

TH1A-2

Independently Tunable Compact Dual-Band Bandpass Filter With High Selectivity and Wide Stopband Using Multilayer Folded Dual-Mode SIDGS Resonator

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Introduction

Tunable Dual-Band Bandpass Filter

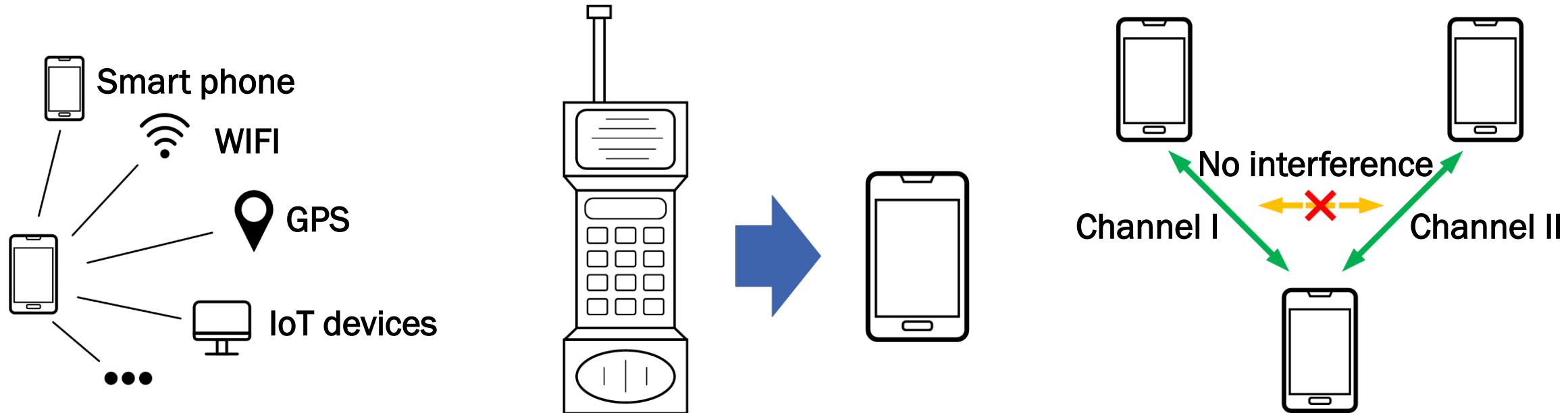
Multilayer Folded SIDGS Resonator

Filter Design

Measurement & Comparison

Conclusion

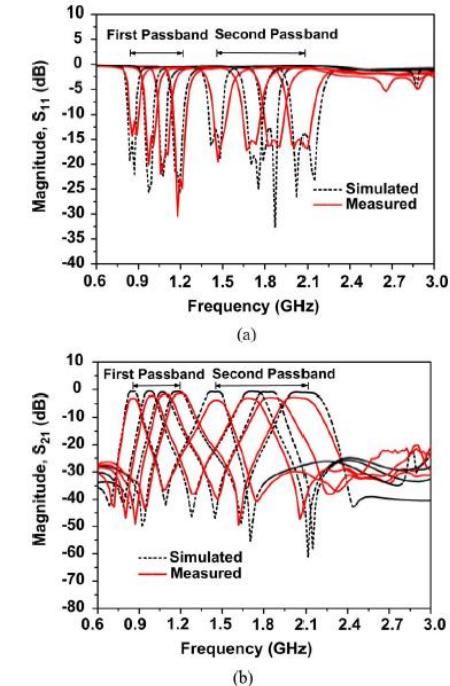
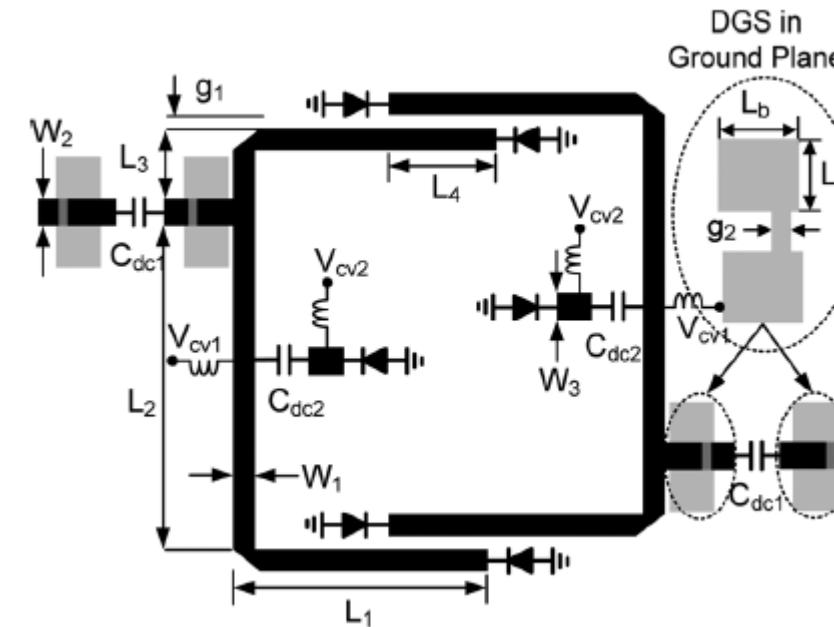
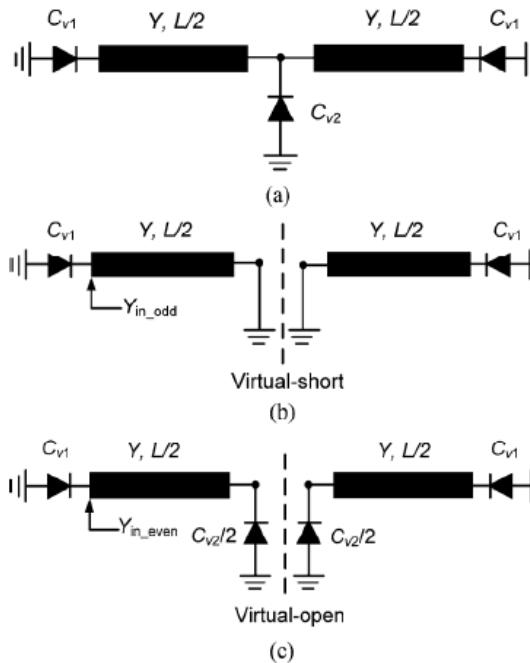
- Future wireless system
 - Multi-channel wireless system
 - Compact for integration
 - No interference between channels



