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A Balanced Stacked GaN MMIC Power Amplifier for 26-GHz 5G Applications

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Outline

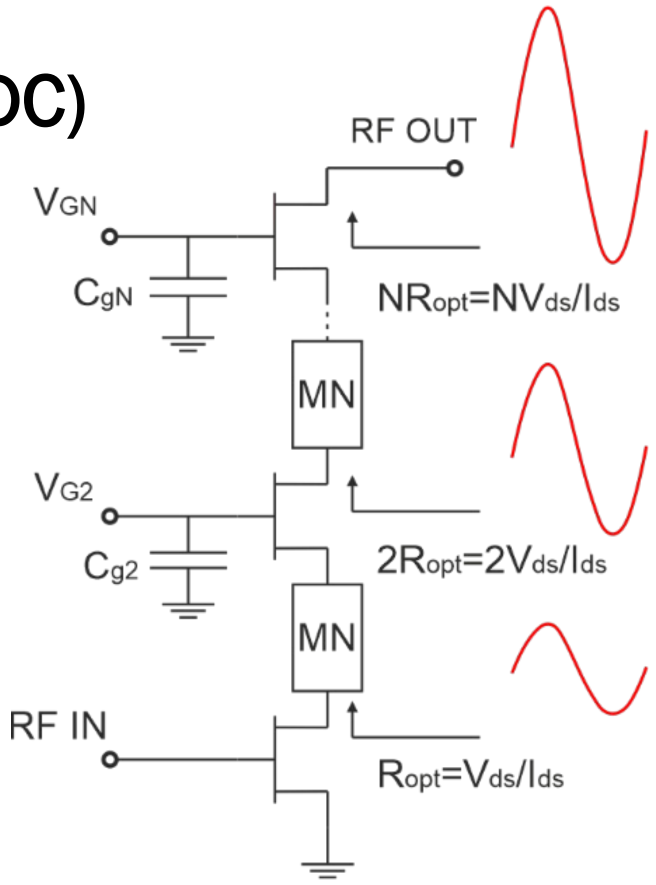
- Motivation
- Background
- Layout
- Design
- Results
- Comparison with state of the art
- Conclusion
- Acknowledgements

Motivation

- Power amplifiers for wireless communications
- Exploitation of >6 GHz bands (FR2 for 5G)
- Challenges at MMIC level:
  - Gain
  - Power combination
  - Compactness
- Possible solution:
  - Transistor stacking

Background

- Transistor stacking
  - Borrowed from Si technologies
  - Initially applied only to increase supply voltage (DC)
  - Concept extended also to RF
  - Beneficial for:
    - Gain (x *N*)
    - Output power (x *N*)
    - Output impedance levels (x *N*)
  - Limited number *N* of stages feasible



Background

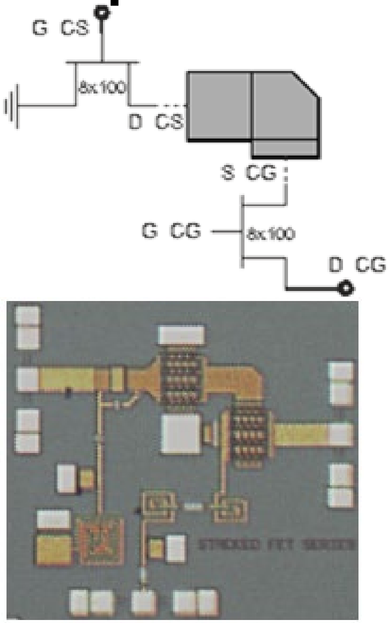
- Challenges:
  - – Critical stability
  - – Impedance matching essential for correct operation
  - – Layout
    - Few metal layers for interconnects (III-V technologies)
    - Crosstalk
  - – EM simulation setup

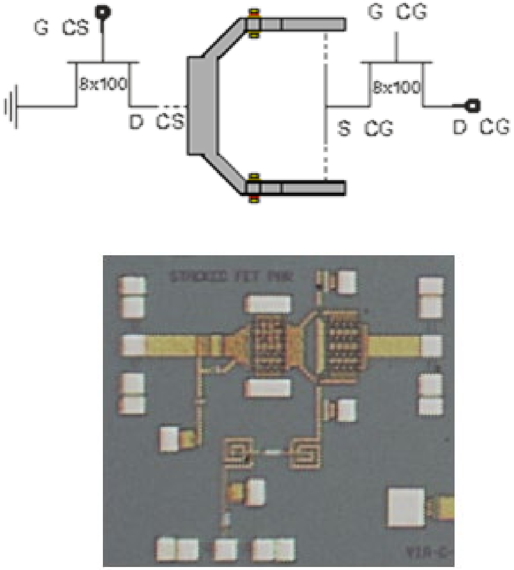
C. Ramella et al. , "Electro-magnetic Crosstalk Effects in a Millimeter-wave MMIC Stacked Cell," INMMiC, Cardiff, UK, 2020, pp. 1-3, doi: 10.1109/INMMiC46721.2020.9160341.

