We1C-2

A 1.5-to-17GHz Non-uniform Distributed Power Amplifier Using Reconfigurable Modules in 0.25μm GaN HEMT

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Outline

- High Efficency NDPA Design Challenges
- PCPCT Design Details
- FRDPA Design Details
- Demonstration of GaN-based FRDPA
- Conclusion

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- **High Efficency NDPA Design Challenges**
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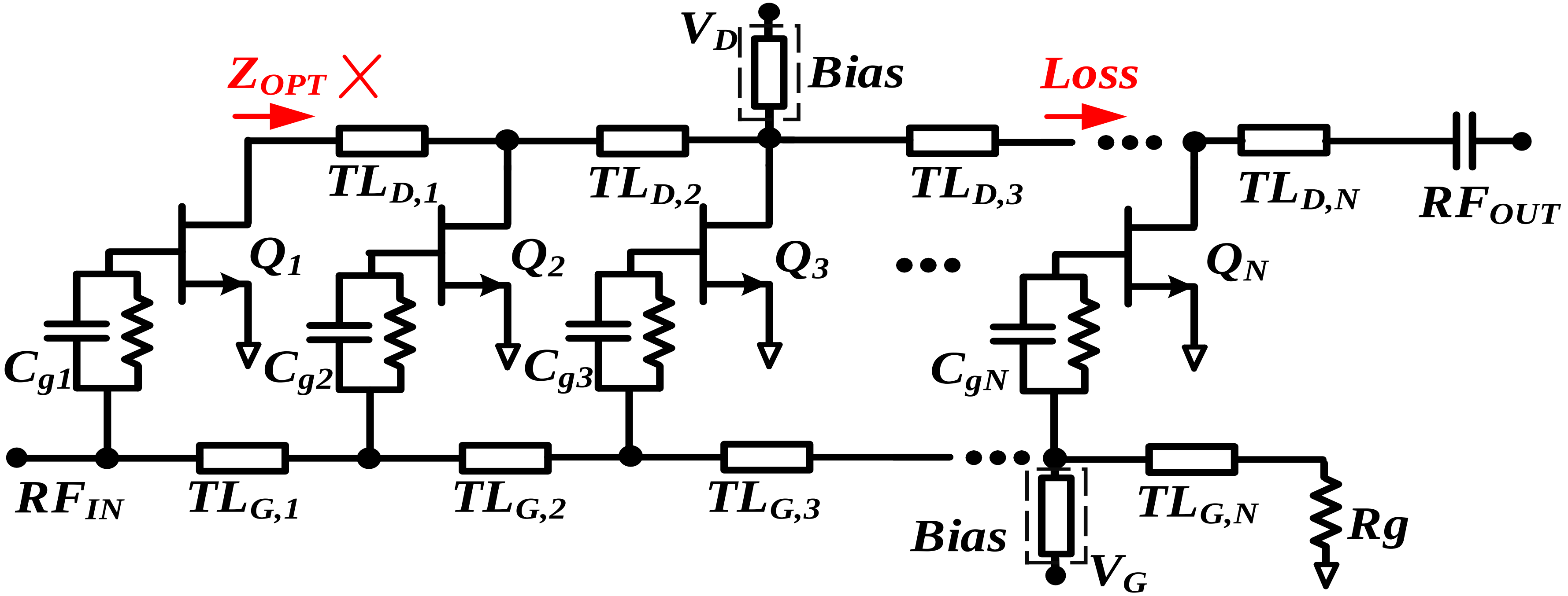
High PAE NDPA Design Challenges

- The reason of Non-Uniform Distributed's (NDPA) low PAE:
  - The impedance mismatch of transistors
  - The loss of output match network
  - The non-ideality of bias circuitry

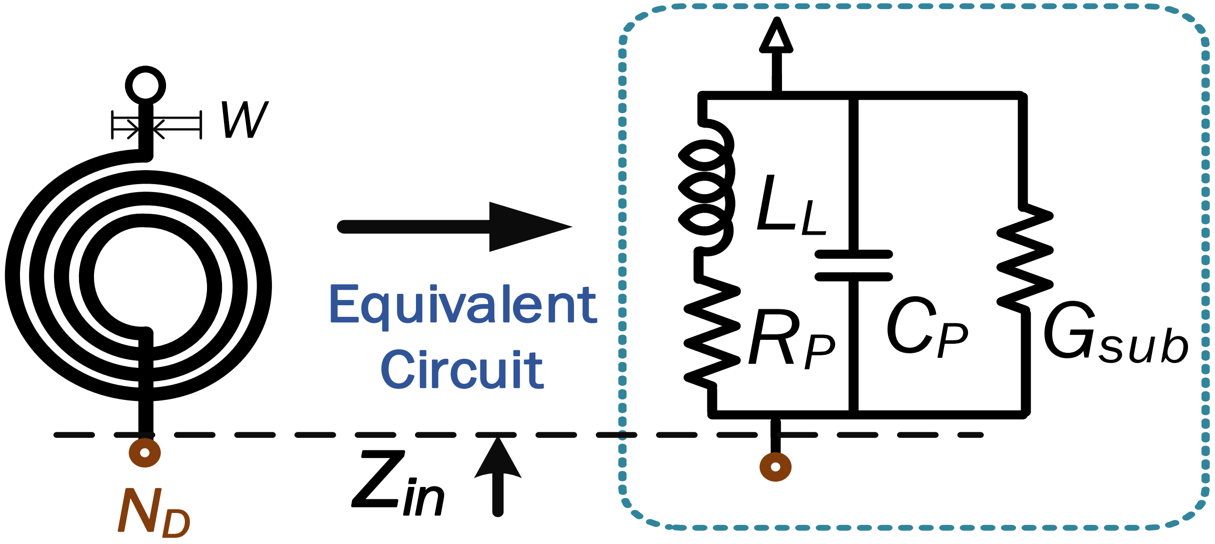


High PAE NDPA Design Challenges

- The characteristic of the ideal on-chip bias circuitry:
  - Higher impedance ⟶ larger inductance L_L
  - Higher self-resonance point ⟶ Smaller parasitic capacitance C_P
  - More sufficient current carrying ⟶ wider transmission lines W