Introduction

- Dual-Band Bandpass Filters With Tunable Passbands

- 😊 Wide stopband
- 😊 Not independently tunable
- 😊 Wide tuning range

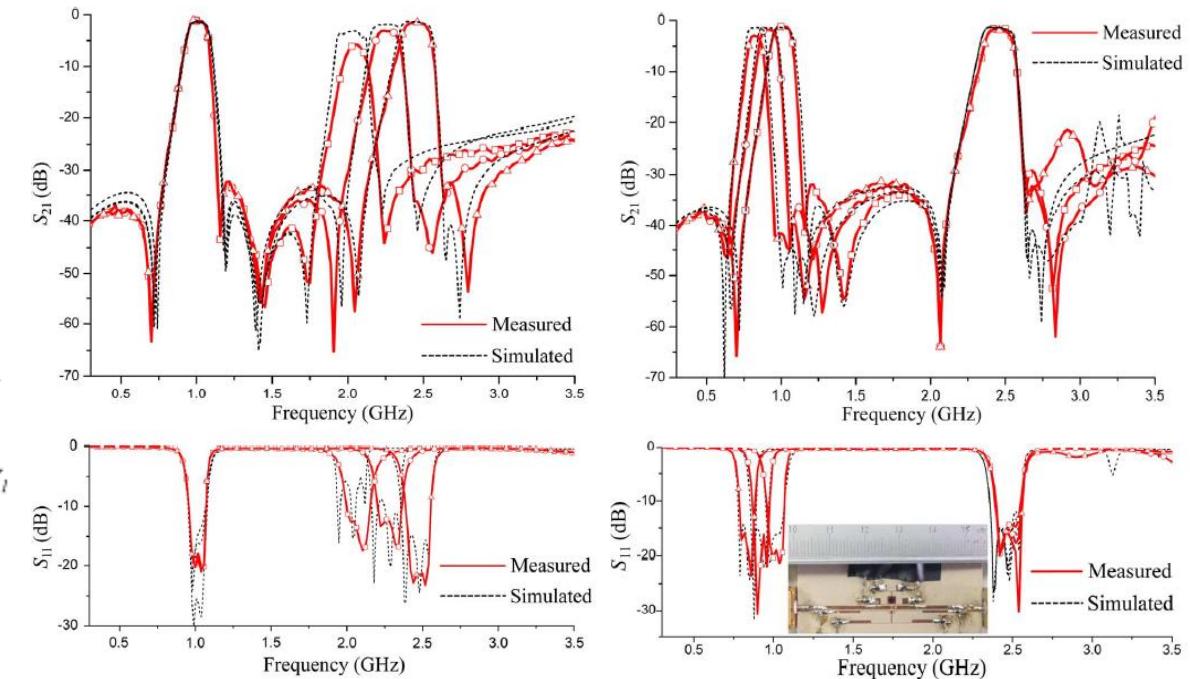
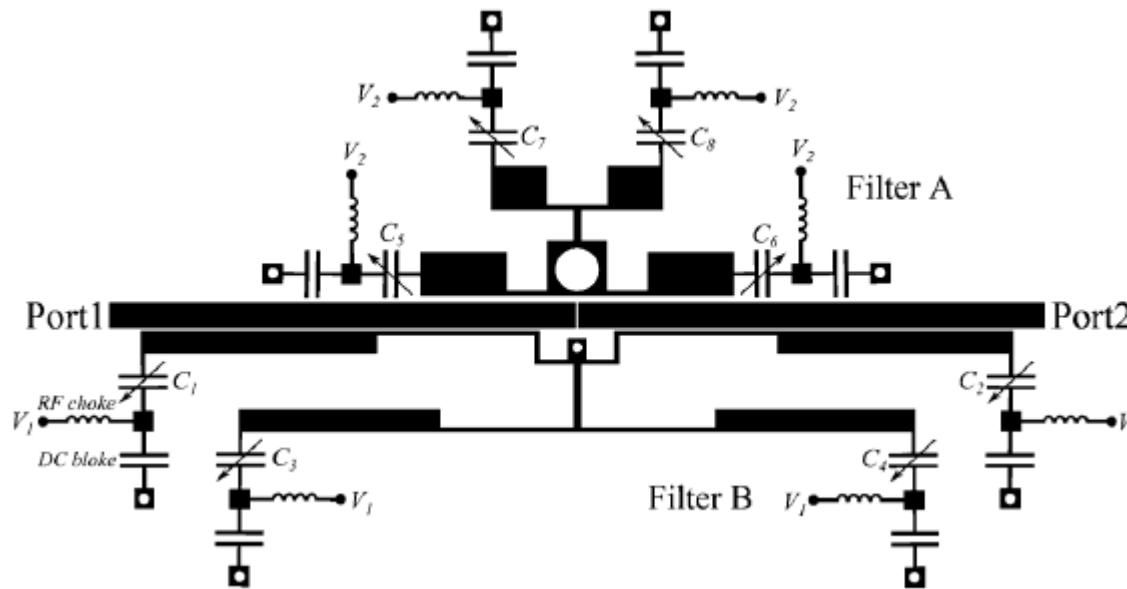


[1] G. Chaudhary, Y. Jeong, and J. Lim, "Harmonic suppressed dual-band bandpass filters with tunable passbands," *IEEE Trans. Microw. Theory Techn.*, vol.60, no. 7, pp. 2115–2123, Jul. 2012.