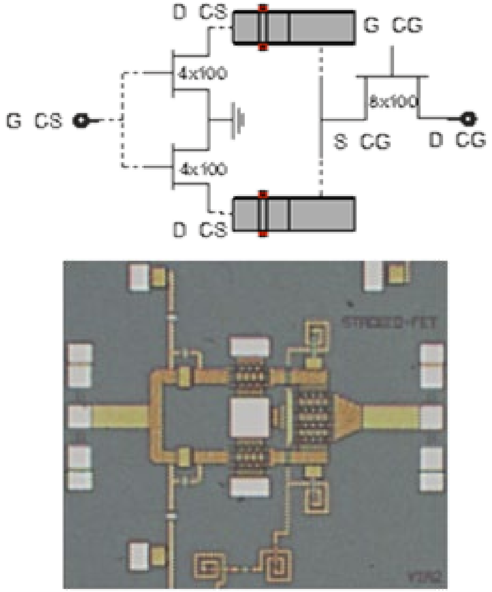
A. Piacibello et al. , “Evaluation of a stacked-FET cell for high-frequency applications”, Int J Numer Model. 2021; 34:e2881. https://doi.org/10.1002/jnm.2881

Layout

- Different configurations possible
  - Feasibility depends on technology and operating frequency
  - Required interstage matching also has an effect







F. Costanzo et al., "A Novel Stacked Cell Layout for High-Frequency Power Applications," in IEEE Microwave and Wireless Components Letters, vol. 31, no. 6, pp. 597-599, June 2021, doi: 10.1109/LMWC.2021.3073219.

Design

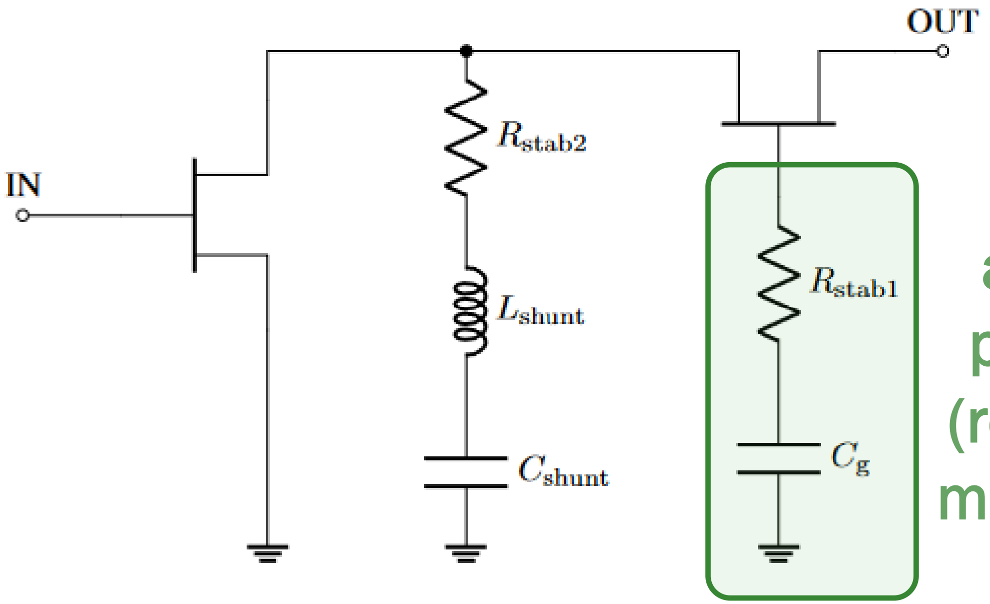
- Requirements
  - Gain: > 10 dB
  - Output power: ≈ 4 W
  - Operating frequency: 26 GHz
- Technology
  - WIN Semiconductors’ NP15 (150 nm GaN/SiC HEMT)
- Target:
  - Exploring feasibility and advantages of GaN transistors stacking (N=2) above K-band

Design

- Procedure:
  - Design & characterization of 2-stacked cells
    - Different layouts tested
    - Different stability/compactness/performance trade-offs
    - Presented at MMS 2022
  - Design & characterization of balanced PAs based on cells
    - This work
  - Next?
    - Adoption of cells in load-modulated PAs

