A 2.5-to-18GHz Reconfigurable LNA With 1.38-to-1.97dB NF Using Switchable Diplexer and Low-Noise Oriented Input

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Outline

- Introduction
- Circuit Design
  - Broadband Low-Noise Oriented Input Stage
  - Coupled-Line-Based Reconfigurable Diplexer
- Measurement & Comparison
- Conclusion

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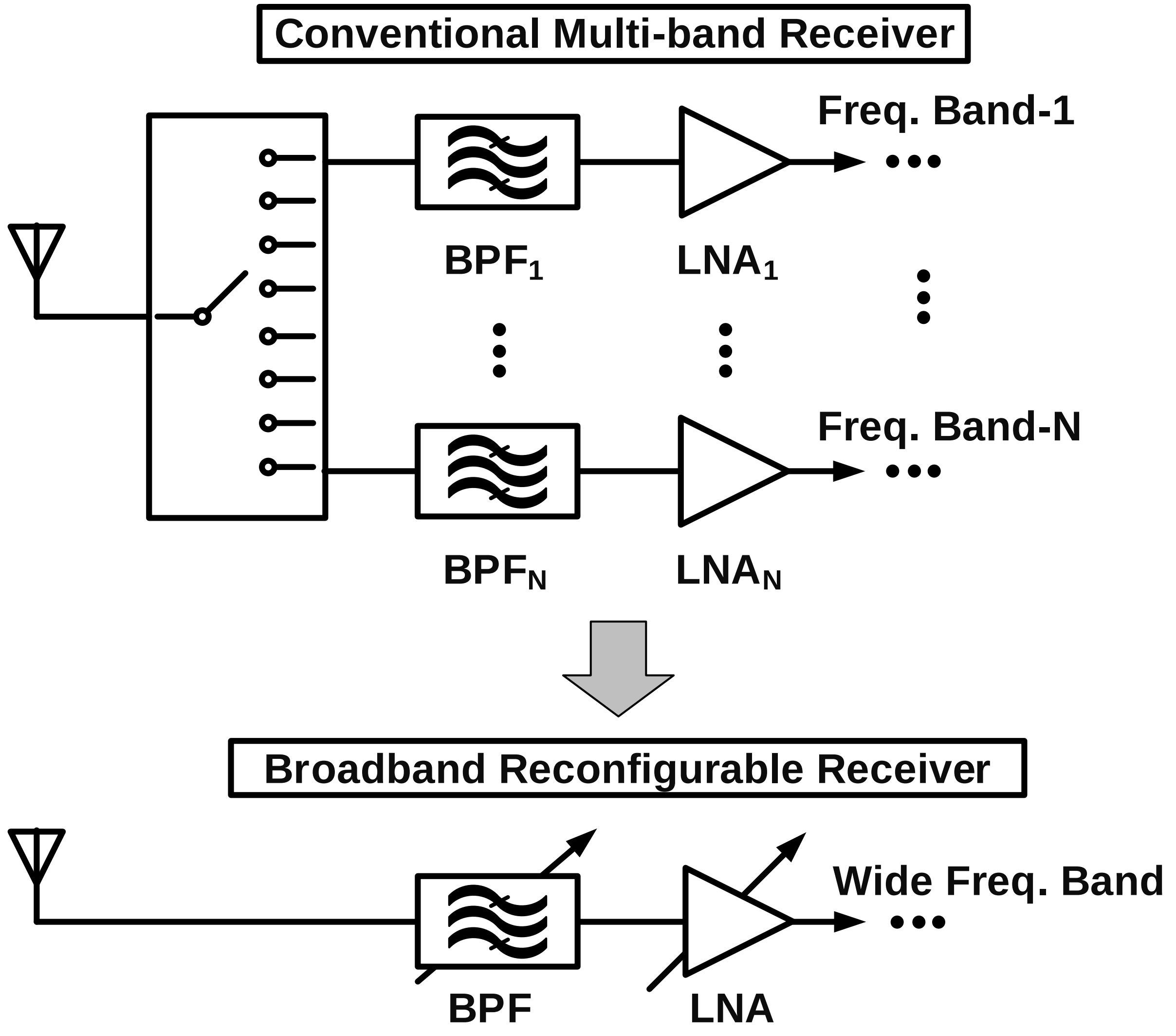
Introduction

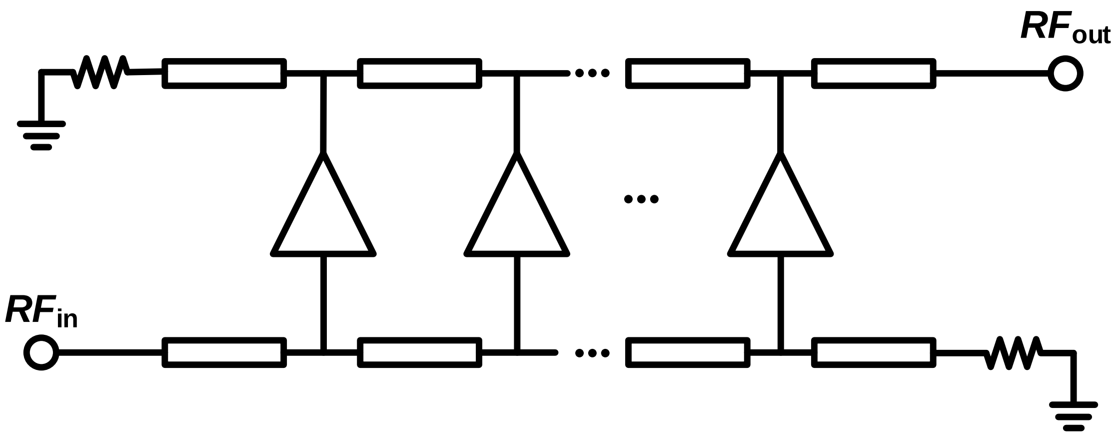
- **Applications**
  - Multiband/Wideband Transceivers
  - Radar Sensing
  - Instrumentation

- **Requirements on LNA**
  - Impedance Matching
  - Adequate Gain
  - Flat In-band Frequency Response
  - Low Noise Figure (NF)