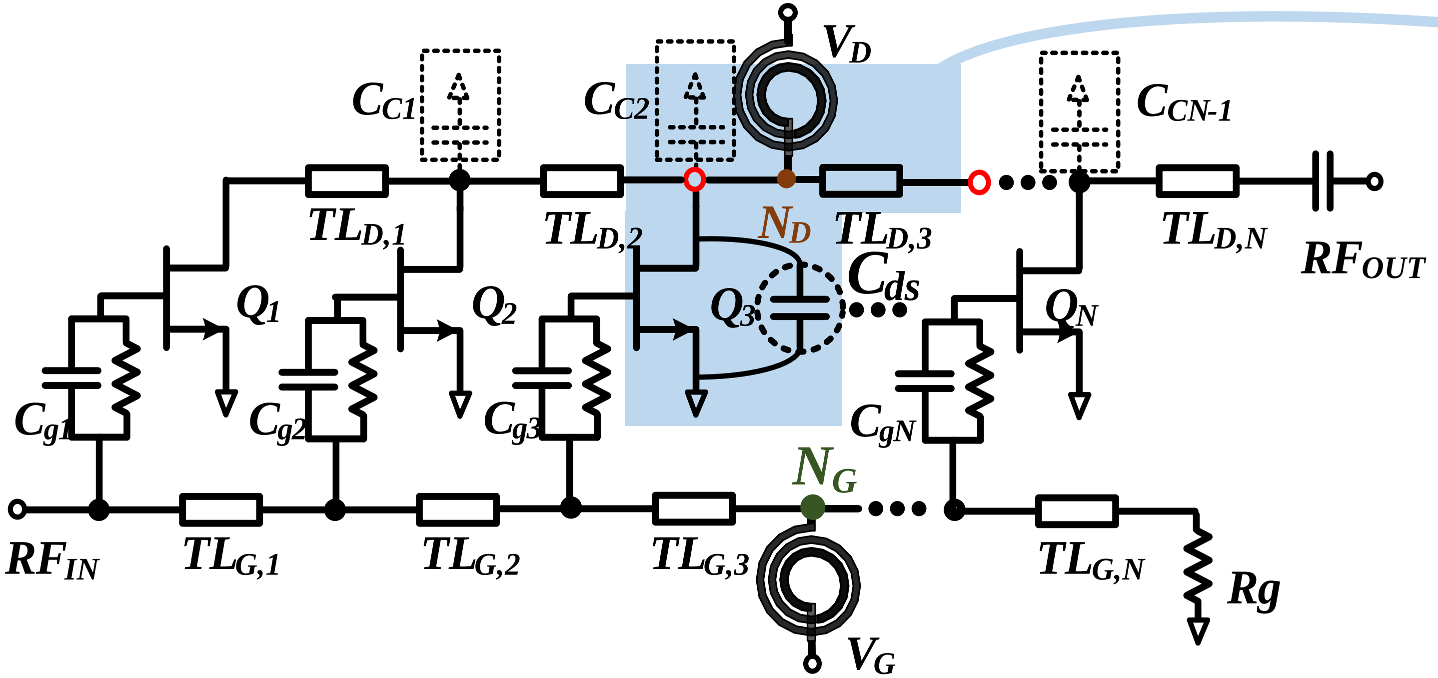
It is difficult to achieve!

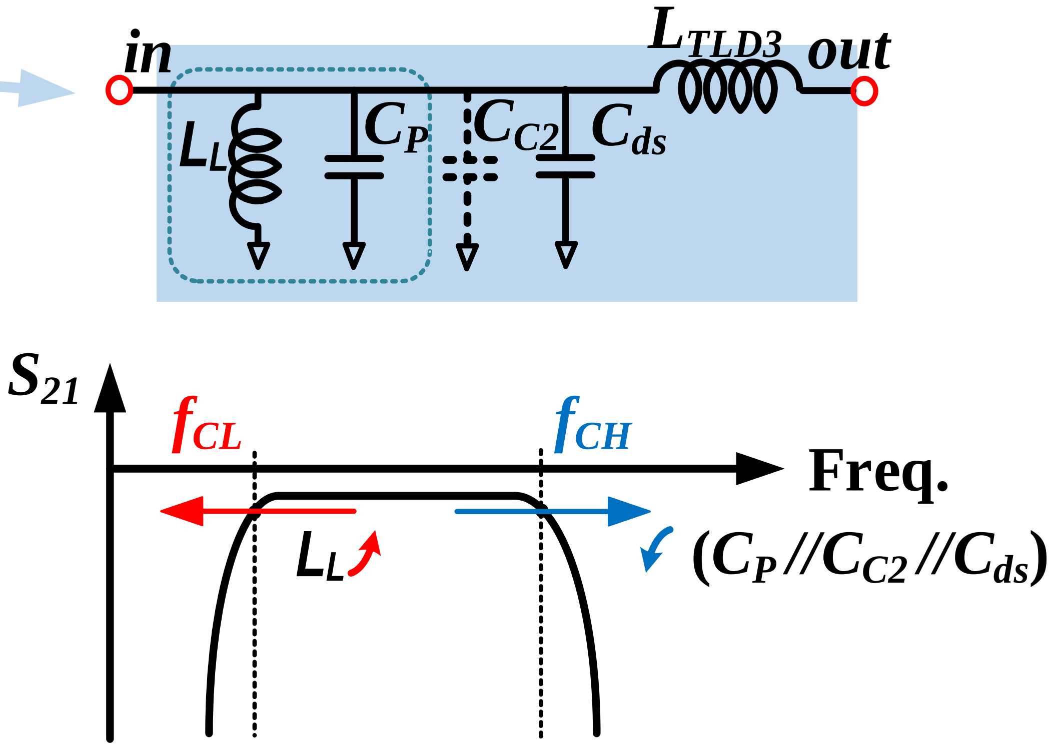
Drain Bias Inductor



High PAE NDPA Design Challenges

- The effect of the non-ideal bias circuitry on NDPA:
  - Exhibiting poor choke effect over a wide bandwidth.
  - Resulting in a bandpass effect.