Introduction

- **Stub-Loaded Stepped-Impedance Resonators**

- 😊 High selectivity
- 😊 Relatively large size
- 😊 Independent tuning

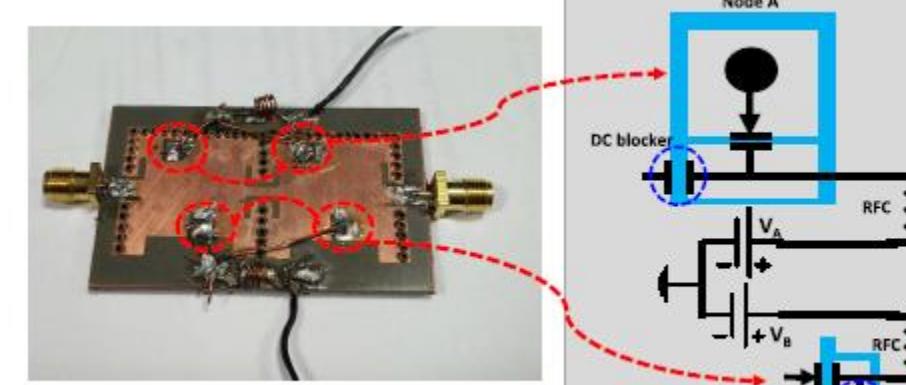
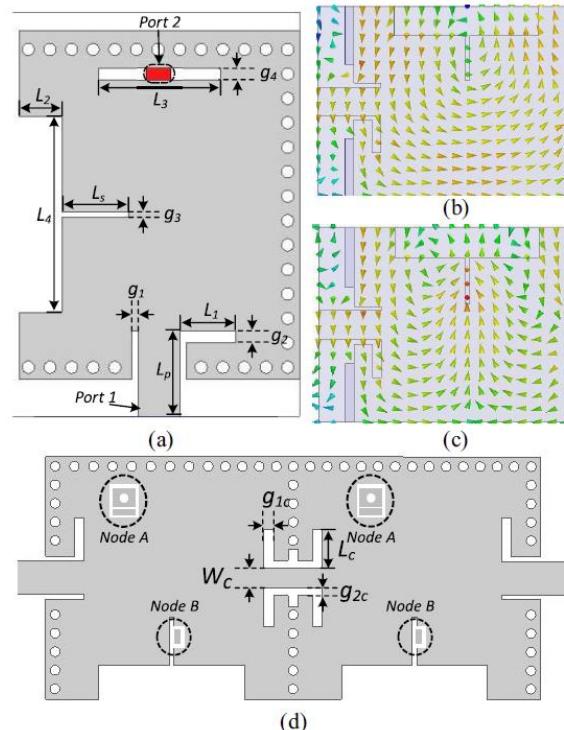


[2] B. You, L. Chen, Y. Liang, and X. Wen, "A high-selectivity tunable dual-band bandpass filter using stub-loaded stepped-impedance resonators," IEEE Microw. Wireless Compon. Lett., vol. 24, no. 11, pp. 736–738, Nov. 2014.