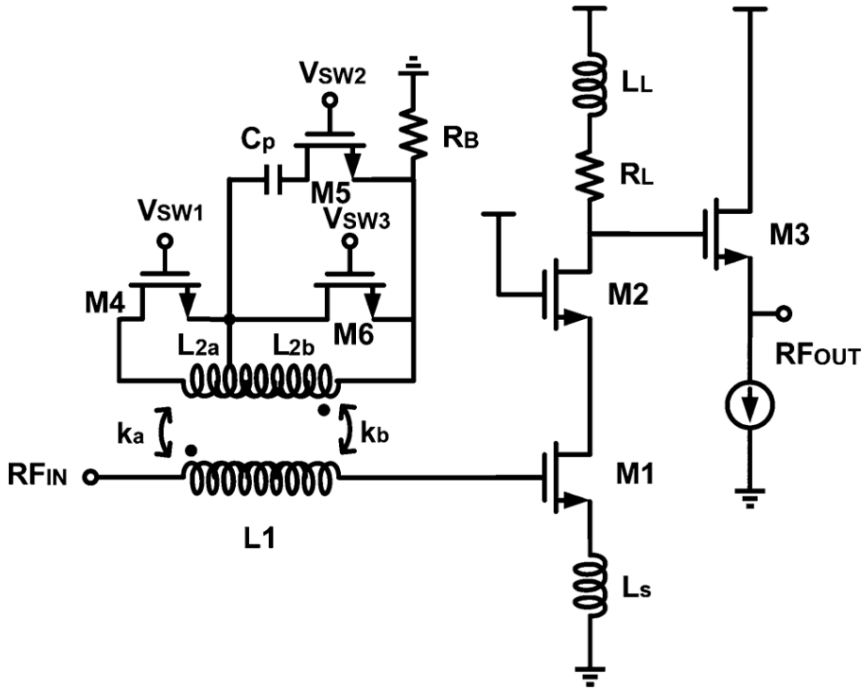
Introduction

- Classical Types
  - Distribute Structure



- ☺ Wide Bandwidth
- ☹ Relatively High NF
- ☹ Low Unity Gain

  - Reconfigurable Structure

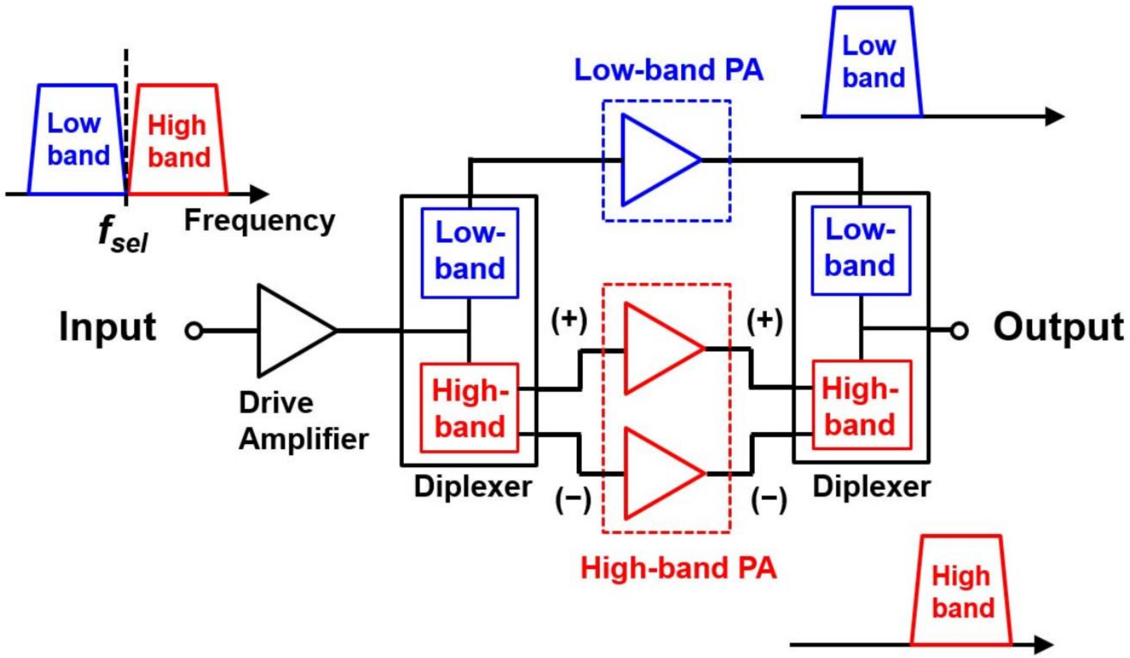


[X. Yu *et al.*, TMTT'2013]

- ☺ Multi-band & Multi-mode
- ☹ Noise Contributions of Switches

Introduction

— Diplexer-based Amplifier

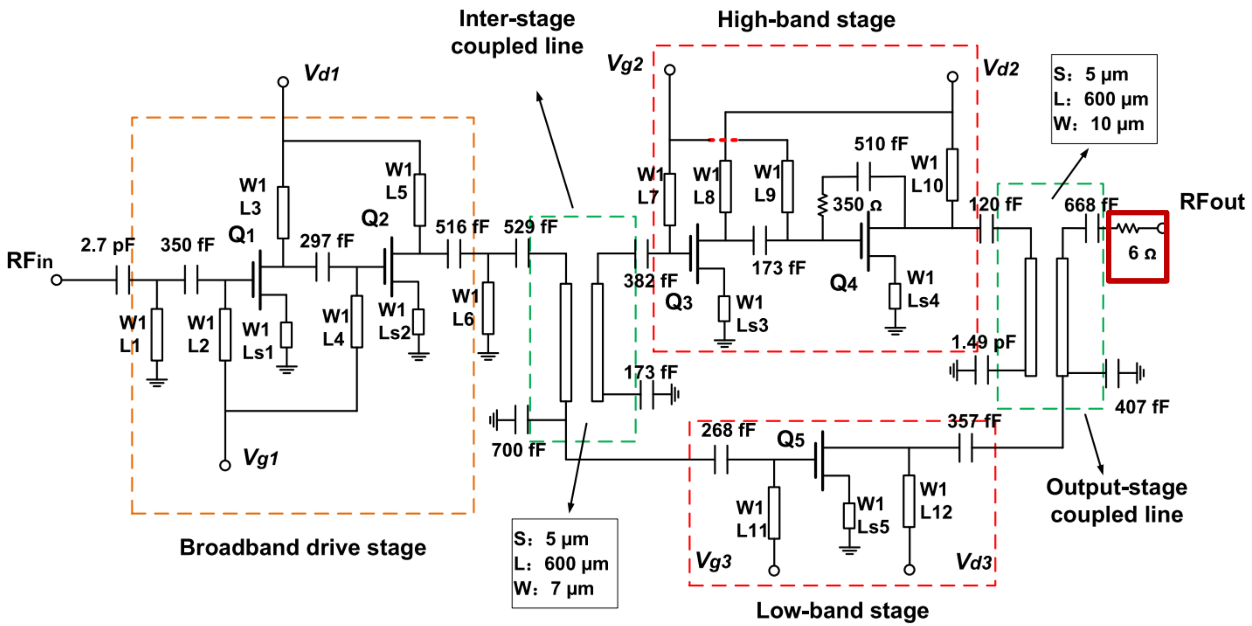


Power Amplifier (PA), [K. Choi *et al.*, IMS'2018]

- Dual-band, Dual-mode (6–10.5, 10.5–18 GHz)
- Discontinuities in Gain and Frequency Response
- Gain Variation = 10 dB