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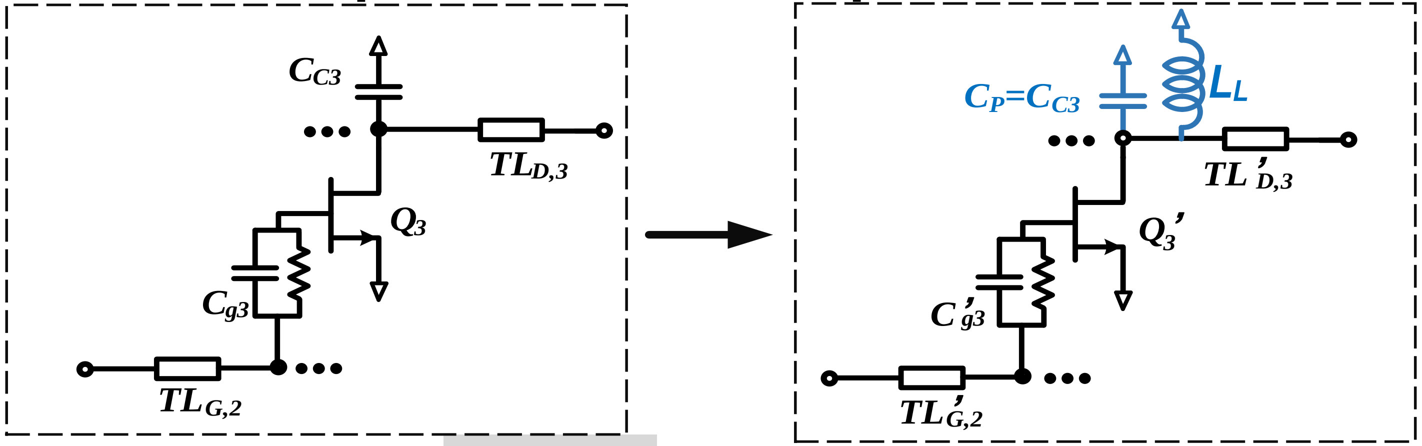
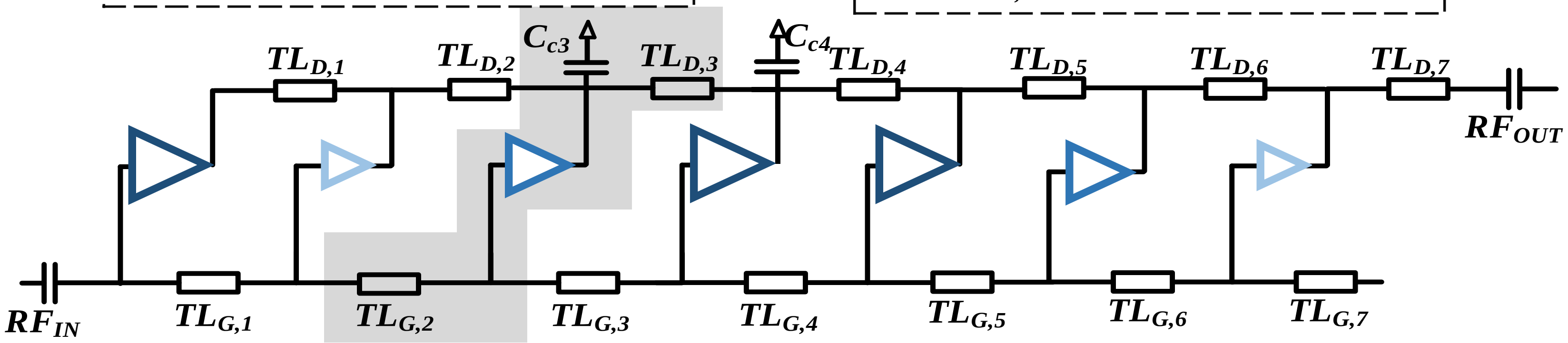
PCPCT Design Details

- Parasitic capacitance phase compensation technique(PCPCT)
  - Utilizing the parasitic capacitance of a bias inductor to compensate for the phase in a circuit