Design

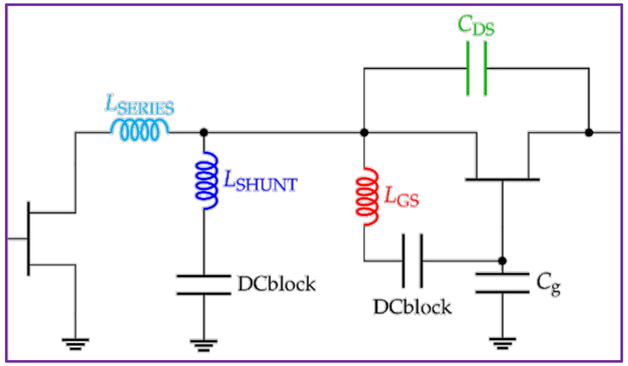
- 2-stacked cells

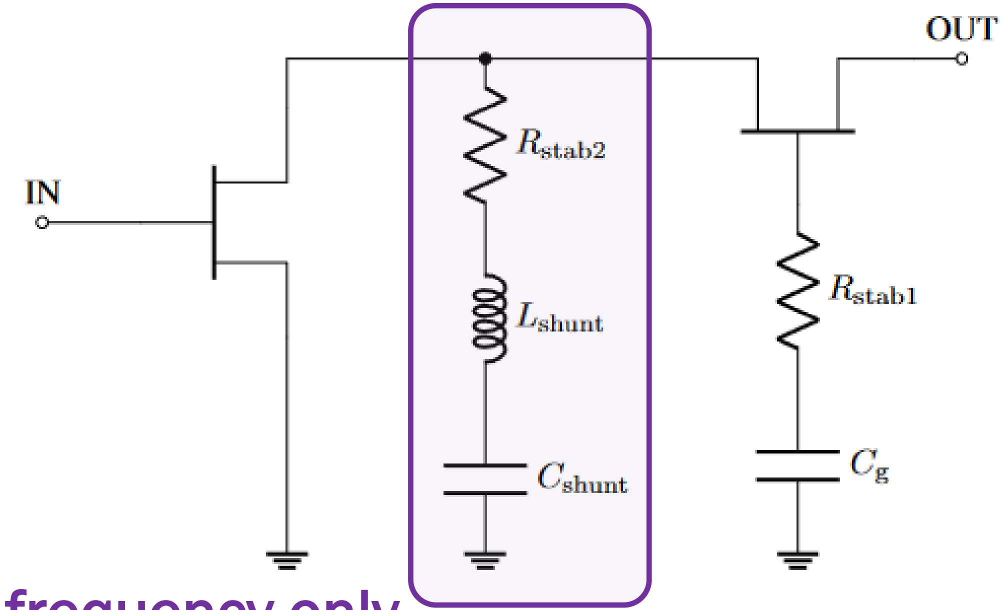


A. Piacibello, et al. , "Compact GaN-based Stacked Cells for 5G Applications at 26 GHz," 2022 Microwave Mediterranean Symposium (MMS), Pizzo Calabro, Italy, 2022, doi: 10.1109/MMS55062.2022.9825501.

Design

- 2-stacked cells





needed at «high» frequency only
(imaginary part matching)

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Design

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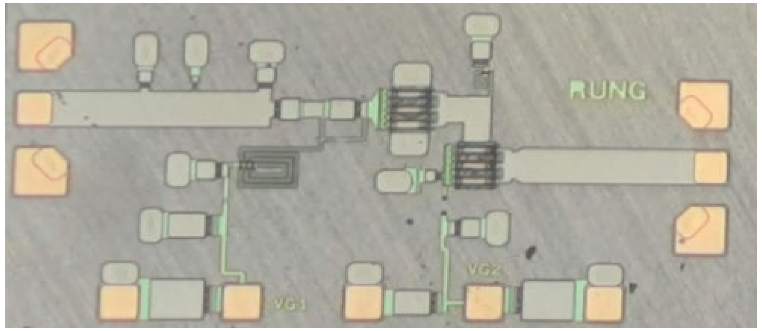
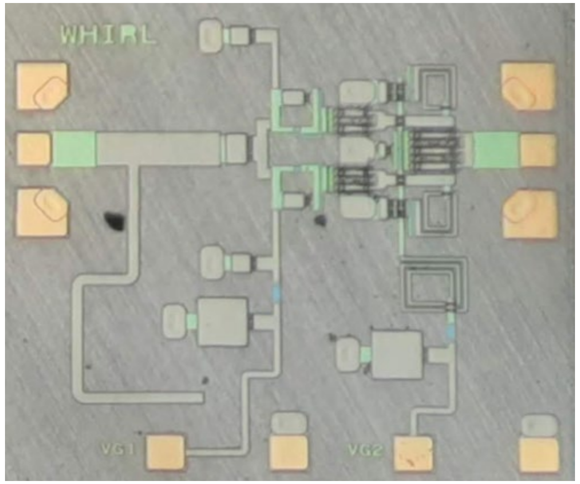
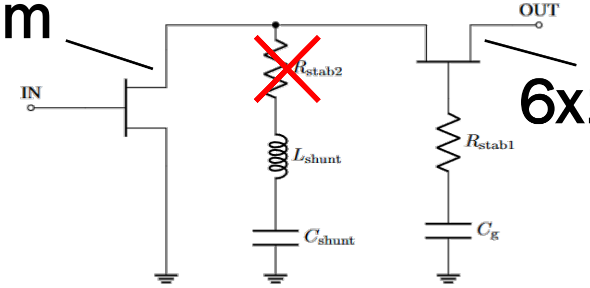