Introduction

— Diplexer-based Amplifier

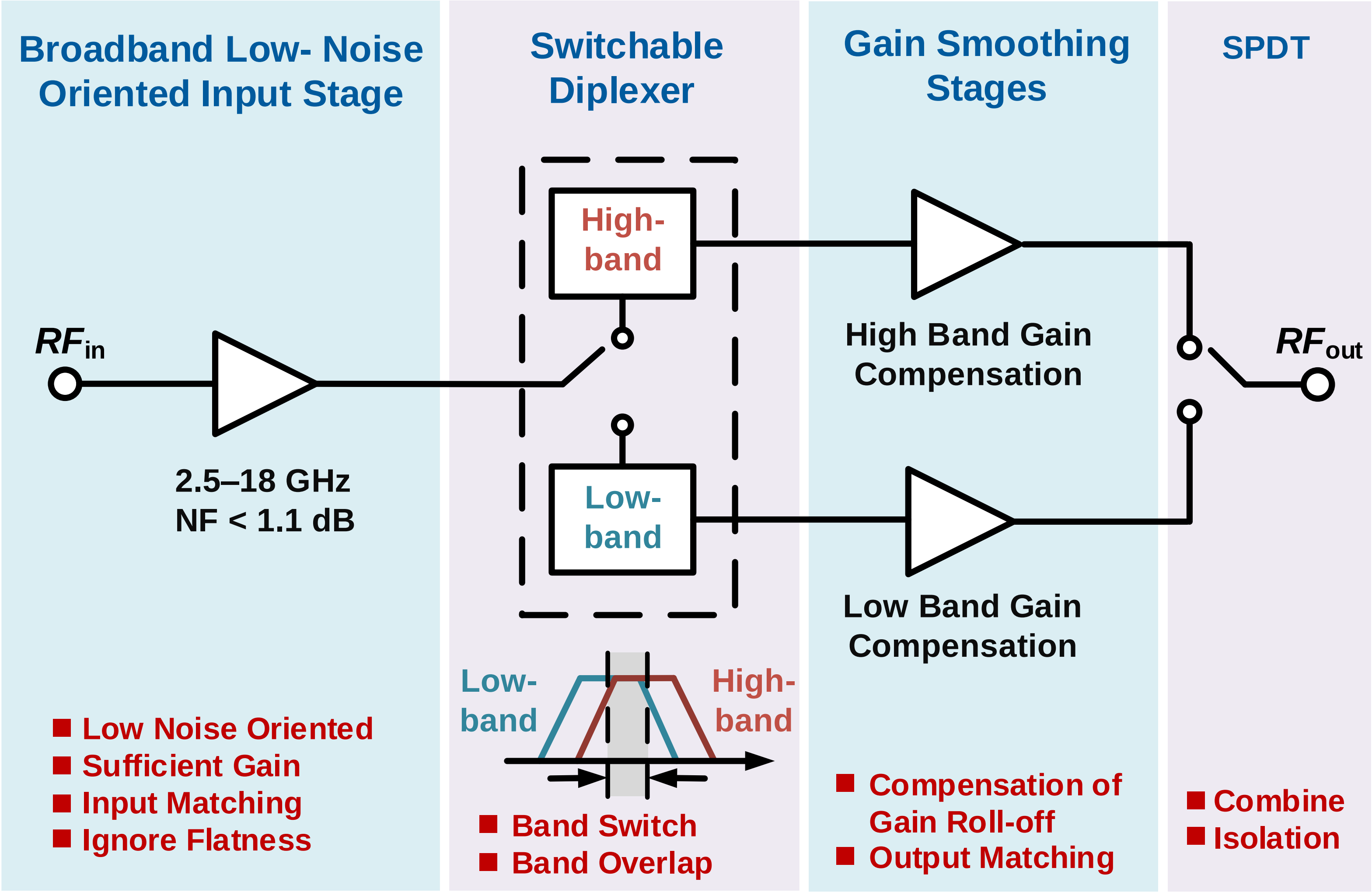


LNA , [C. Xie *et al.*, Access'2020]

- Dual-band, Dual-mode (8–10, 12–20 GHz)
- Low Noise Figure
- Discontinuities in Gain and Frequency Response
- Gain Variation ≈ 8 dB
- Concerns about Oscillation

Introduction

— The Proposed LNA



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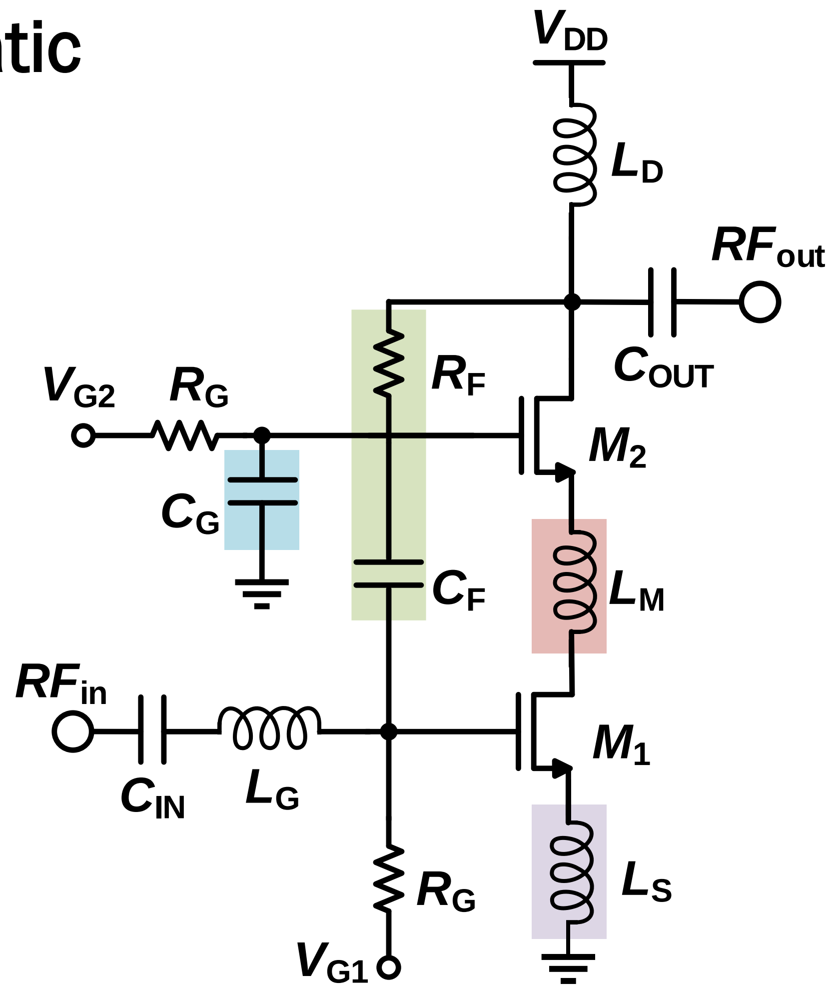
Circuit Design

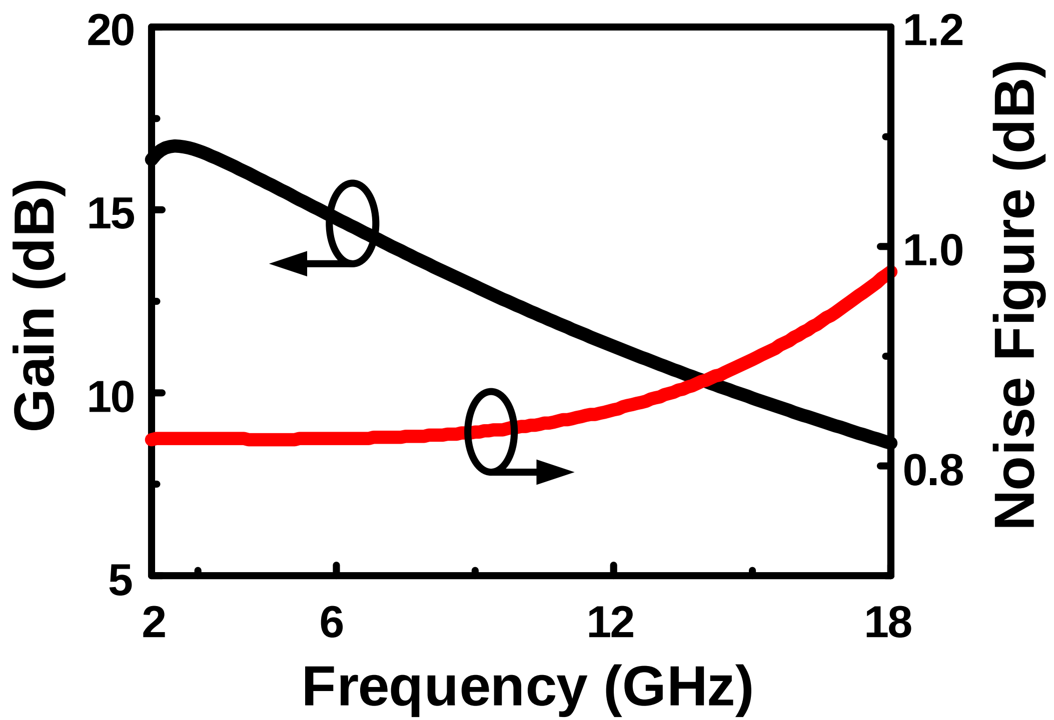
- The Cascode LNA Unit Cell
  - Schematic

