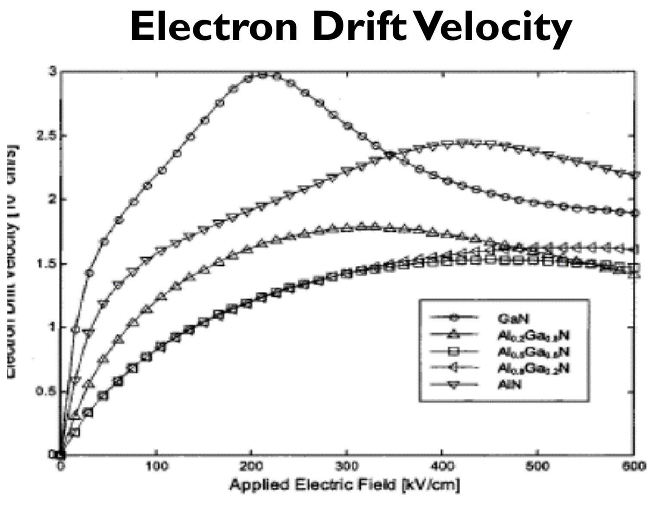
Ultra-Wide-Bandgap (UWBG) semiconductors have attractive properties for power switching and RF applications, particularly at high T_J

- High critical electric field (E_C) for improved unipolar Figure of Merit
- Saturation velocity comparable to binary alloys (GaN, AlN)
- High-temperature operation