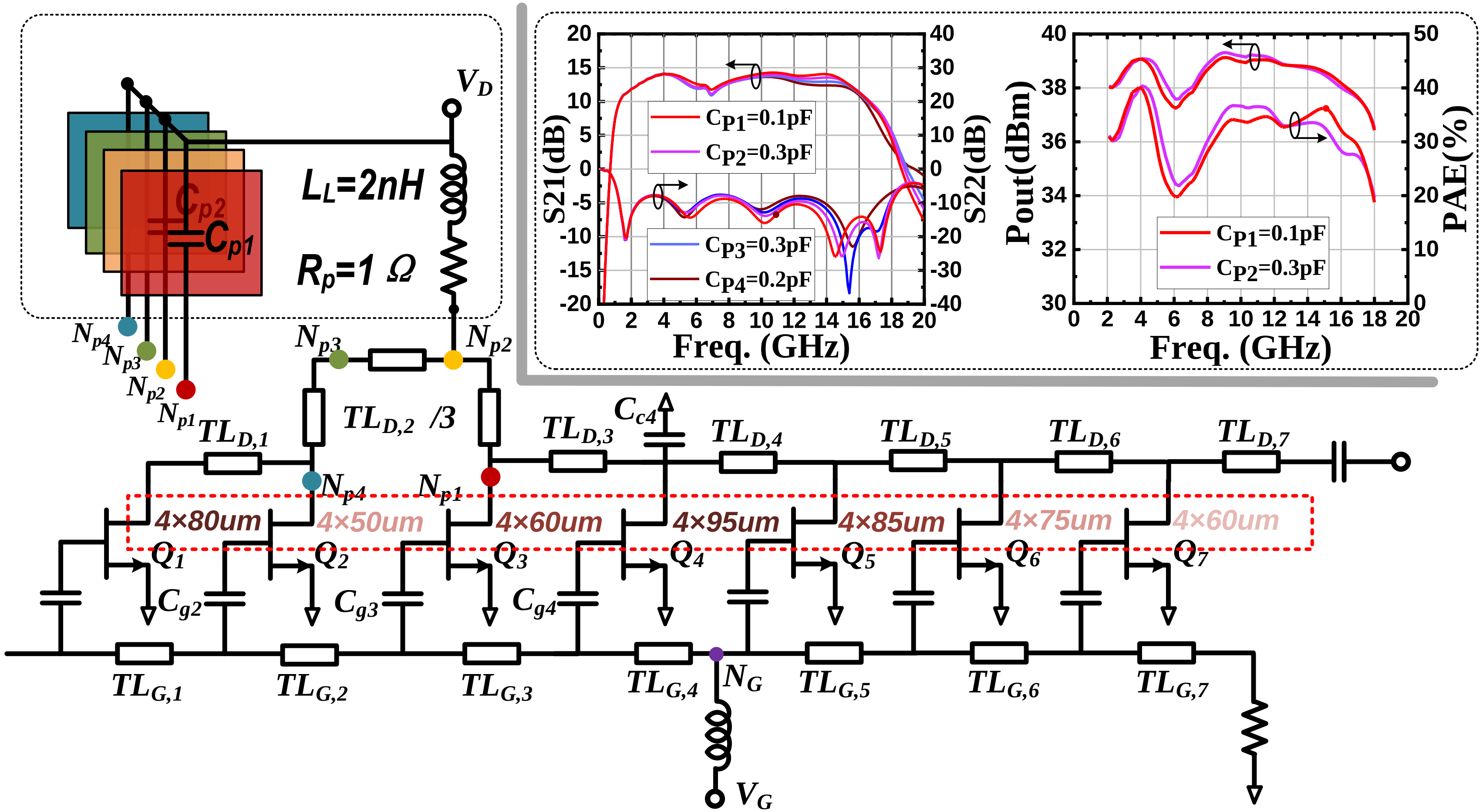


$$C'_{c3} = \frac{\cos\theta_{D,3} - 1 + \omega^2 L_{G,2} C_{g,3}}{\omega^2 L_{D,3}} - C_{ds,3}$$



PCPCT Design Details

- A simulation of S_{22}, PAE and P_{sat} for different $C_{pi\ (i=1,2)}$ are nearly identical



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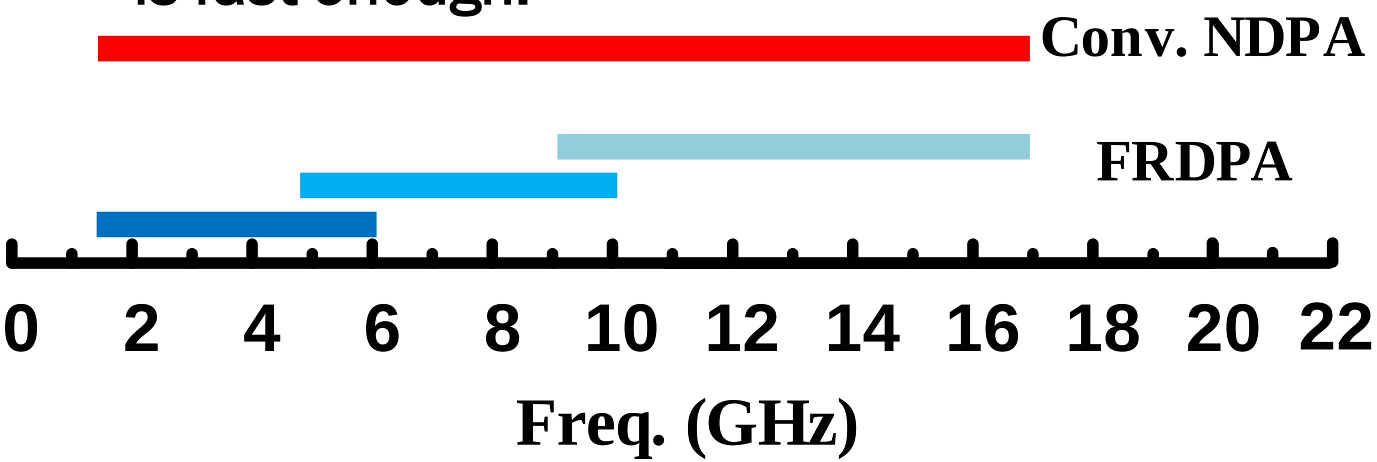
FRDPA Design Details

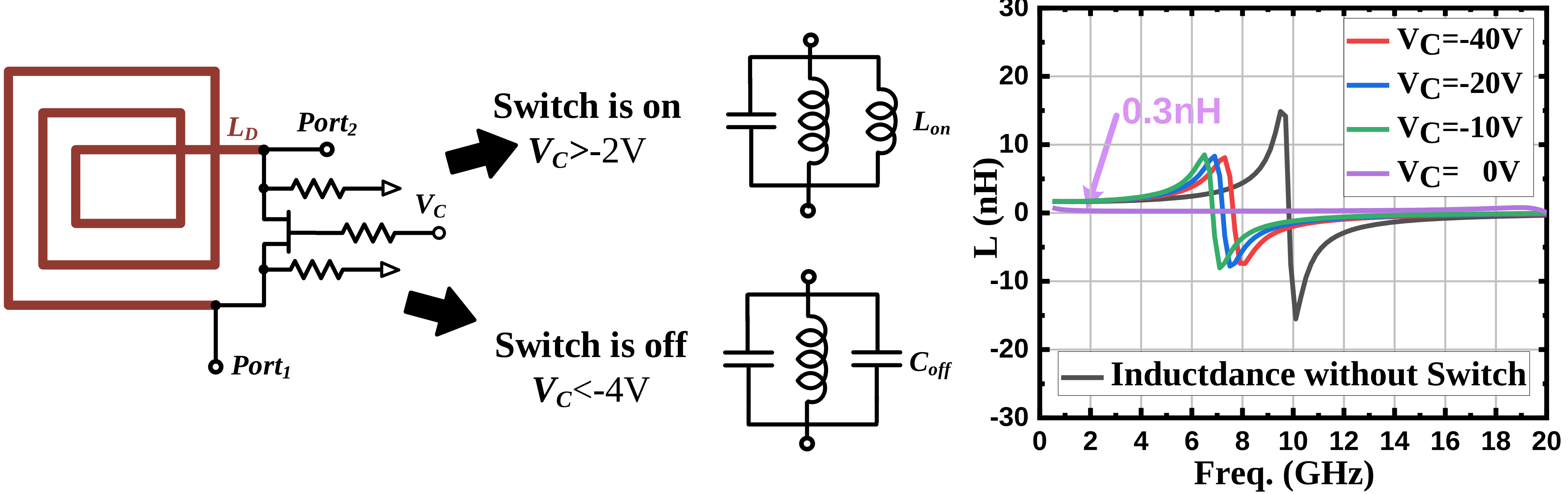
- Frequency Reconfigurable Distributed PA(FRDPA) Design
  - Frequency reconfigurable application scenarios
    - For multi-bandwidth PAs, the instantaneous operating bandwidth do not need to be so wide.
    - FRDPA has the potential to replace conventional NDPA if the switching speed is fast enough.