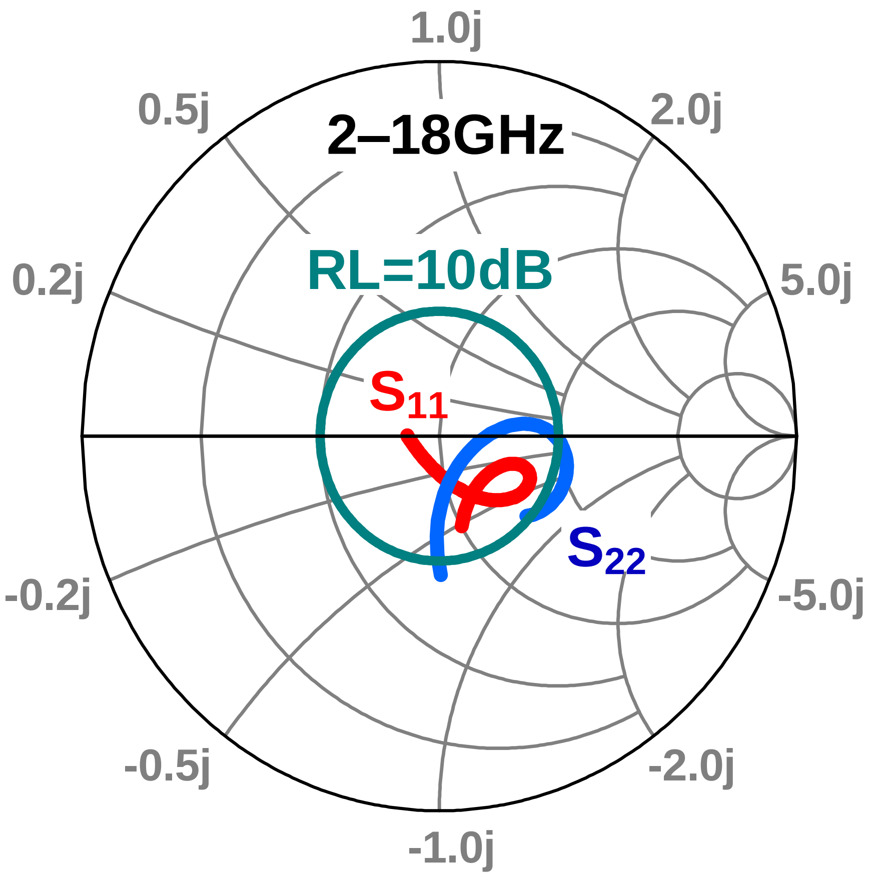


- Source Degeneration Inductor for High-frequency Matching
- Shunt-Resistive Feedback for Wideband Impedance Matching
- Middle Inductor for Middle Pole Tuning
- Gate Capacitor for Impedance Matching Tuning

Circuit Design

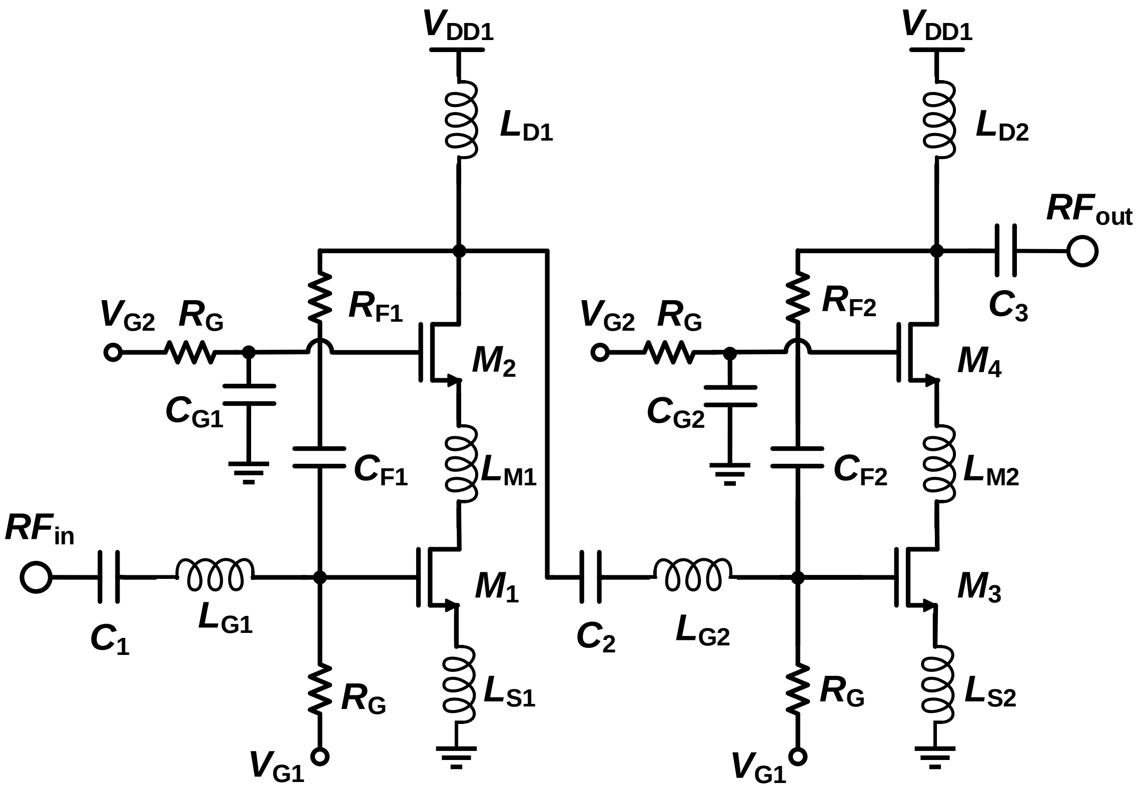
- The Cascode LNA Unit Cell
  - Simulation Results



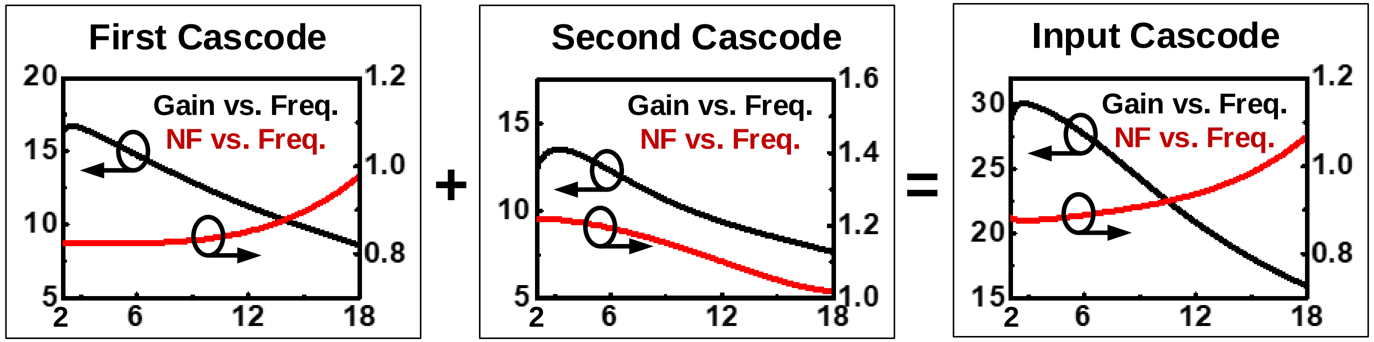


Circuit Design

■ The Broadband Low-noise Input Stage



Ultra-low Noise Broadband Input Stage



- Two Cascode Stages to Boost Gain
- Not for Gain Balance
- For Gain Improvement Without Sacrificing Noise
- Similar Zeros and Poles

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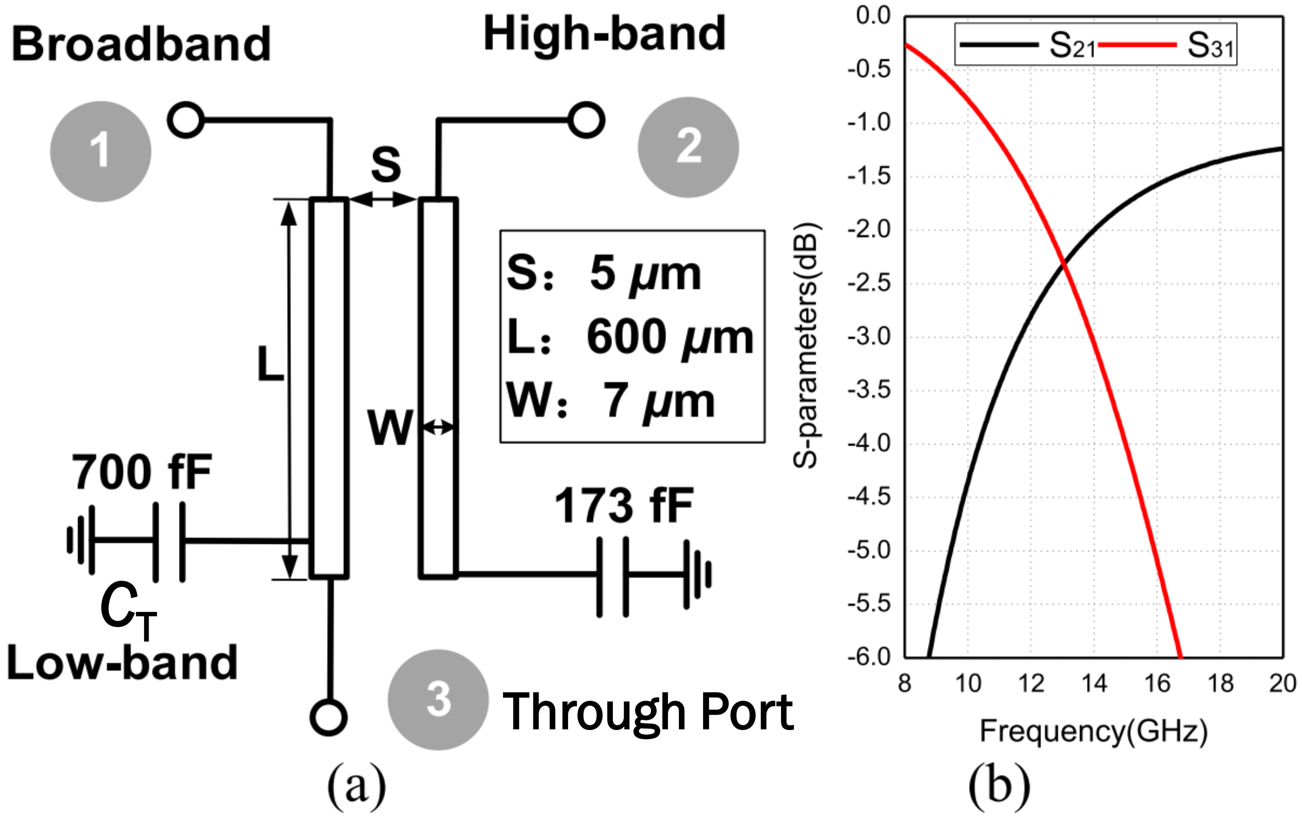
Circuit Design