Specific On-Resistance

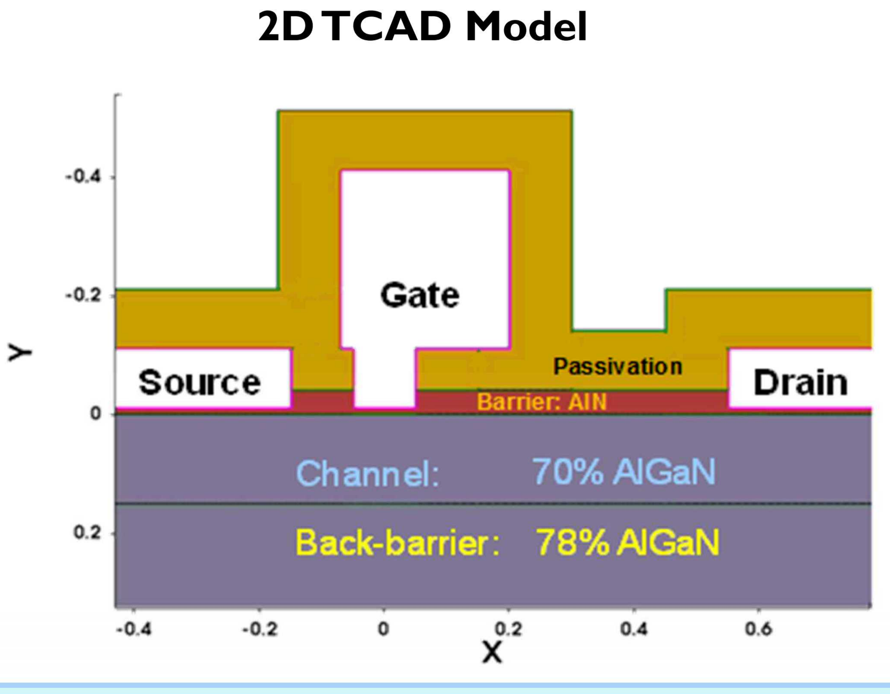


Electron Drift Velocity

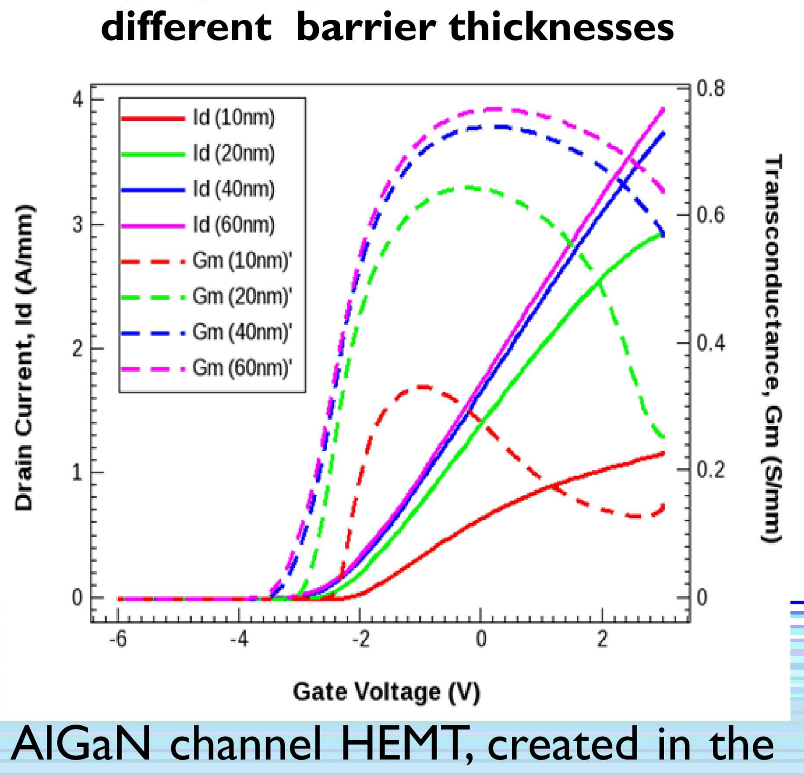


Device Structure and Geometry

2D TCAD Model



I_D-V_G at V_D = 40 V, shown for different barrier thicknesses

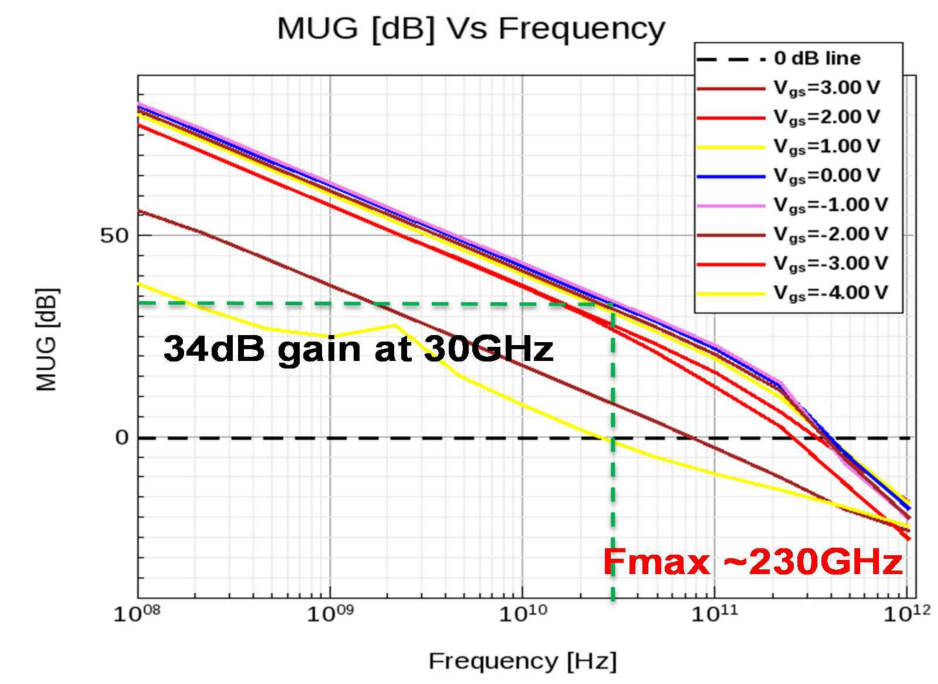


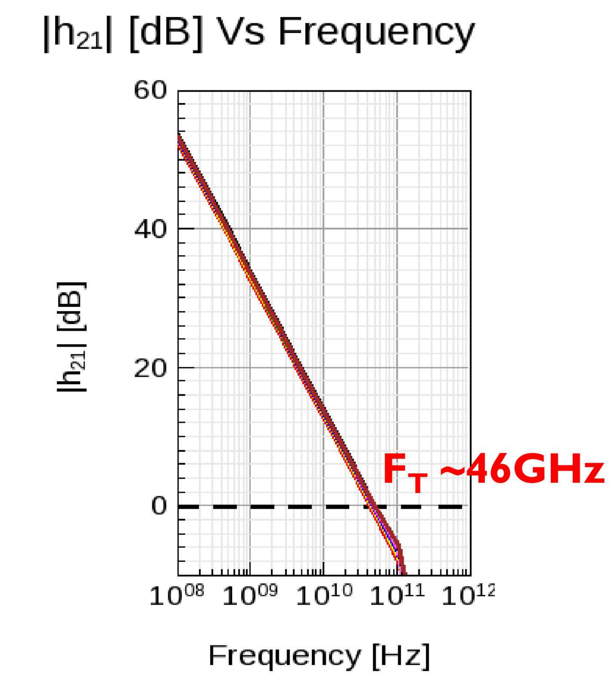
Physics-based TCAD model for Al-rich AlGaN channel HEMT, created in the Sentaurus® simulation platform, was used for device simulation. A design of experiments