Bandwidth narrowed, performance improved!

FRDPA Design Details

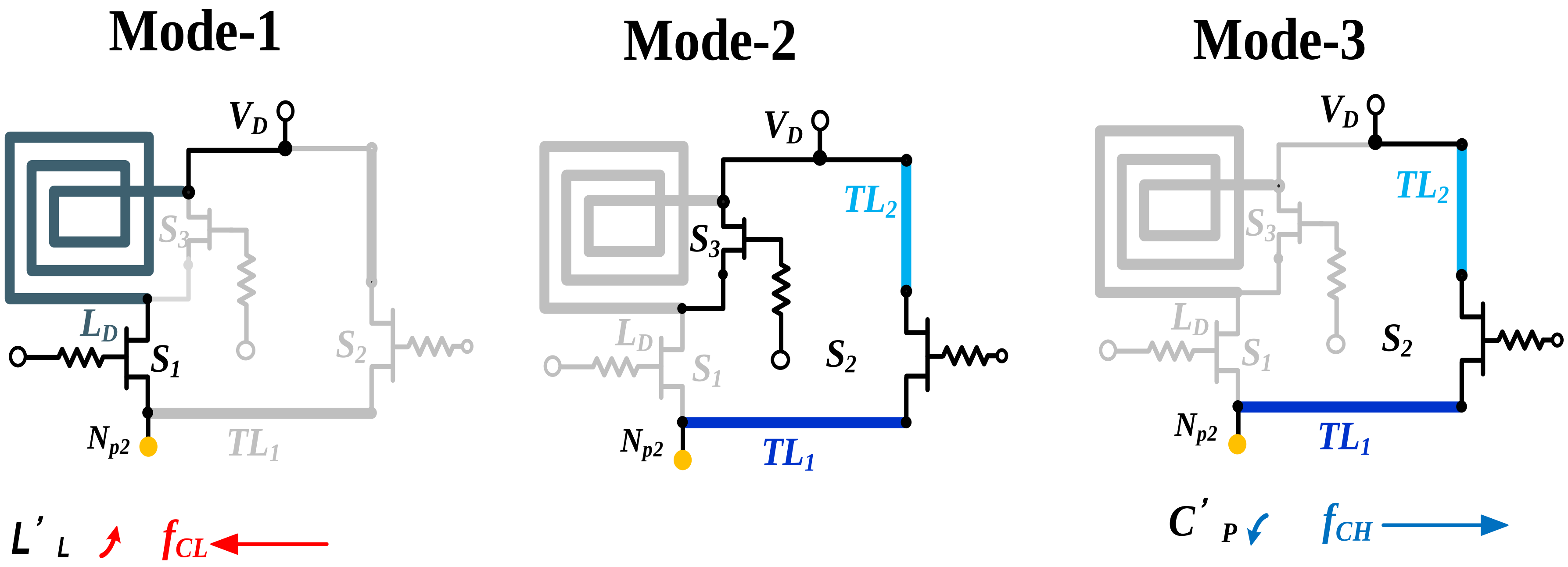
- Frequency Reconfigurable Distributed PA(FRDPA) Design
  - Reconfigurable Drain Bias Choke Module
    - The self-resonant point and inductance of the square inductor needs to be changed accordingly by switching



FRDPA Design Details

– Reconfigurable Drain Bias Choke Module

- Mode 1 provides a larger inductance L'_L at low frequencies.
- Mode 2 provides the better load impedance for transistors.
- Mode 3 provides a smaller capacitance C'_P at high frequencies.

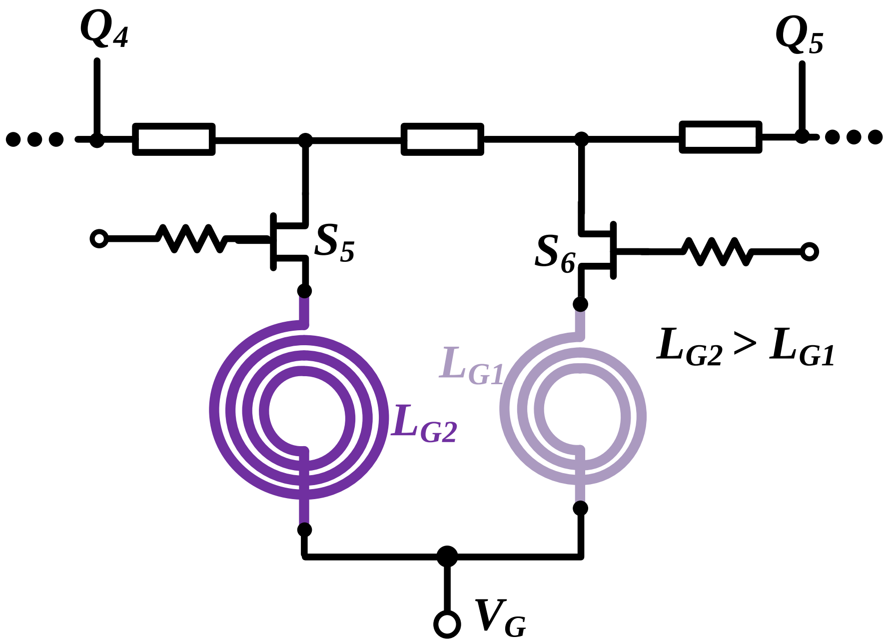


FRDPA Design Details

– Reconfigurable Gate Bias Choke Module and dumping load module

- These two rec. module can optimize S_{11} and optimize source impedance of transistors.