■ Conventional Couple-Line-Based Diplexer



LNA , [C. Xie *et al.*, Access'2020]

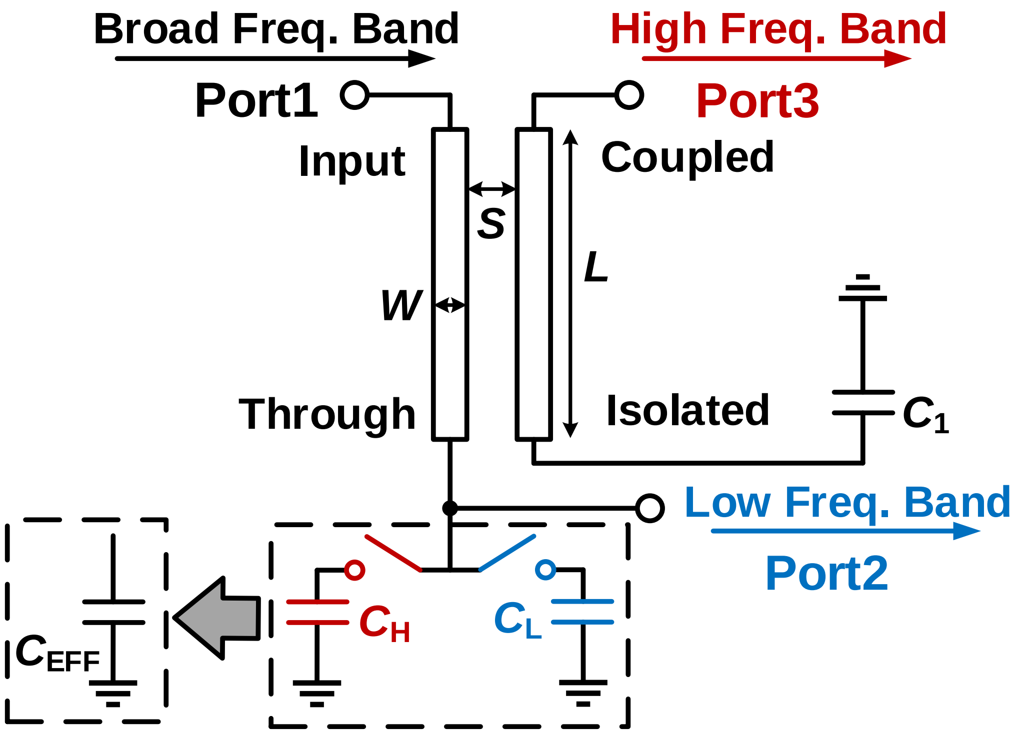
- A Capacitor C_T at the Through Port;
- For Low Freq. Signal, C_T → Open Circuit
- For High Freq. Signal, C_T → Short Circuit

☺ Frequency Division

☹ Large Amplitude Variation at Overlapping Freq. Band

Circuit Design

■ The Proposed Reconfigurable Diplexer



W : 10 μm
S : 4 μm
L : 700 μm
C_1 : 0.8 pF
C_L : 0.2 pF
C_H : 1.2 pF

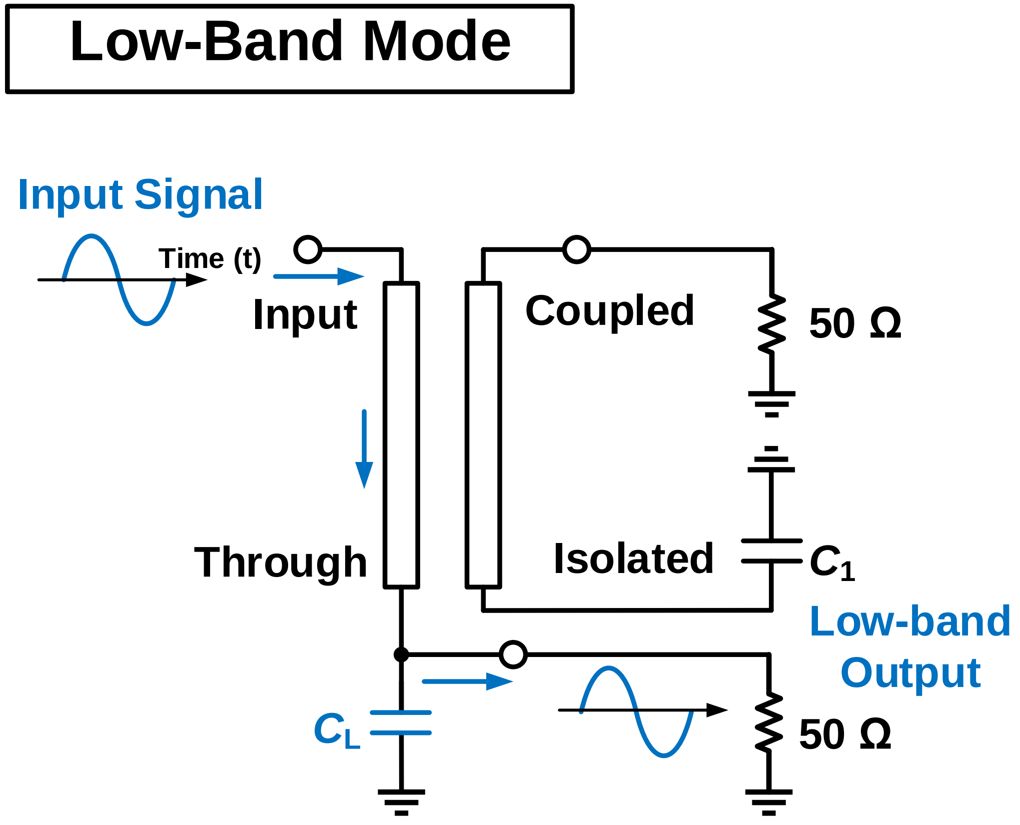
- Two Switched Capacitors at the Through Port
- Larger Capacitor for High-Band Mode, Smaller Capacitor for Low-Band Mode