based on small-signal TCAD simulation results was used for device optimization.

References

[1] J.W. Chung *et al.*, *65th Device Research Conference Technical Digest*, (Notre Dame, IN, IEEE, 2007), p. 111.
[2] S. M. Sze, *"Physics of Semiconductor Devices, 2nd ed.,"* (Wiley Interscience, New York, 1981), p. 463.
[3] S. Schöche *et al.*, *Applied Physics Letters* **103**, 212107 (2013).

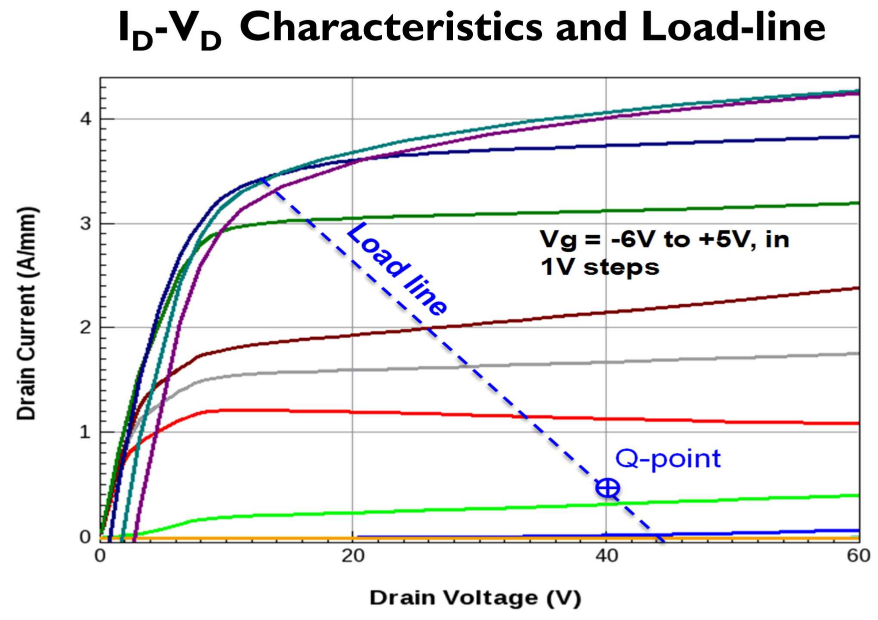
Small-Signal Gain and High-Frequency Performance