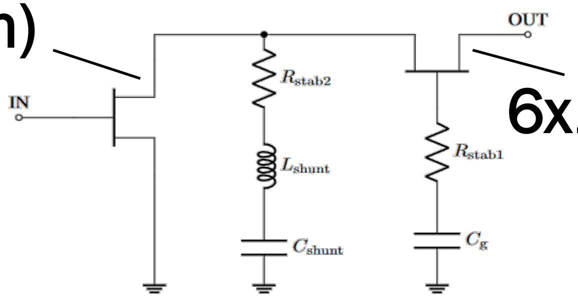


6x100µm



6x100µm

2x(4x75µm)



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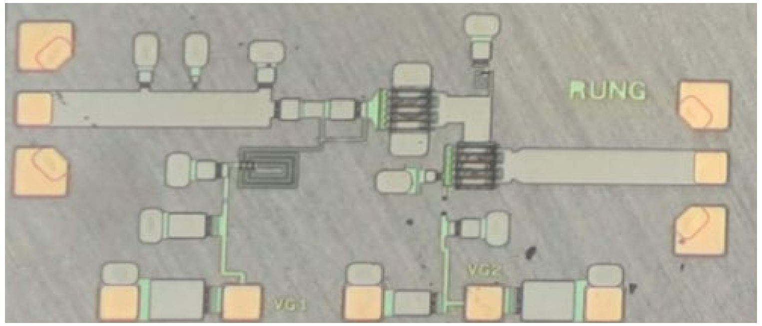
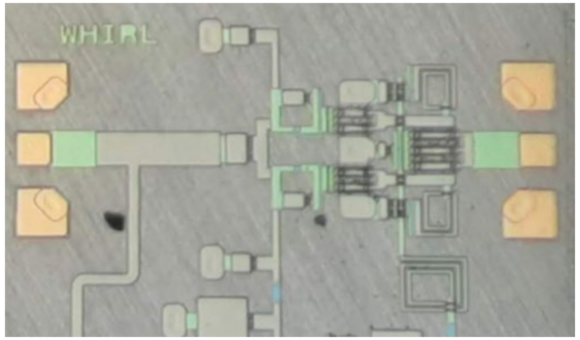
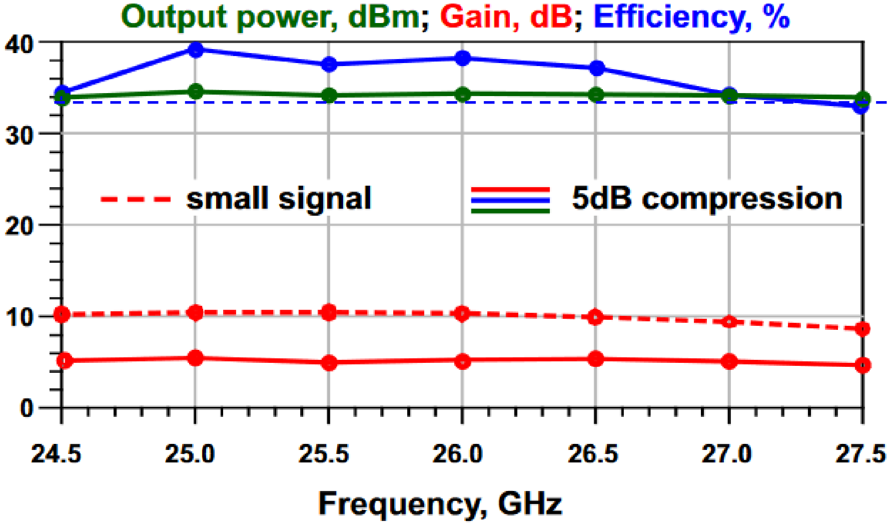
Design