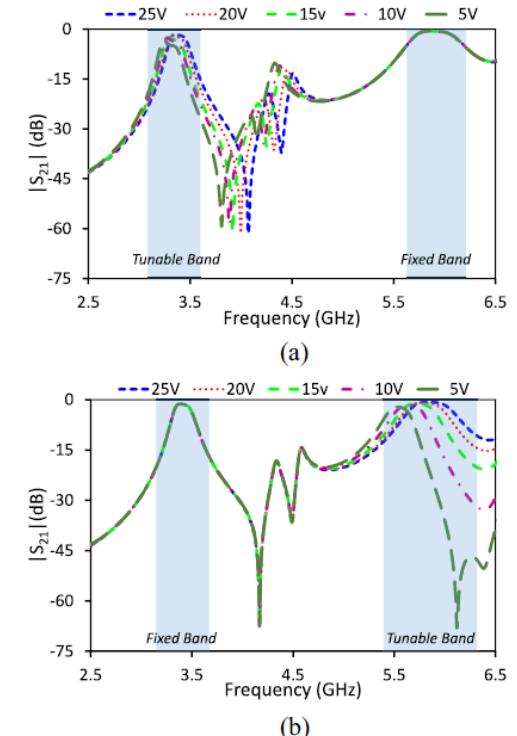
Introduction

• Half Mode Substrate Integrated Waveguide Filter

- 😊 Low insertion loss
- 😊 Independent tuning



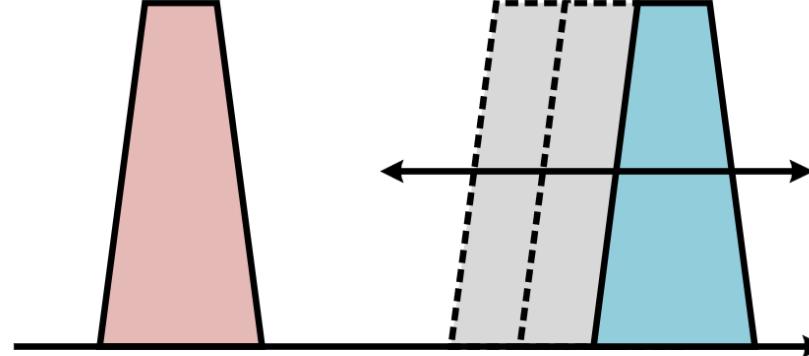
- 😦 Relatively large size



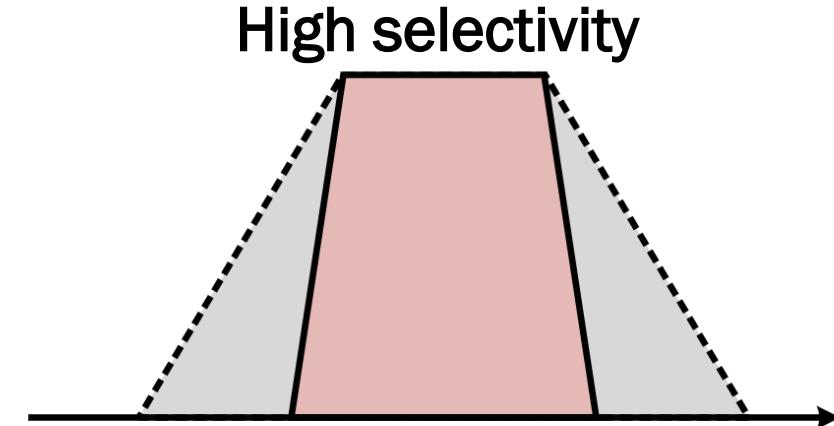
[3] A. Iqbal, J. J. Tiang, C. K. Lee, N. K. Mallat, and S. W. Wong, "Dual-band half mode substrate integrated waveguide filter with independently tunable bands," *IEEE Trans. Circuits Syst. II, Exp. Briefs*, vol. 67, no. 2, pp. 285–289, Feb. 2020.