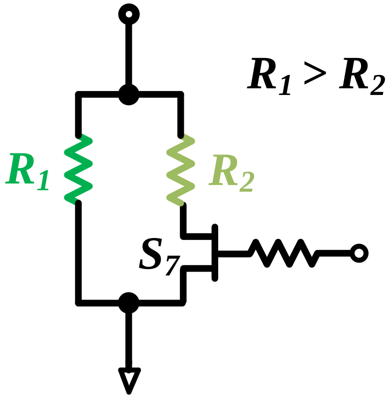
Reconfigurable Gate Bias Module



Mode Control Table

Mode	Gate Control Voltage		
	S5	S6	S7
1(1.5-6GHz)	0V	-10V	-32V
2(5-10GHz)	0V	-30V	0V
2(9-18GHz)	0V	0V	0V

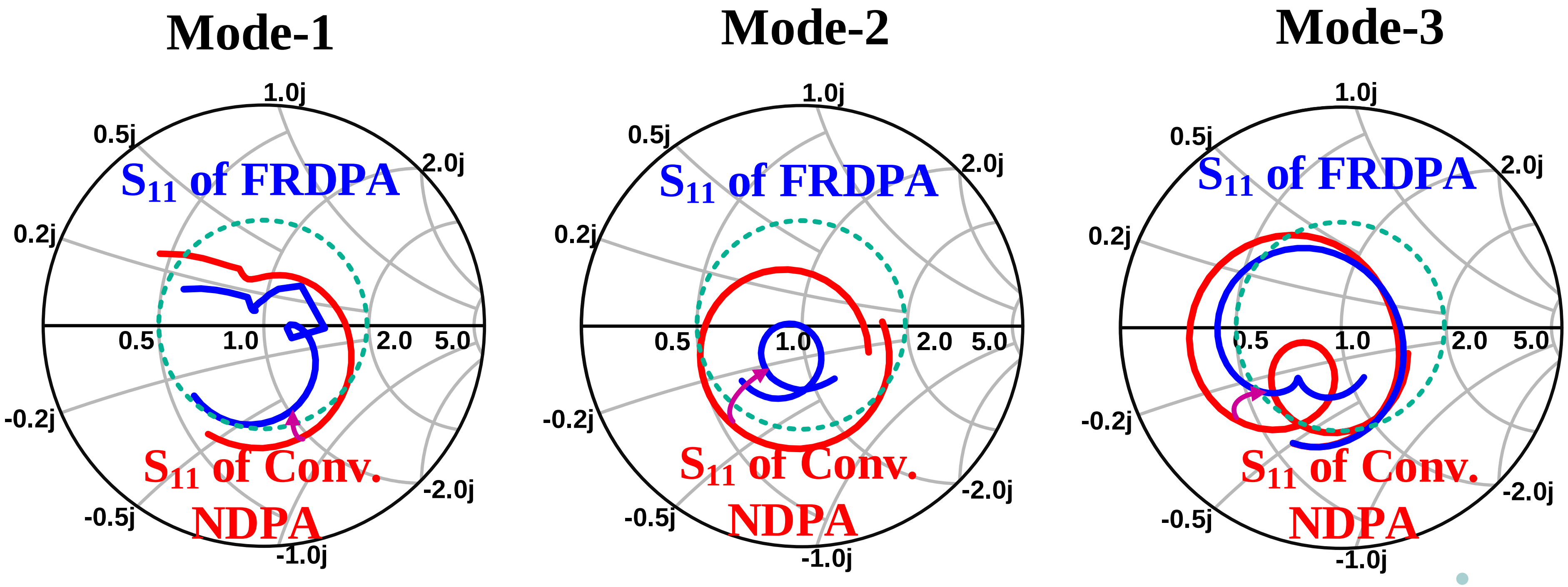
Reconfigurable Dumping Load



FRDPA Design Details

– Reconfigurable Gate Bias Choke Module and dumping load module

- The optimization of the reconfigurable module for input matching in three modes.