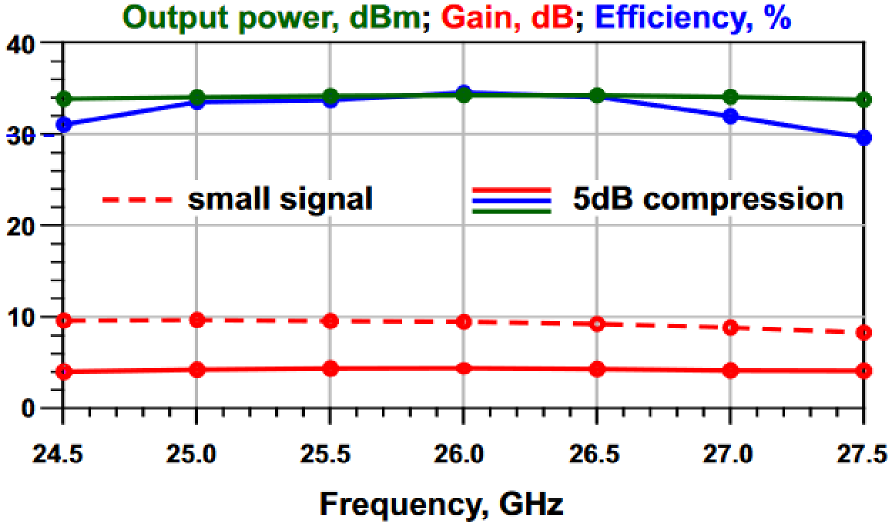
- 2-stacked cells







≈4% pts efficiency



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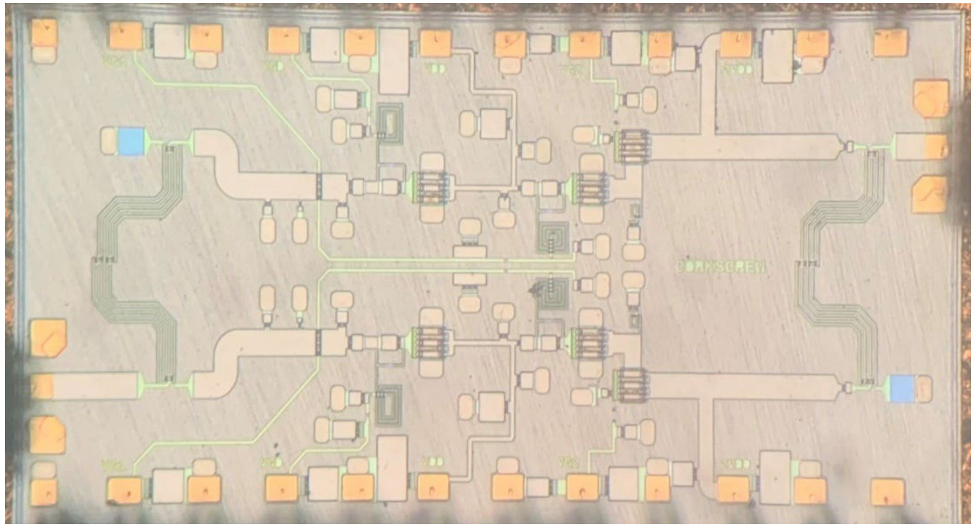
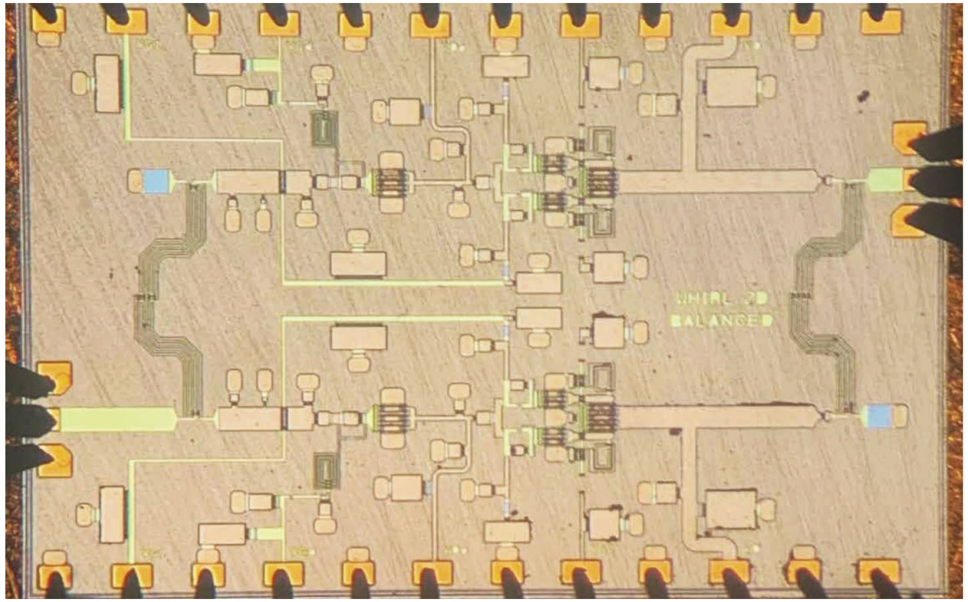
Design