Introduction

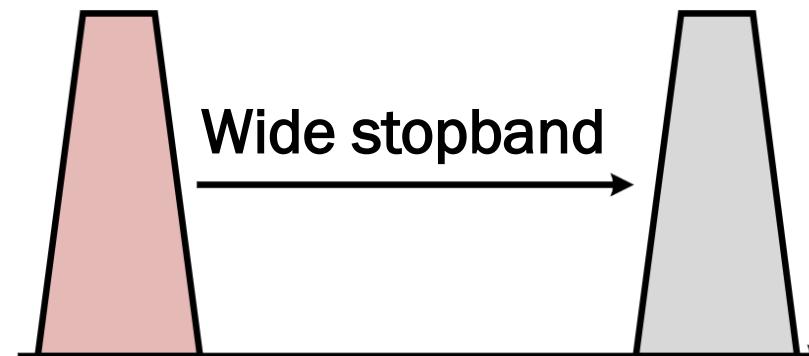
- Challenges



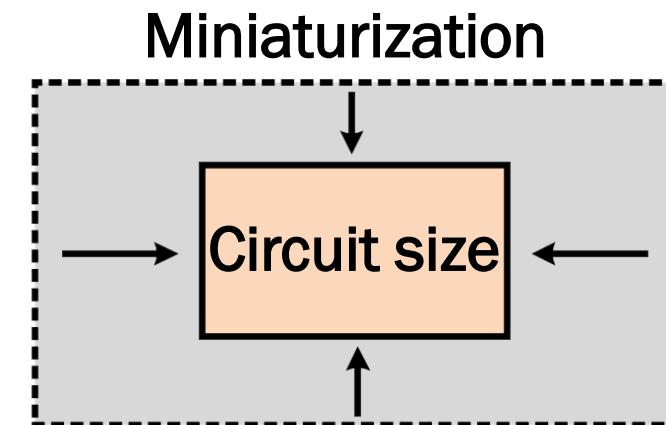
Independent tuning



High selectivity



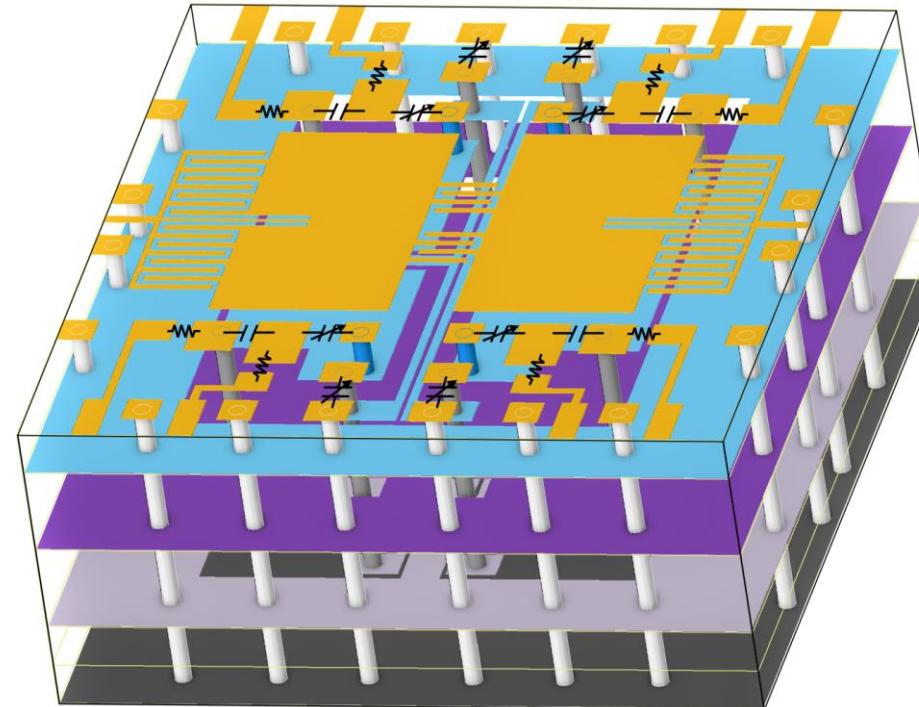
Wide stopband



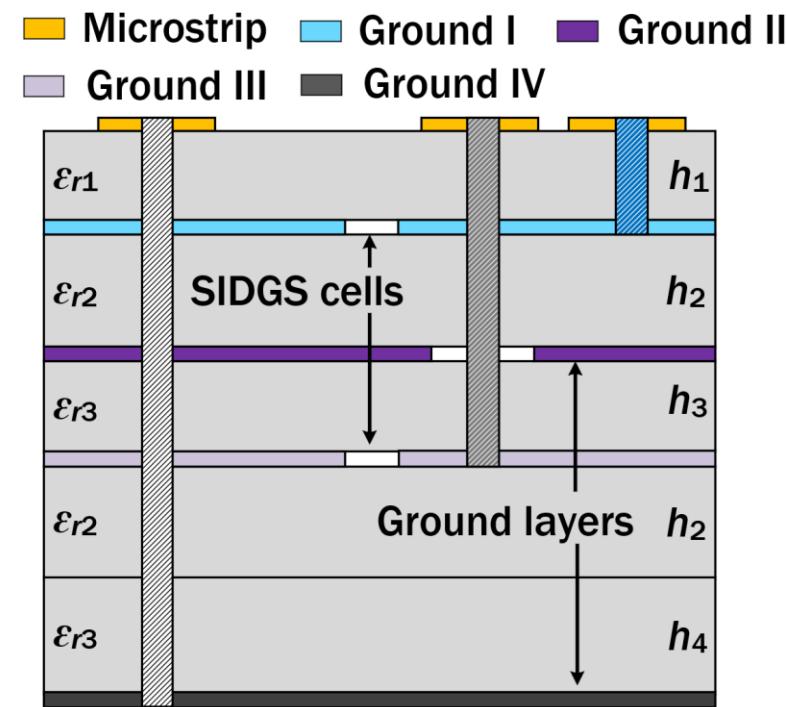
Miniaturization

Tunable Dual-Band BPF

- Independently tunable dual-band BPF using multilayer folded dual-mode SIDGS resonator
 - Two ground layers are employed for SIDGS implementation
 - SIDGS cells are implemented at Ground I and Ground III