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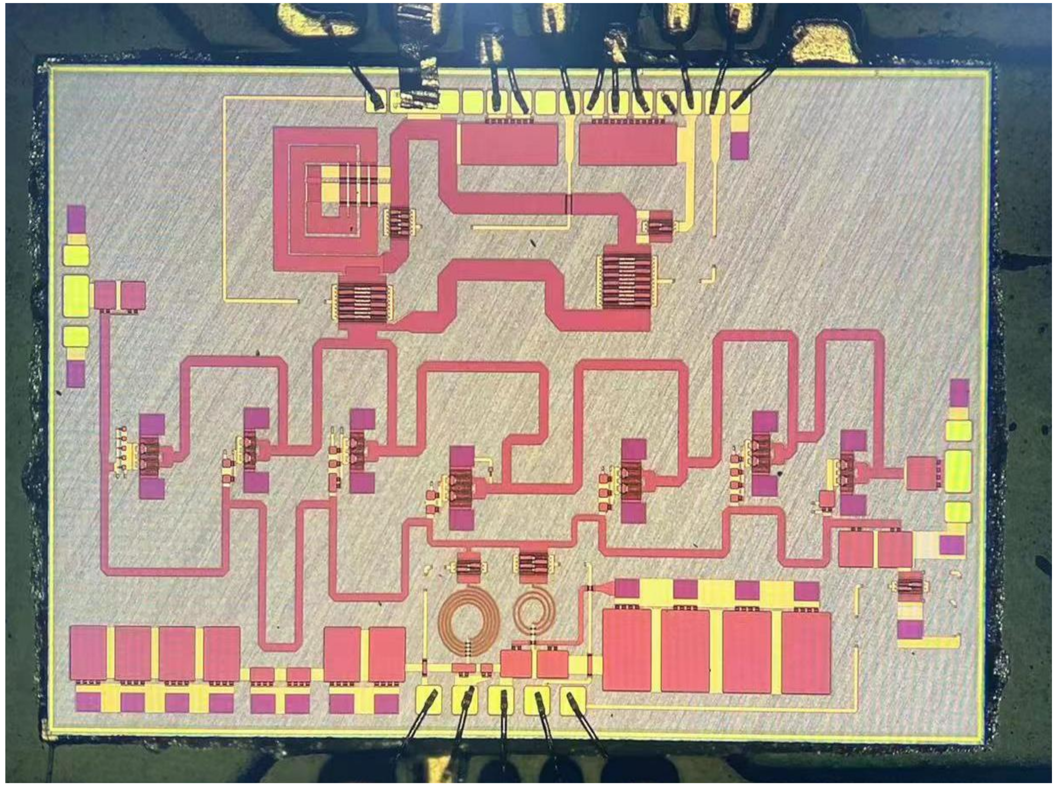
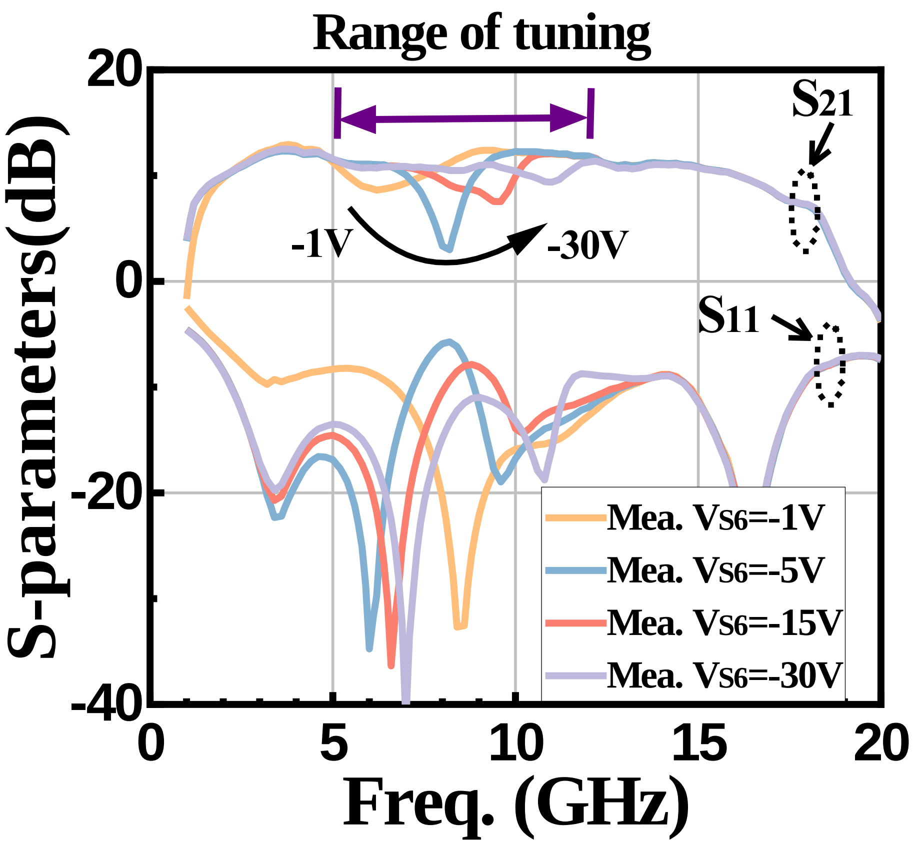
Demonstration of GaN-based FRDPA

- Die micrograph
  - Area with PADs: 3.76mm x 2.4mm
- Technology
  - 0.25 μm GaN HEMT
  - f_T = 25 GHz



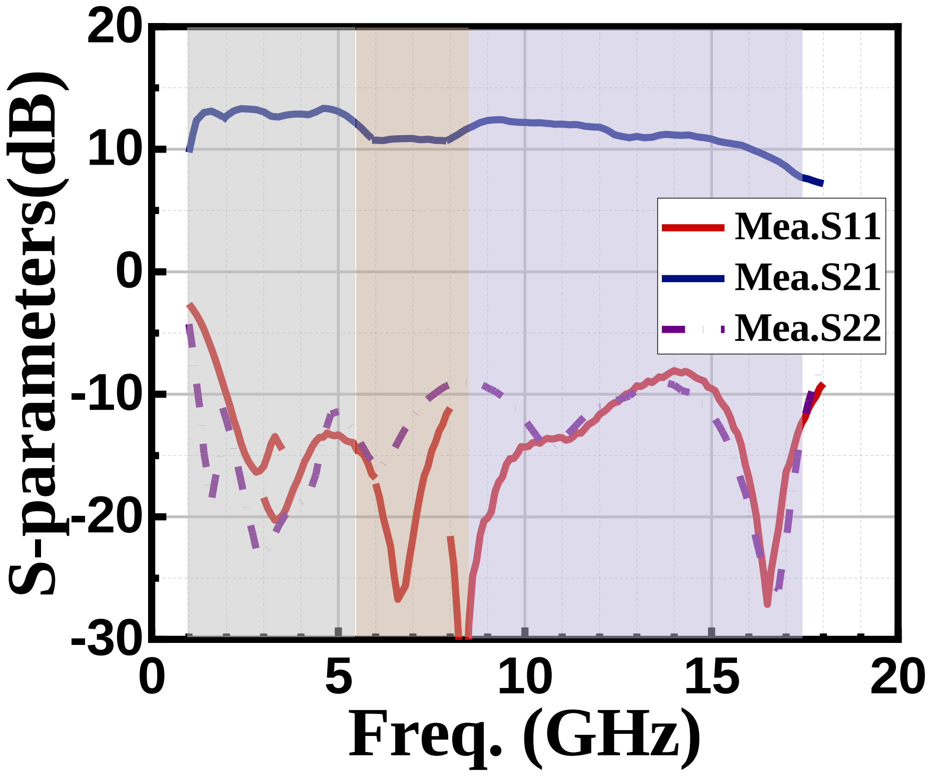
Demonstration of GaN-based FRDPA

- Minimize the discrepancy between the simulated model and the measured performance by the tuning of the switch control voltage.



