120nm Gate length field-plated GaN HFET

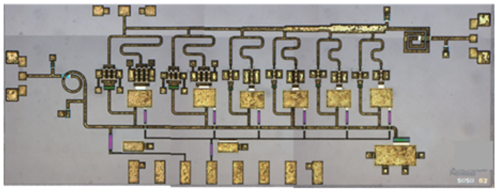
Figure 1(a) shows a schematic of a scaled 120-nm gate length field-plate (FP) GaN HEMT, where the FP GaN HFET was processed with ohmic regrowth instead of n+ GaN source contact ledge demonstrated in previous work [12]. The ohmic source-drain spacing was 3 µm. The on-state resistance was 1.6 Ω-mm. The maximum source-drain current (I_{max}) was 1.0 A/mm at Vds = 10 V. The table in Figure 1 summarizes the GaN HEMT performance compared to prior 140-nm gate length GaN HEMTs used in previous linear distributed amplifiers. The MMICs shown in Figures 2(a) and 3(a) were fabricated in a microstrip layout with 2-mm-thick SiC substrate and via source contacts, SiN_x and HfO_2 MIM capacitors. TaN resistors were used in MMIC fabrication.

Measured GaN MMIC Performance

To maximize PAE over the frequency band, the GaN NDPAs were built in six sections with different transistor sizes, ranging from 6 x 85 µm to 2 x 65 µm in a nonuniform distributed amplifier approach.

Figure 2(a) shows a photograph of the fabricated GaN linear NDPA, consisting of main and auxiliary cells in each section, where the auxiliary cells were biased in class-C to cancel in-band intermodulation products such as IM3. Figure 2(b) shows measured on-wafer S-parameters at Vds = 20 V with a small signal gain of >10 dB over 0.1 – 8 GHz, a more than 6 – 9 dB improvement over the prior linear NDPA [10].

(a) Linear wideband DPA



(b) Linear Wideband DPA: Vds = 20 V, Ids= 220 mA

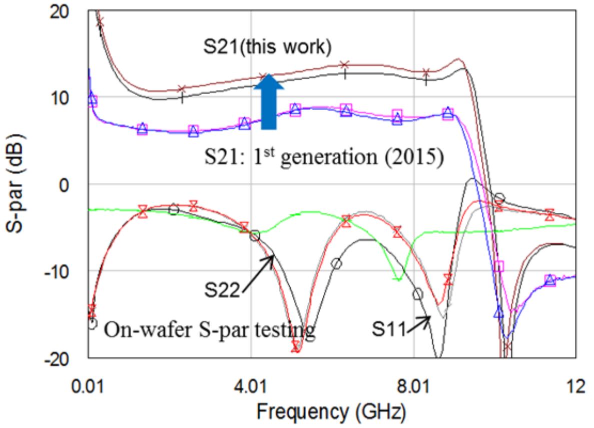


Figure 2. (a) Photograph of the fabricated GaN NDPA, (b) Measured on-wafer S-parameters at Vds = 20 V and Ids = 220 mA

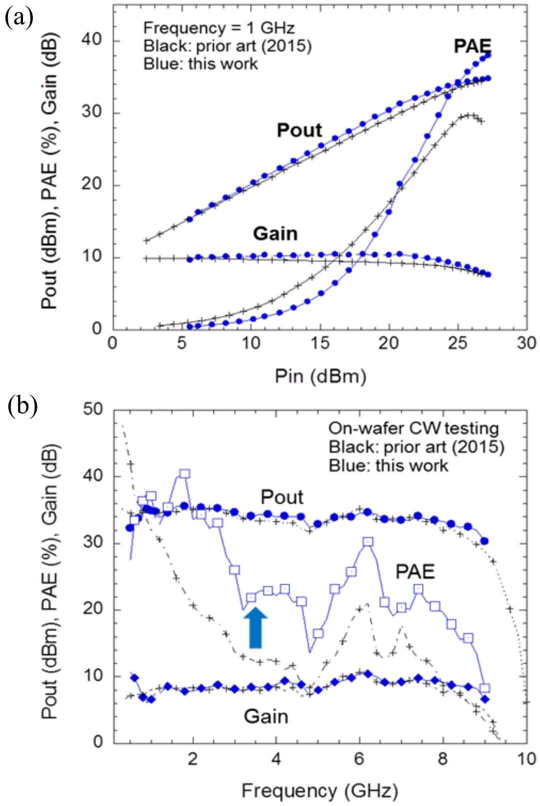


Figure 3. Measured on-wafer large-signal CW performance of GaN linear NDPA at Vds = 17 V at (a) 1 GHz and (b) as a function of frequencies, in comparison to the prior linear NDPA large-signal performance