- Balanced PAs
  - 2-stage for >10 dB gain
  - 6x100 µm driver
  - Same topology



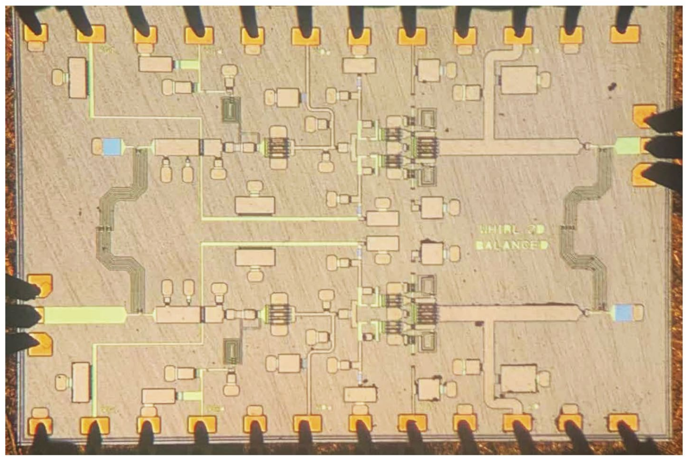


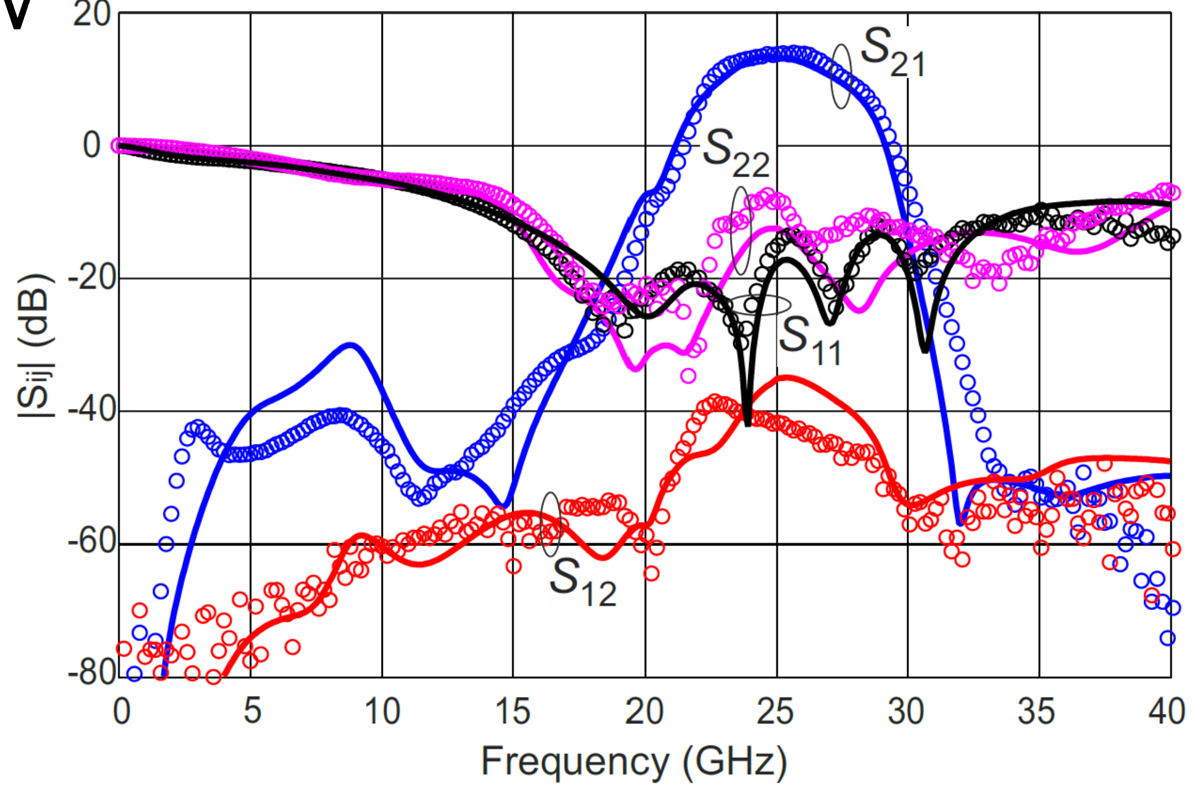
Results

- Small signal

$V_{DD,driv}$ =20 V
$V_{GG,driv}$=-2 V
$I_{D,driv}$=30 mA

$V_{DD,stack}$=40 V