☺ Enable Band Overlap

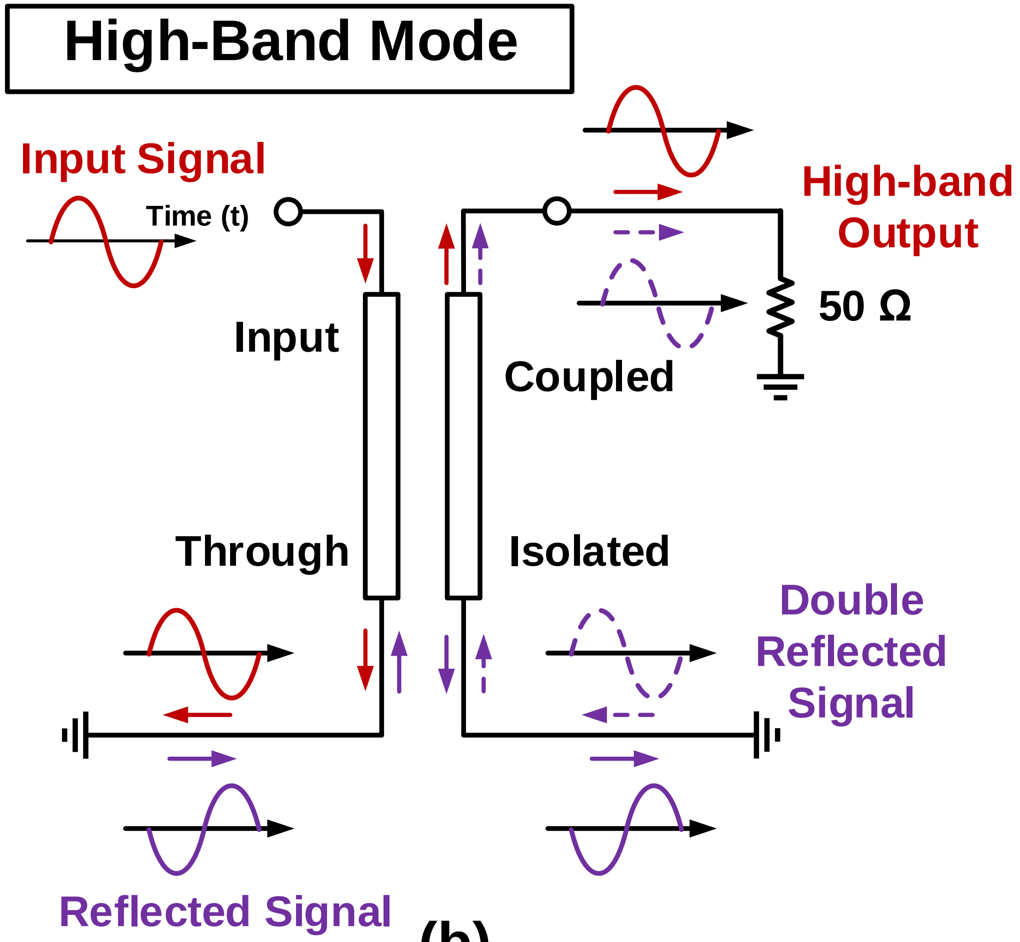
☺ Minimize Gain Variation within the Two Bands

Circuit Design

■ The Proposed Reconfigurable Diplexer



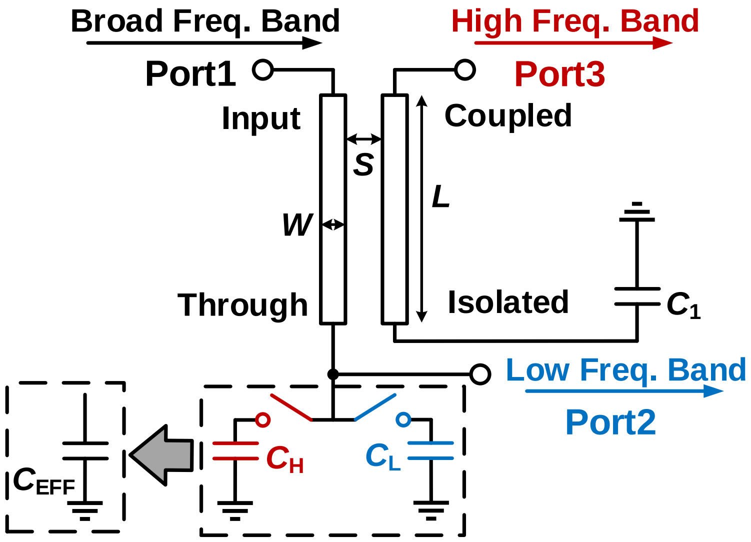
(a)

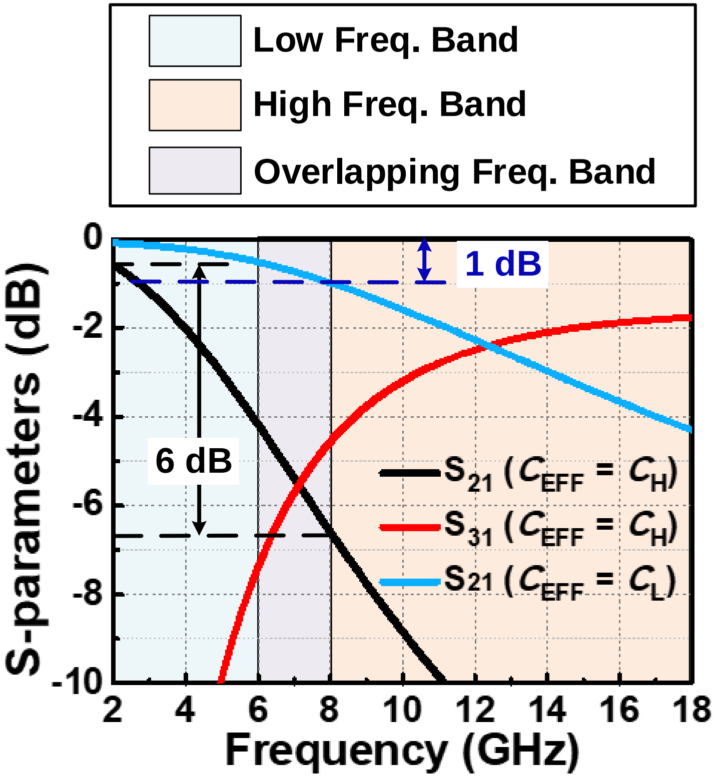


(b)