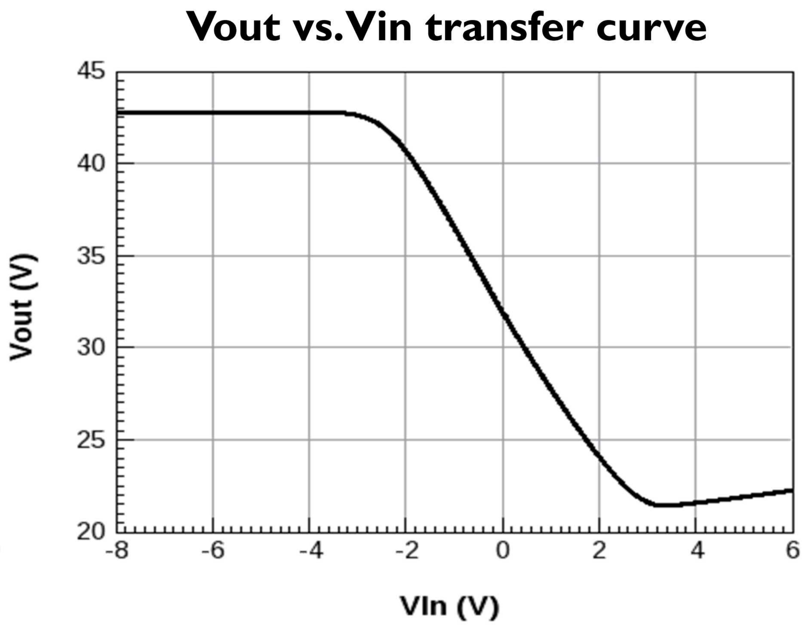


Large-Signal Gain and Linearity

I_D-V_D Characteristics and Load-line

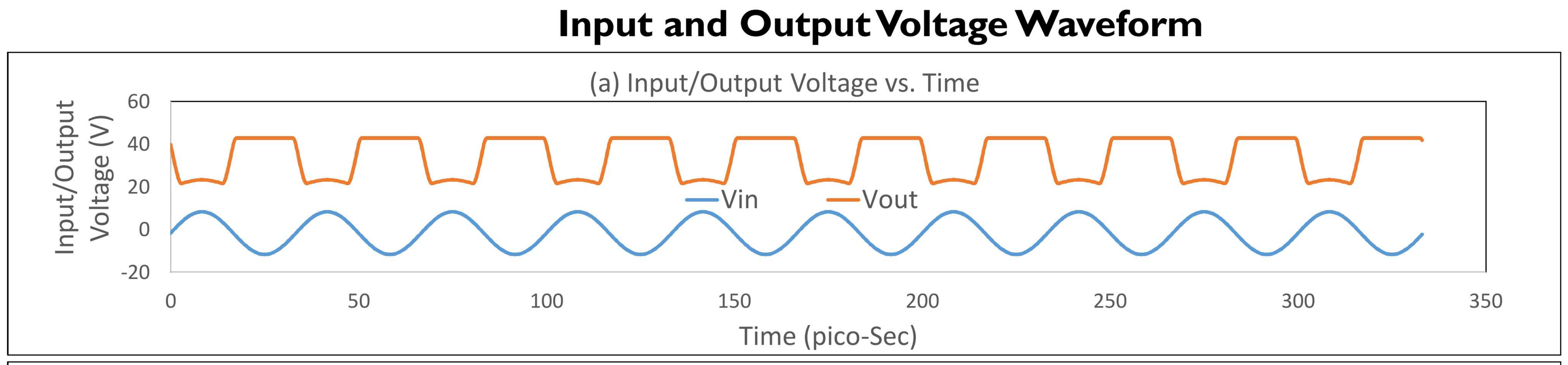


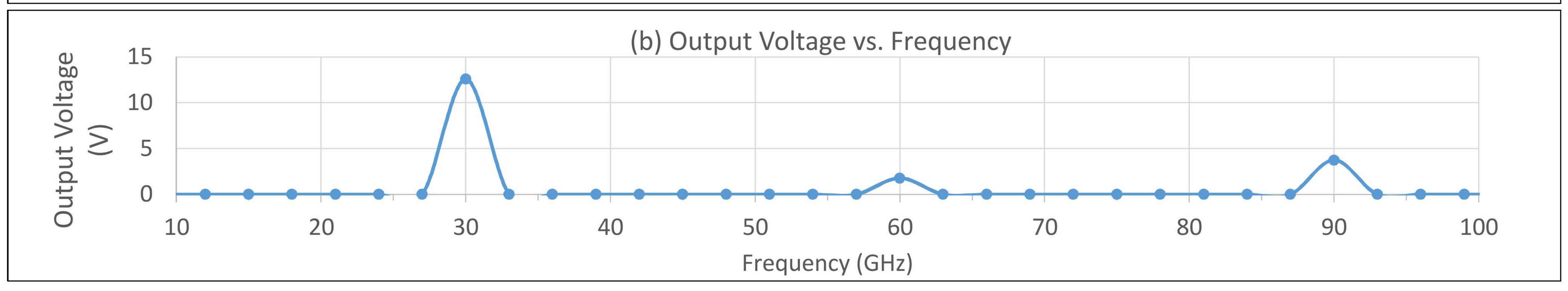
Vout vs. Vin transfer curve



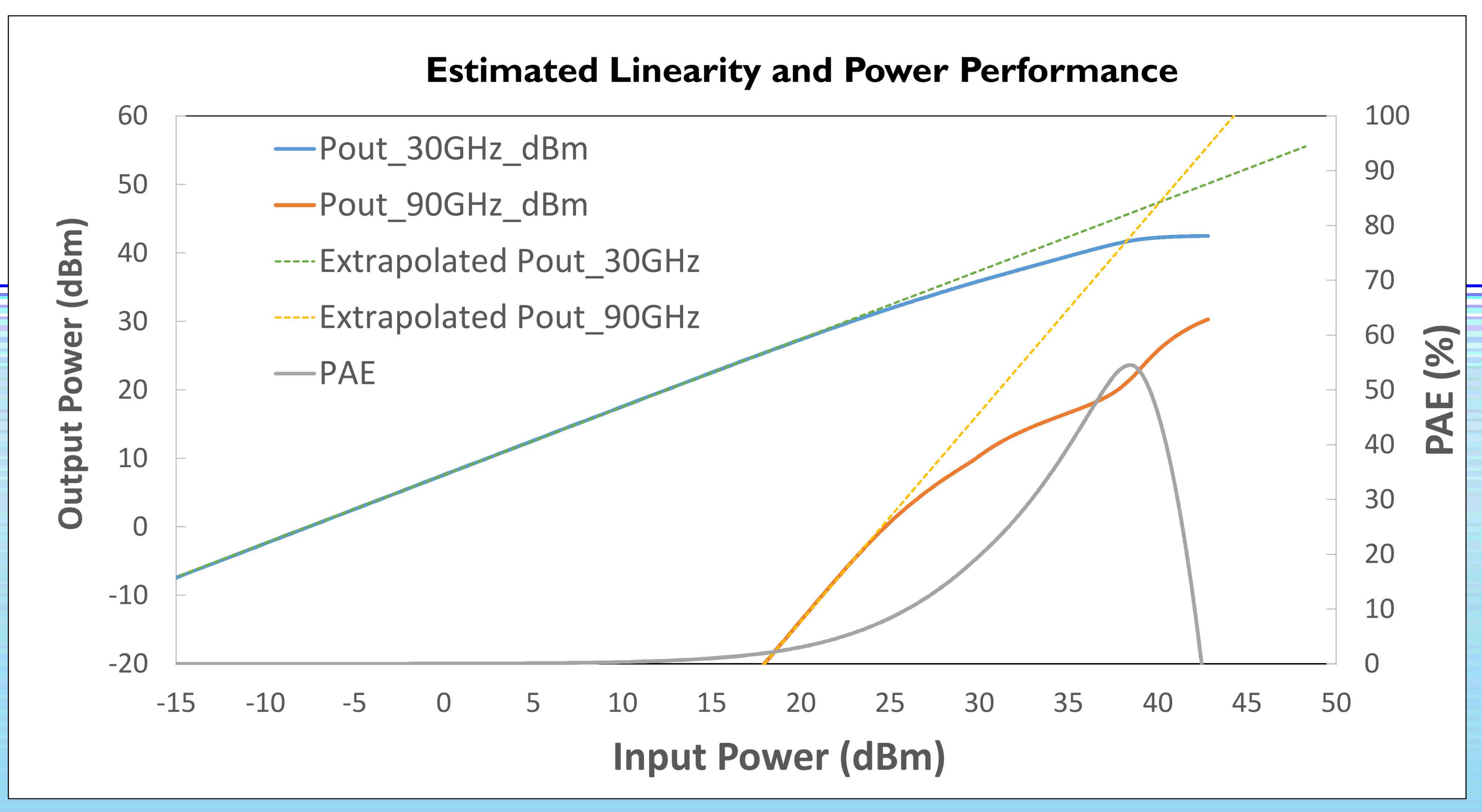
The V_{out} vs. V_{in} transfer curve was obtained from DC sweep simulations using a resistive load-line and a Q-point selected for maximum output voltage swing.

Input and Output Voltage Waveform





A MATLAB-based algorithm was used to calculate the output power waveforms for a sinusoidal 30 GHz input. The output powers 3rd harmonic performance, and PAE were calculated from the Fourier transform of the output voltage waveform.



Simulation results indicate that a saturated power density of 18 W/mm with 55% PAE and OIP3 of over 40 dBm can be achieved for this device.