$V_{G,CS}$=-2 V, $V_{G,CG}$=18 V
$I_{D,stack}$=30 mA





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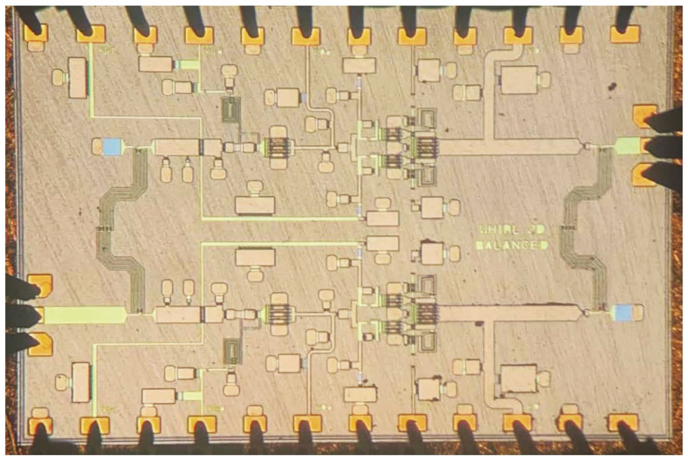
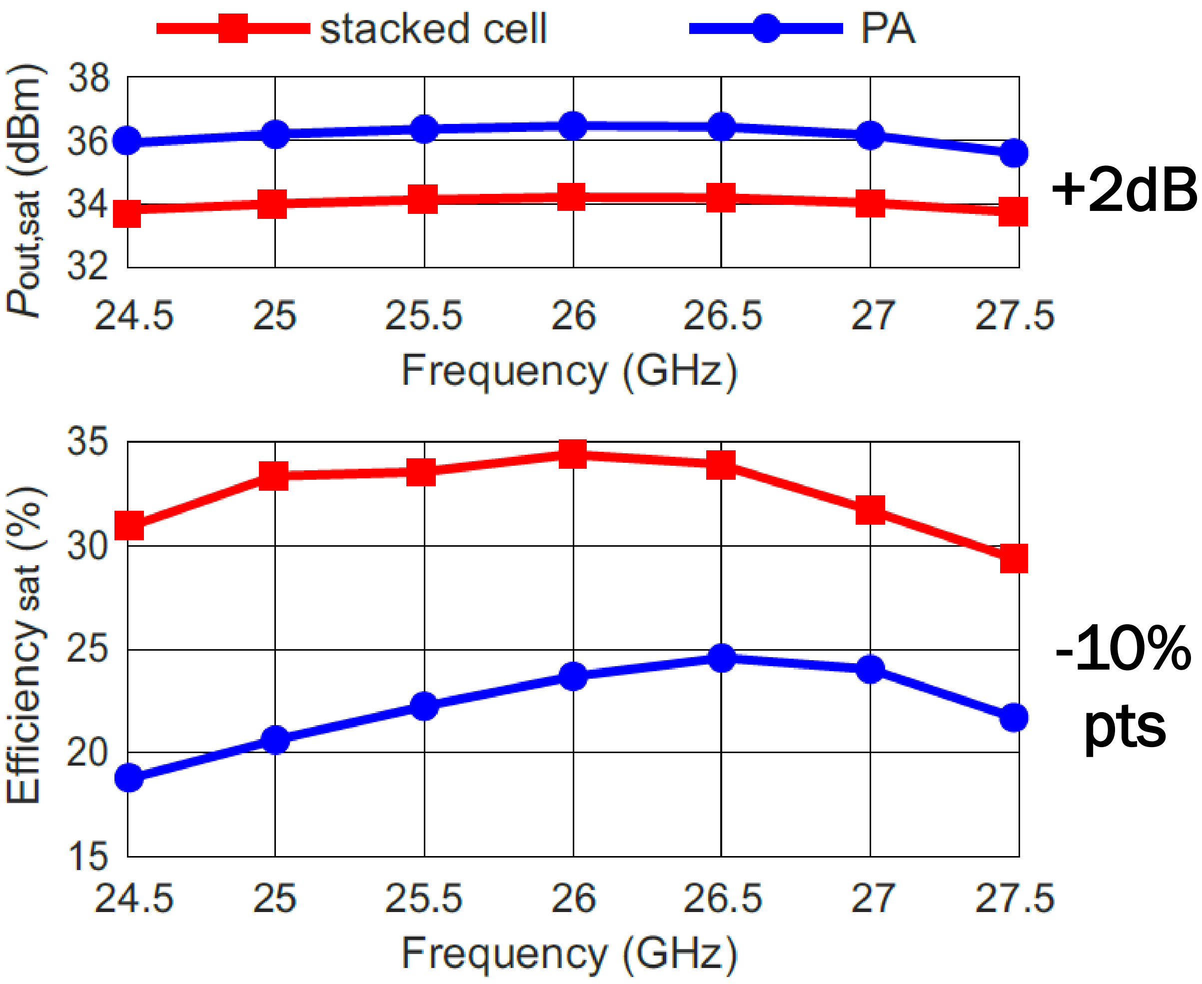
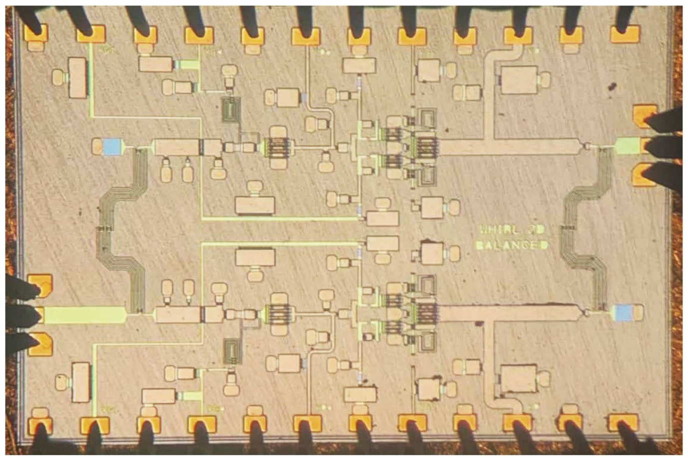
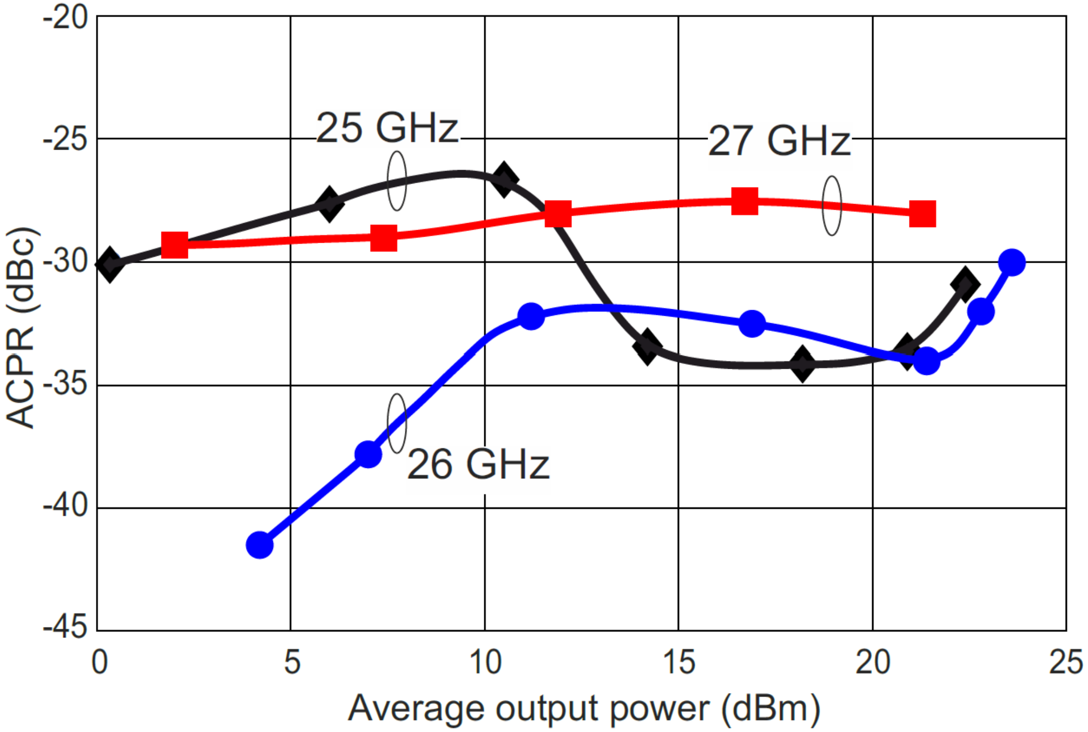