Circuit Design

■ The Proposed Reconfigurable Diplexer





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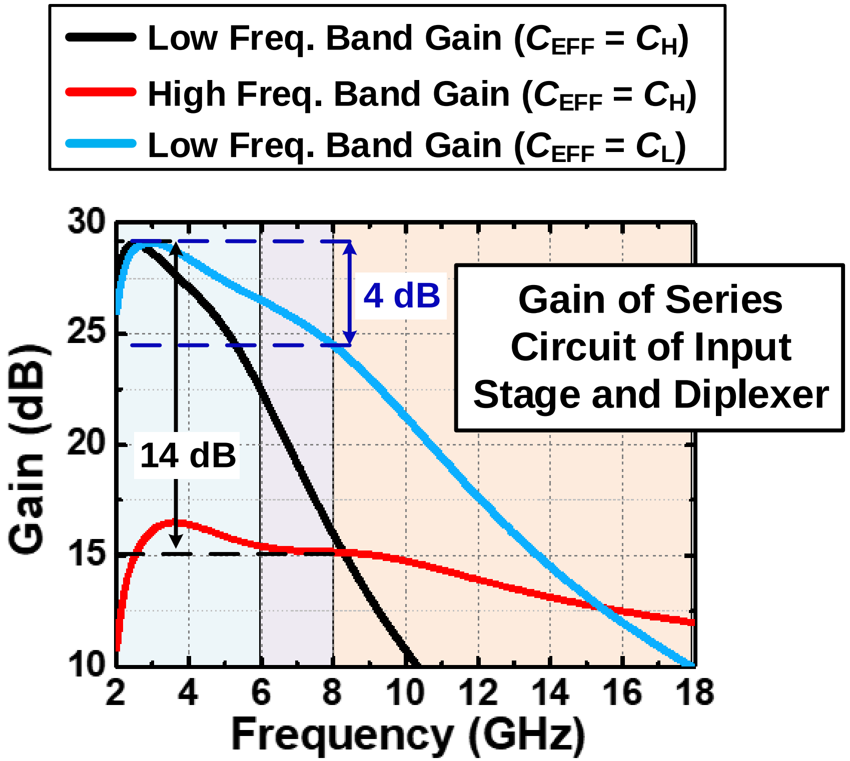
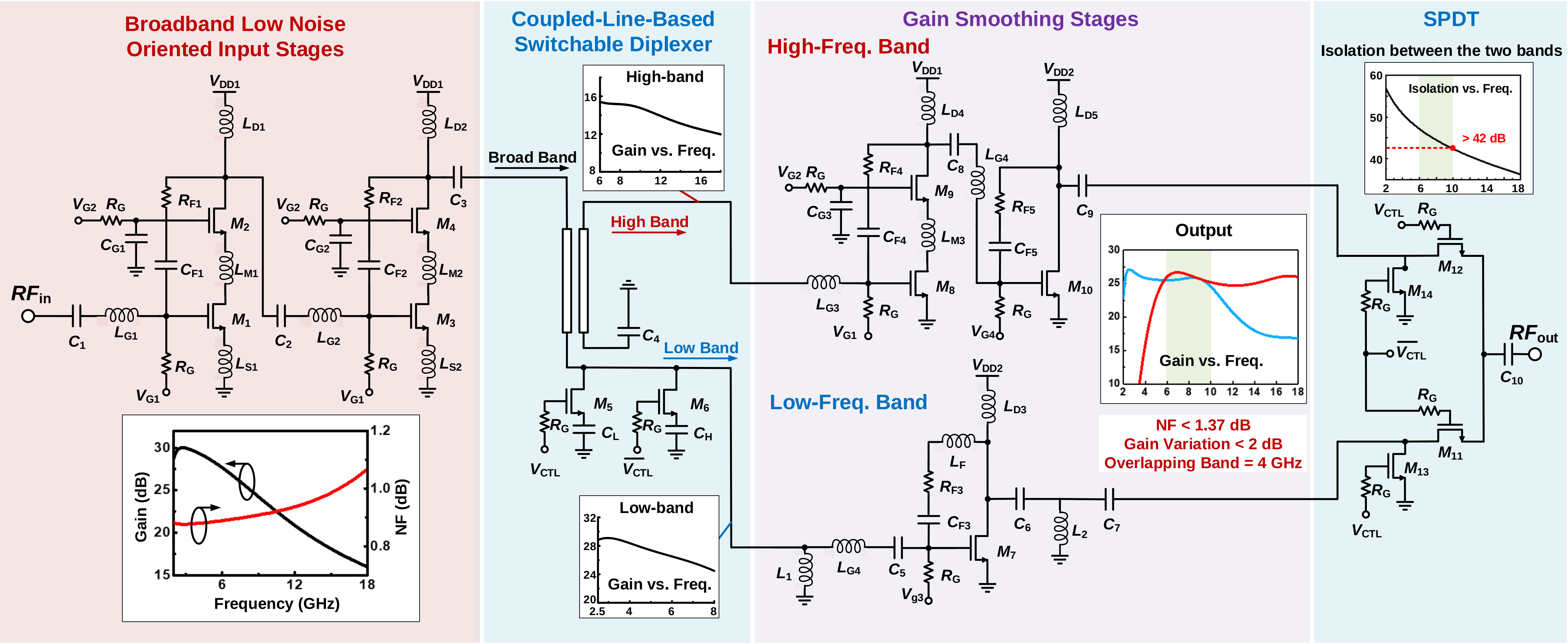


(b)

Circuit Design

■ The Proposed Reconfigurable LNA



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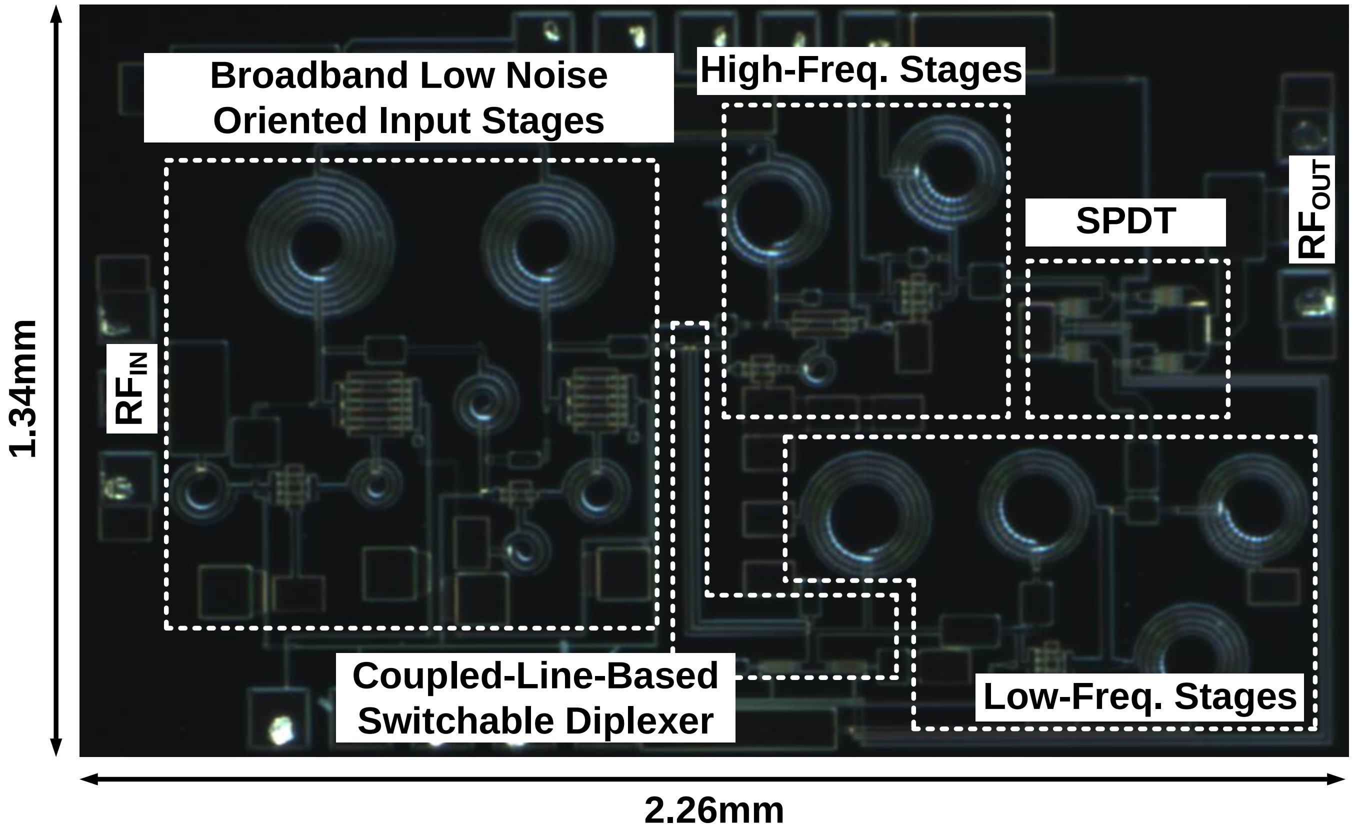
Measurement