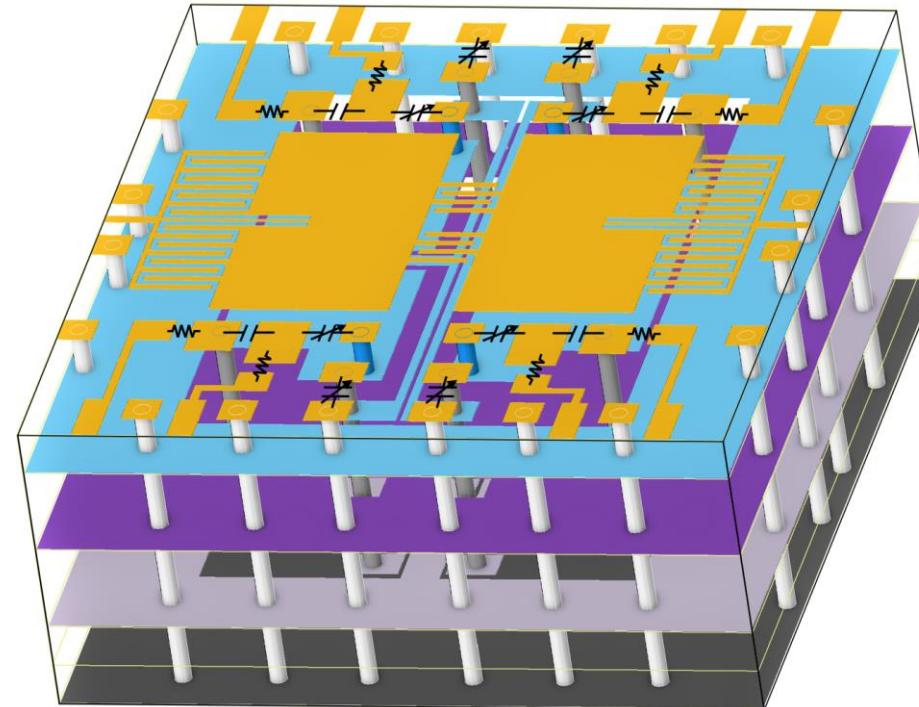
3-D view



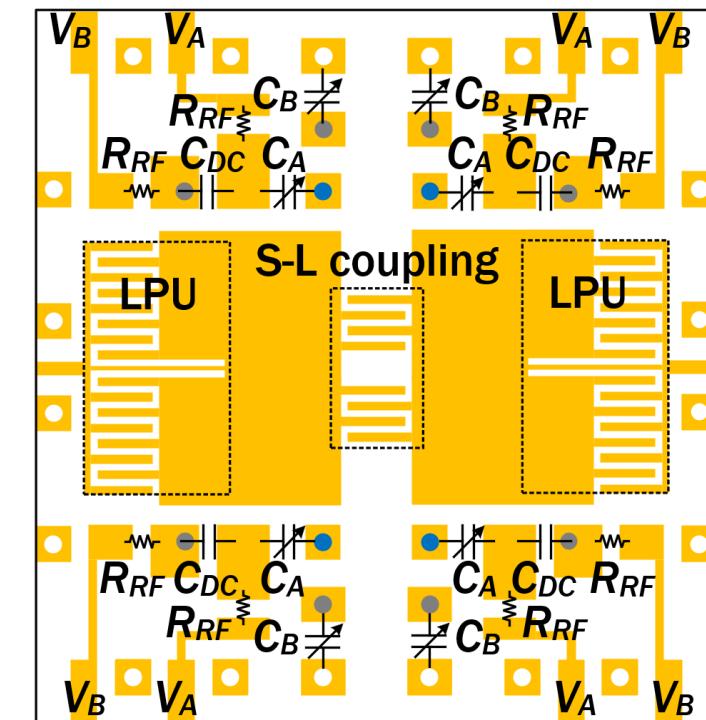
Layout diagram

Tunable Dual-Band BPF

- Independently tunable dual-band BPF using multilayer folded dual-mode SIDGS resonator
 - Two microstrip T-stubs act as feed-line with S-L coupling
 - Lowpass units (LPUs) are embedded in feed-lines



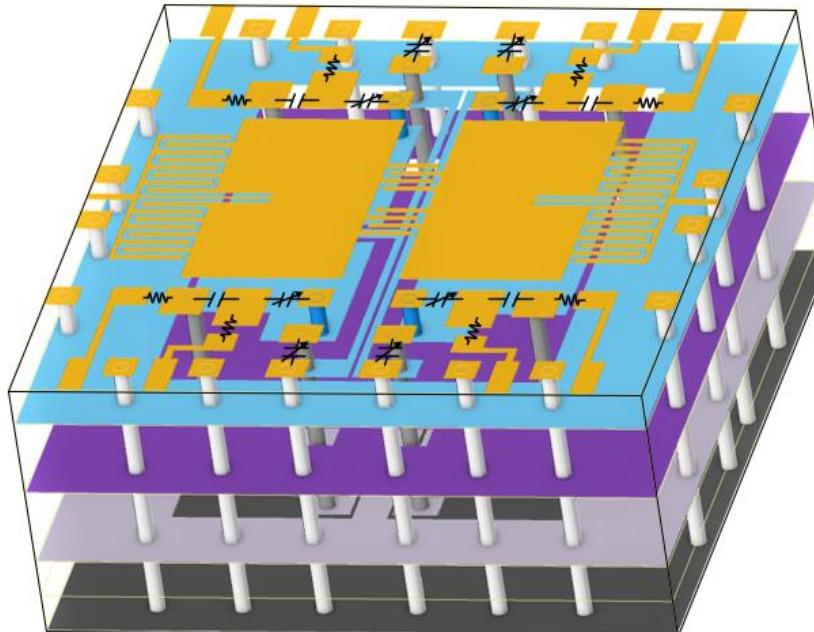
3-D view



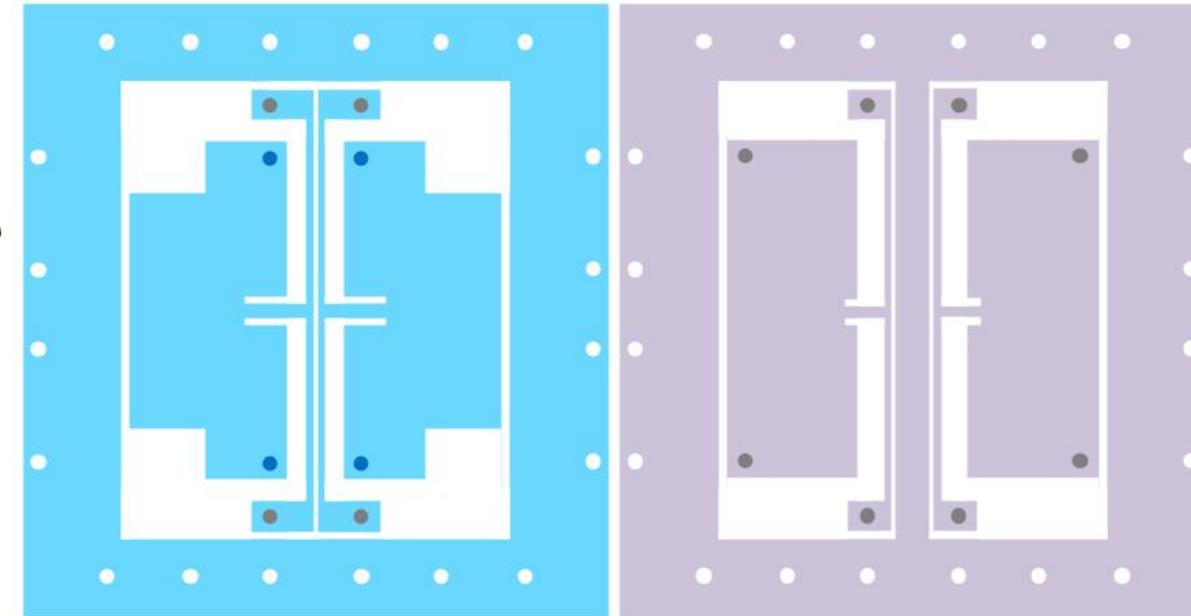
Detail of the top layer

Tunable Dual-Band BPF

- Independently tunable dual-band BPF using multilayer folded dual-mode SIDGS resonator
 - SIDGS cells are implemented at the second and the fourth layer
 - Two pairs of cells are connected by metal-vias to form two resonators