Results

- Modulated signal
  - 64-QAM standard NR downlink signal, 50 MHz BW, 10 dB PAPR
  - Baseline ACPR (source + driver): < -48 dBc





Comparison with SoA

Ref ♯	Tech nm	Freq. GHz	Psat dBm	Gain dB	ACPR, dBc @ PAPR, dB
[9]	150 GaAs	28	26	12	-28 @ 7.3
[10]	150 GaAs	28	28.5	23	-30.1 @ 7
[11]	150 GaAs	28	28.7	14.4	-32 @ 10.5
[12]	150 GaN	28	30	6.2	-28.5 @ 9
[13]	150 GaAs	24	30.9	12.5	-30 @ 7.5
[14]	150 GaN	28.5	35.6	12	-27 @ 8
[15]	150 GaN	27.5	36	19	NA
[16]	150 GaN	28.5	39	30	-35 @ 10
This work	**150 GaN**	**26**	**36***	**10**	**-30 @ 10**

⟸ stacked

Conclusion

- Balanced PA based on stacked cells
  - Effect of layout on performance
  - Compact gain enhancement solution
  - Potential interest for GaN at ≈26 GHz
  - Stability and sensitivity critical
- Next steps
  - Adoption in load-modulated PAs
  - Feasibility at >>26 GHz?

Acknowledgements

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  - WIN Semiconductors: University Program
  - Italian Universities Consortium (MECSA)
- Instrumentation:
  - Keysight Technologies
- Financial support:
  - Italian Ministry of Universities and Research (MUR)