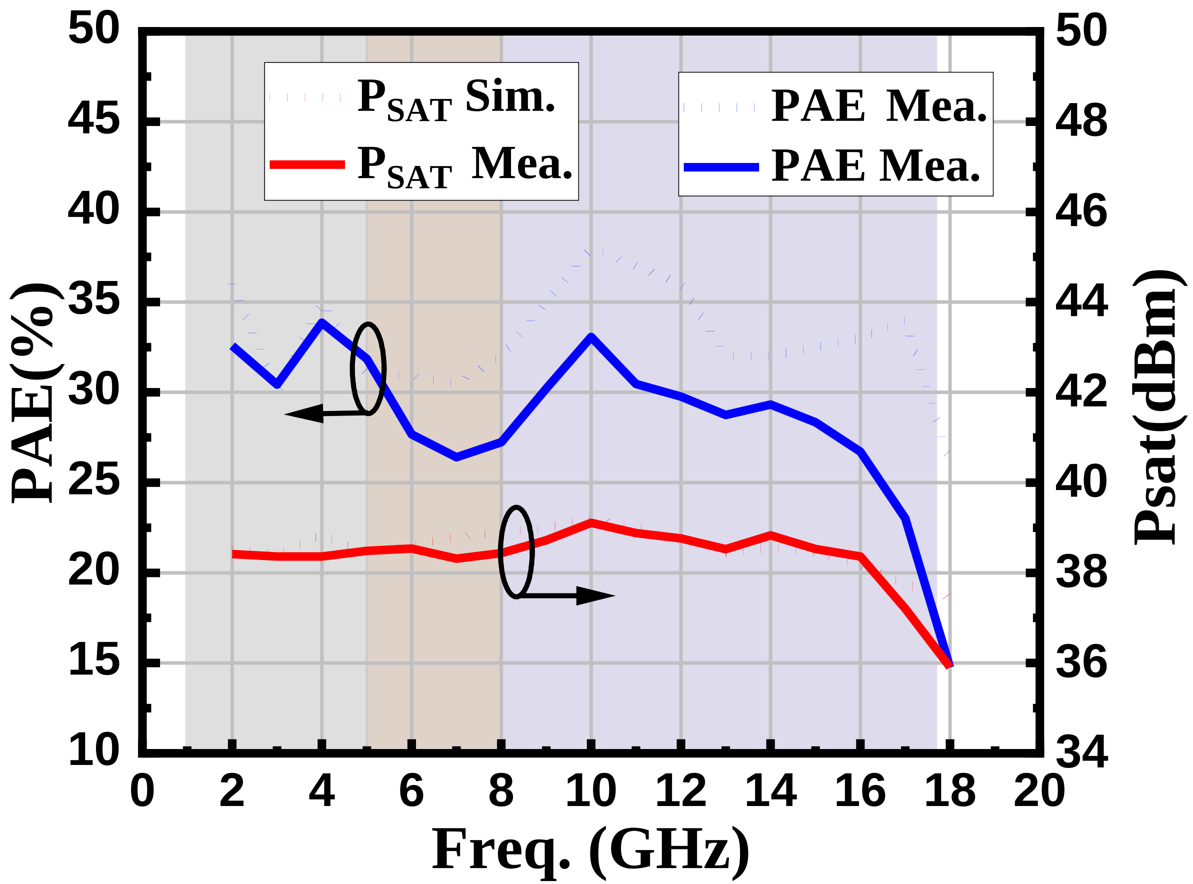
Demonstration of GaN-based FRDPA

- S_{21}
  - >12dB@1.5-6GHz
  - >11dB@6-9GHz
  - >10.5dB@9-17GHz
- S_{11}&S_{22}
  - <-7dB@1.5-6GHz& <-11dB@1.5-6GHz
  - <-12dB@6-9GHz& <-9.5dB@6-9GHz
  - <-9dB@9-17GHz& <-9.5dB@9-17GHz



Demonstration of GaN-based FRDPA

- PAE_{max}
  - >31%@2-6GHz
  - >27%@6-9GHz
  - >23.5%@9-17GHz
- P_{sat}
  - >38.1dBm@2-6GHz
  - >38.2dBm@6-9GHz
  - > 37.1dBm @9-17GHz



Demonstration of GaN-based FRDPA

– Comparison

Parametric	Technology	Freq.BW (GHz)	Gain (dB)	Supply (V)	Total Gate width(mm)	P_{sat} (dBm)	PAE (%)	Average PAE* (%)
[3] IMS	QGaN15	4-16	15.8-17.5	18	1.05	33.8-35.4	11.8-33.9	20
[4] TMTT	0.25μm GaN	6-18	10±2	30	6	38.7-41.2	13.6-33.8	24
[7] IMS	0.2 um AlGaN	2-20	9.7	30	6	39.9-43.4	15.3-35.7	26
This work	0.25μm GaN	2-6	12.9	28	2.02	38.1-38.8	31-35	28
		6-9	11.2			38.2-38.6	27-30	
		9-17	11.1			37.1-39.2	23.5-34	

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Conclusion

- A GaN-based FRDPA is designed and fabricated.
- PCPCT and reconfigurable module is proposed.
- 0.25 μm GaN HEMT.
- Ultra-wideband from 1.5 to 17 GHz.

Thank You!

The following are the authors' emails. Questions are welcome.

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