Figure 3 shows the measured on-wafer, large-signal CW performance at Vds = 17 V at 1 GHz compared to prior linear NDPA large-signal performance. Peak PAE improved to 38% with drain efficiency (DE) of 45%, compared to a prior PAE of 29% and DE of 35%. Output power was similar, at ~35 dBm, and associated power gain was 7.8 dB.

Linearity Improvement

We measured small-signal, two-tone spectra of the GaN NDPA and linear NDPA at Vd = 17 V versus frequency range of 100 MHz to 8 GHz. As shown in Figure 4, the linear NDPA showed OIP3 improved to 45 – 50 dBm with an average of 47 dBm within 100 MHz to 6 GHz, compared to OIP3 of 42 dBm for the conventional NDPA without linearization. The resulting maximum OIP3/Pdc was 14:1. Green et al., reported GaN NDPAs with OIP3 of 43 dBm [2]. Kobayashi reported excellent OIP3 of 51 dBm over a 3-GHz bandwidth, where a cascode feedback design was used with high-voltage operation of 40 V [9]. The OIP3/Pdc was 5.2:1, which consumed about 30 W.

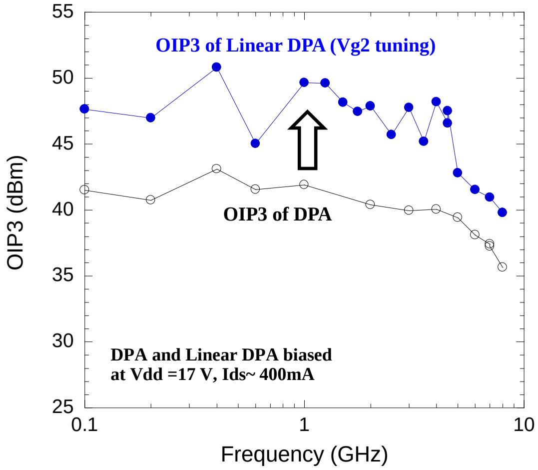


Figure 4. Measured 2-tone OIP3 performance of linear GaN DPA and a conventional GaN DPA over frequency range of 100 MHz to 8 GHz

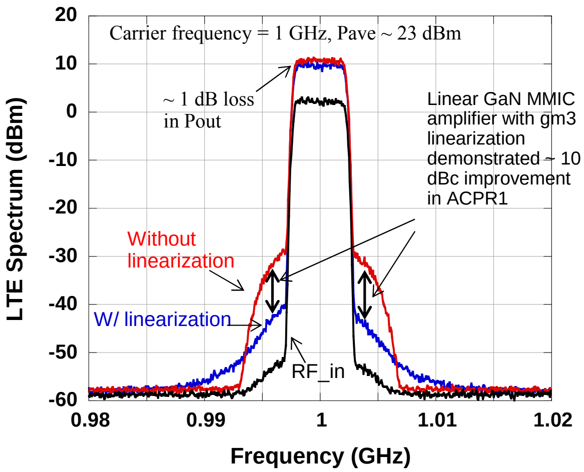


Figure 5. 5MHz QPSK LTE spectra of NDPA and linear NDPA at 17 V with average output power of 23 dBm

Figure 5 shows the 5 MHz QPSK LTE spectra of the conventional NDPA and linear NDPA at Vdd = 17 V. The spectral regrowh was evaluated with ACPR1. At an average output power of 23 dBm, the linear NDPA offers ~10 dB improvement in ACPR1 at 5 MHz offset, compared to the conventional NDPA.

Conclusion

Utilizing a 120-nm gate length field-plate GaN HEMT MMICs process, we demonstrated 0.1 – 8 GHz linear distributed amplifiers at the MMIC level with improved PAE. Two-tone testing showed excellent OIP3/Pdc ratio of ~14 among GaN distributed amplifiers. For the first time, a ACPR1 of -40 dBc was demonstrated at an average output power of 28 dBm over a wide frequency range.

Acknowledgement

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