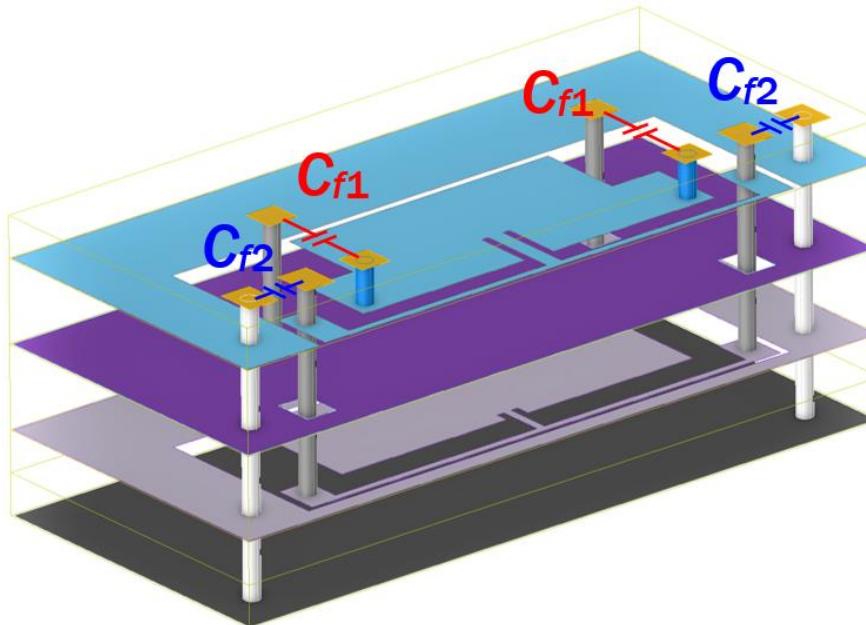


3-D view

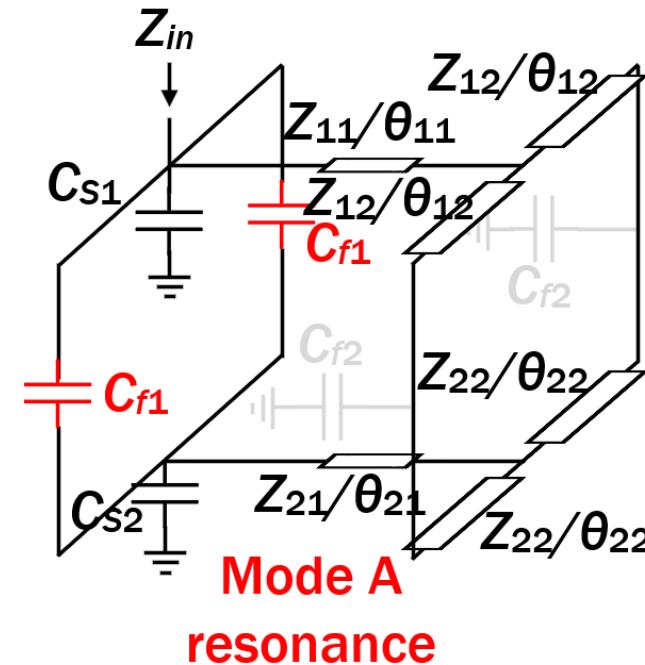


Detail of the second and the fourth layer

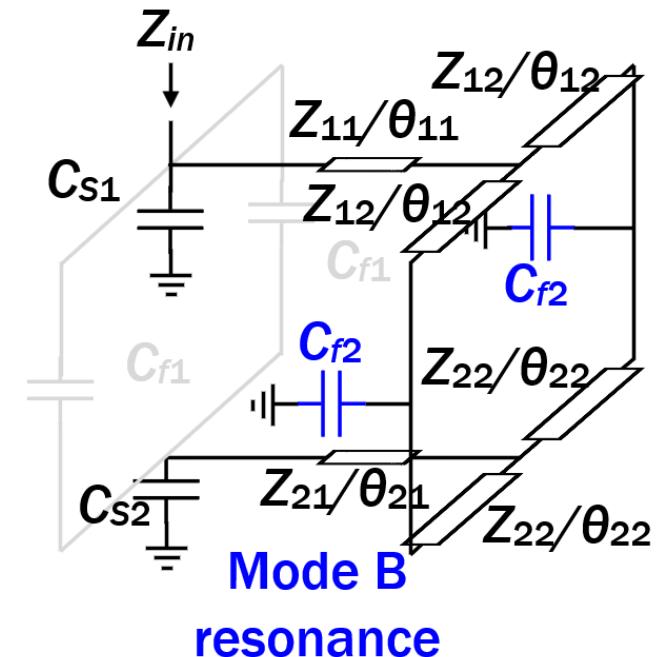
- SIDGS dual-mode resonator
 - Two independent resonance modes