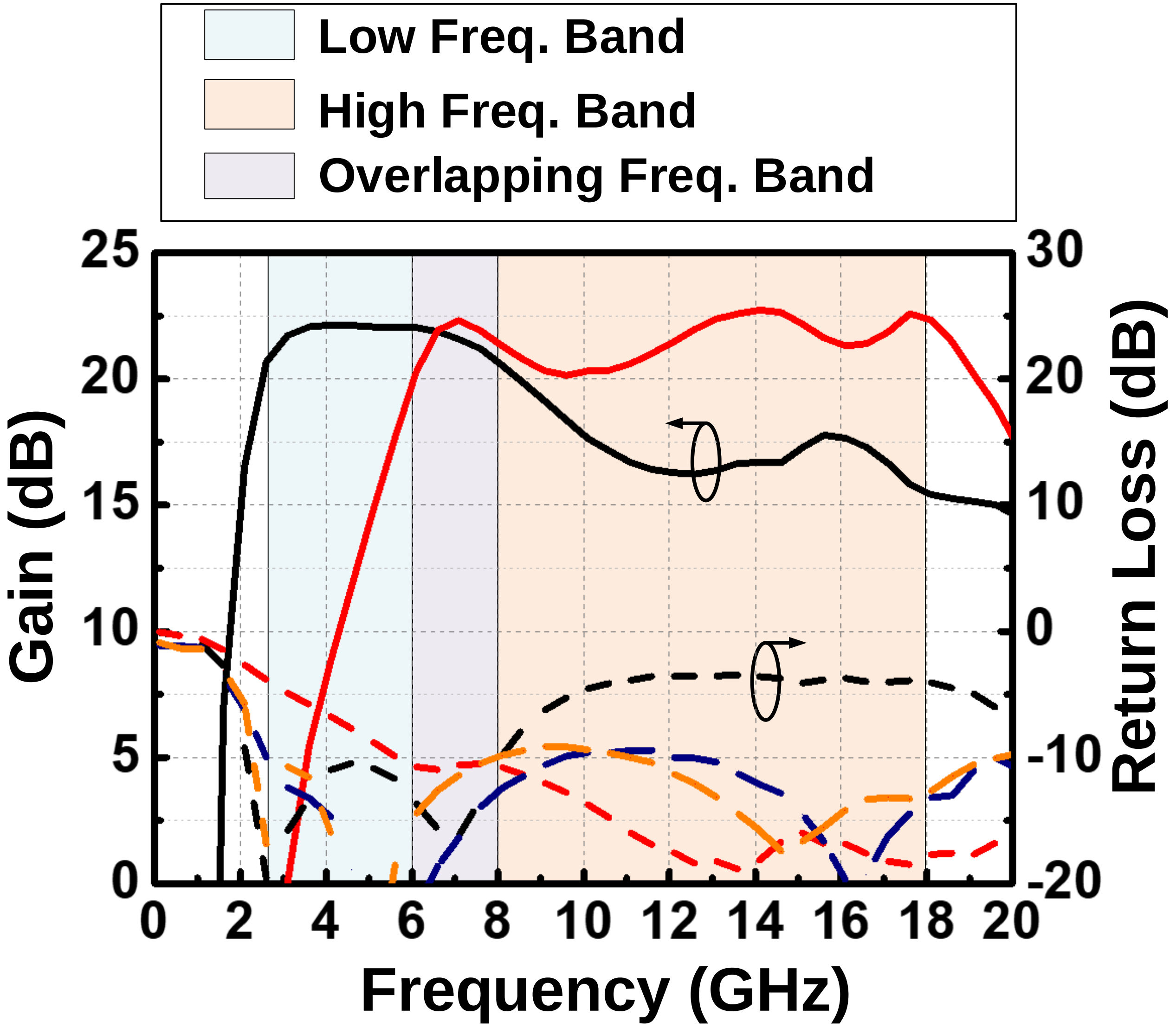
- Die micrograph
  - Area with pads: 3 mm^2
  - 0.15 μm GaAs pHEMT
  - f_t = 115 GHz



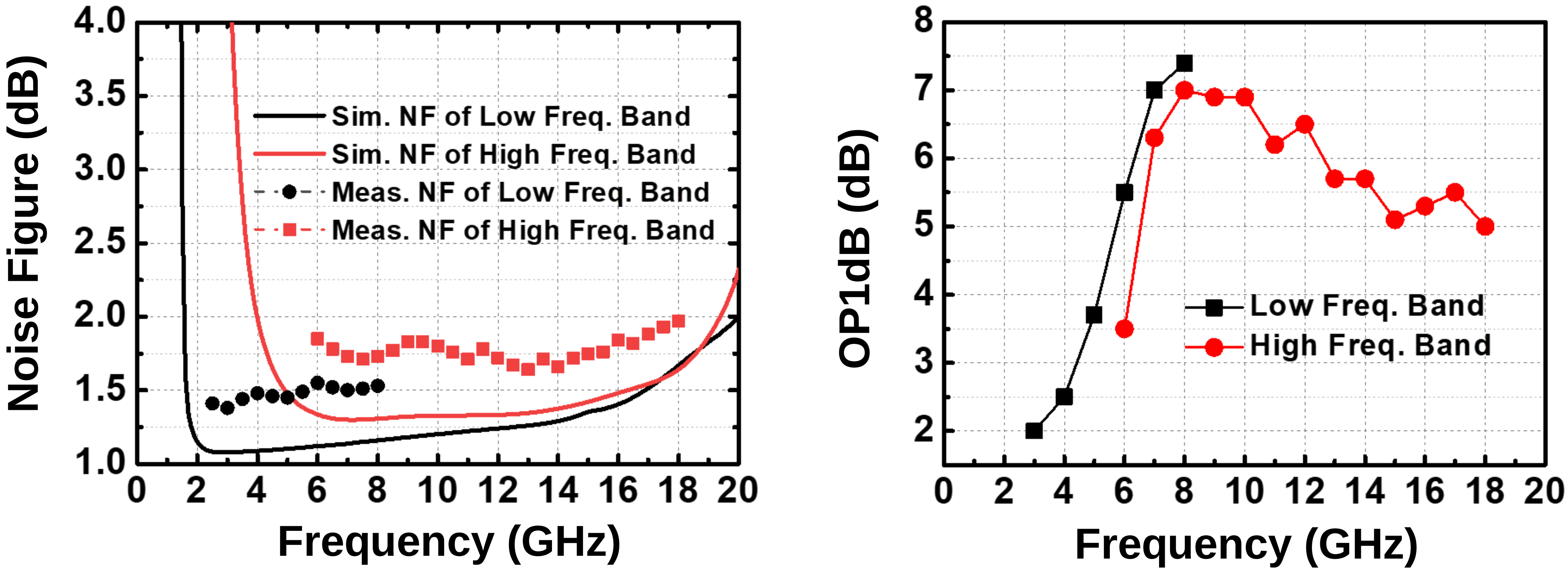
Measurement

- Low-Band Mode
  - Frequency: 2.5–8 GHz
  - Gain (S21): 20.3–22.1 dB
  - Input RL (S11): >10 dB
  - Output RL (S22): >10 dB

- High-Band Mode
  - Frequency: 12–18 GHz
  - Gain (S21): 20.2–22.7 dB
  - Input RL (S11): >9.1 dB
  - Output RL (S22): >10 dB



Measurement



- **Low-Band Mode**
  - NF: 1.38 –1.53 dB
  - OP1dB: 2–7.4 dB
- **High-Band Mode**
  - NF: 1.64 –1.97 dB
  - OP1dB: 3.5–7.2 dB

Comparison

Table 1. Comparisons to the state-of-arts

	Freq. (GHz)	Bandwidth (GHz)	Overlapping Bandwidth (GHz)	Gain (dB)	Gain Variation (dB)	NF (dB)	RL (dB)	P_{DC} (mW)	Area (mm^2)	Tech.
This work	**2.5–8**	**5.5**	**2**	**20.3–22.1**	**<2.5**	**1.38–1.53**	**>9*, >10**	**128.4**	**3**	**0.15µm GaAs pHEMT**
	6–18	**12**		**20.2–22.7**		**1.64–1.97**		**237.2**		
[6]	8–10	2	0	25–25.2	<7.9	1.28–1.41	>10	190	3.6	0.15µm GaAs pHEMT
	12–20	8		20.1–28		1.23–1.51		227.5		
[2]	0.1–20	19.9	–	27.4–29.8	<2.4	3.1–5.8	>10	505	1.53	0.15µm GaAs pHEMT
[7]	0.1–23	22.9	–	25.9–28.9	<3	2.7–4	>5**	336	1.36	0.15µm GaAs pHEMT
[8]	3.2–14.7	11.5	–	34	<3	1.3–2.5*	>5	45	2	0.15µm GaAs pHEMT

*Input Return Loss, **Read value from figures

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Conclusion

- A reconfigurable LNA with ultra-broad and very low-noise is presented and fabricated in a 0.15 μm GaAs technology;
- Using the proposed low-noise oriented input stage and switchable diplexer, the LNA solves the issues of emerging diplexer-based concepts and presents attractive performance .
- The measurement results show a 2.5~18 GHz, <1.97 dB NF, and <2.5 dB Gain Variation.
- It is believed to be useful for ultra-wideband applications.

Summary

Thank You !