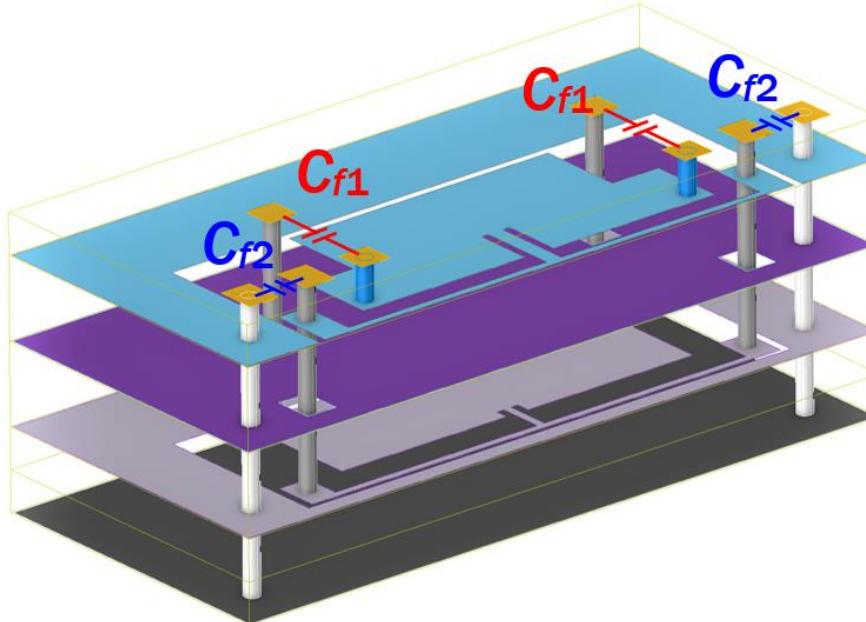
3-D view



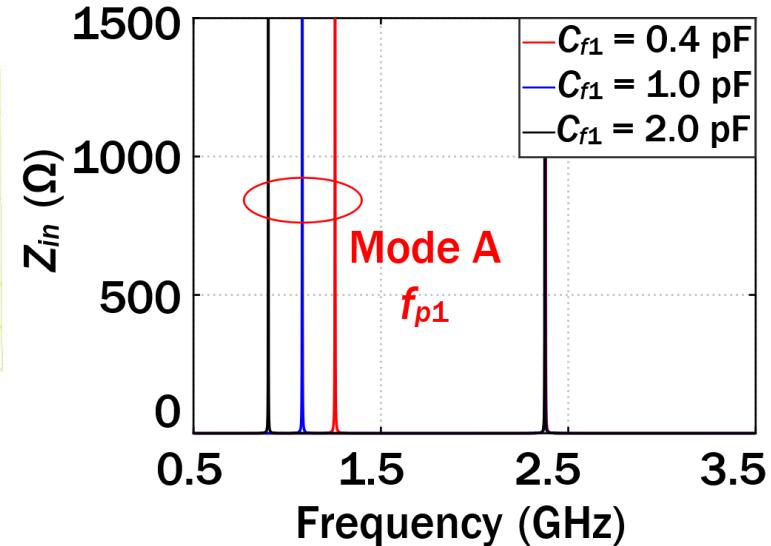
Simplified equivalent transmission model



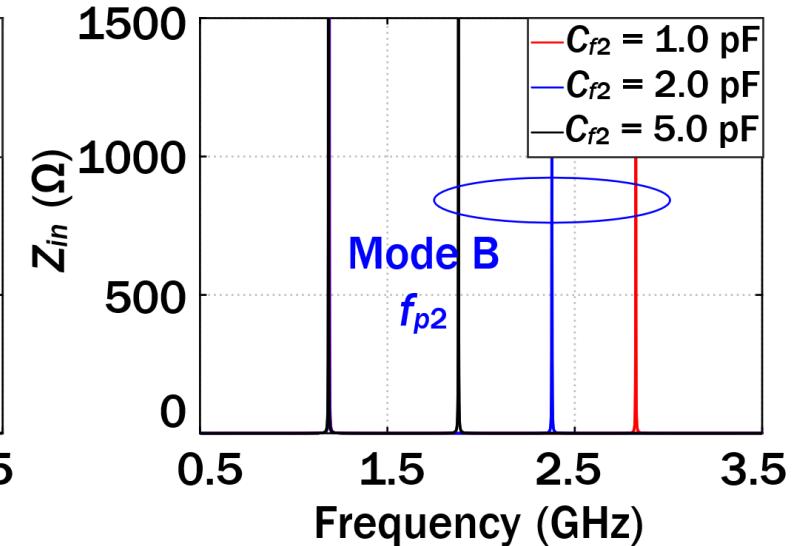
- SIDGS dual-mode resonator
 - f_p independently controlled by C_f



3-D view

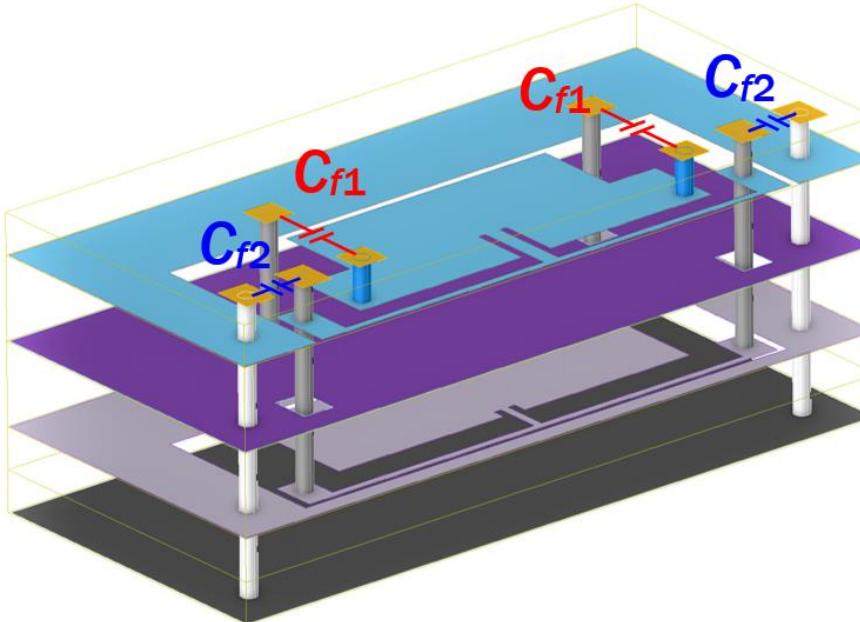


Simulated input-impedance

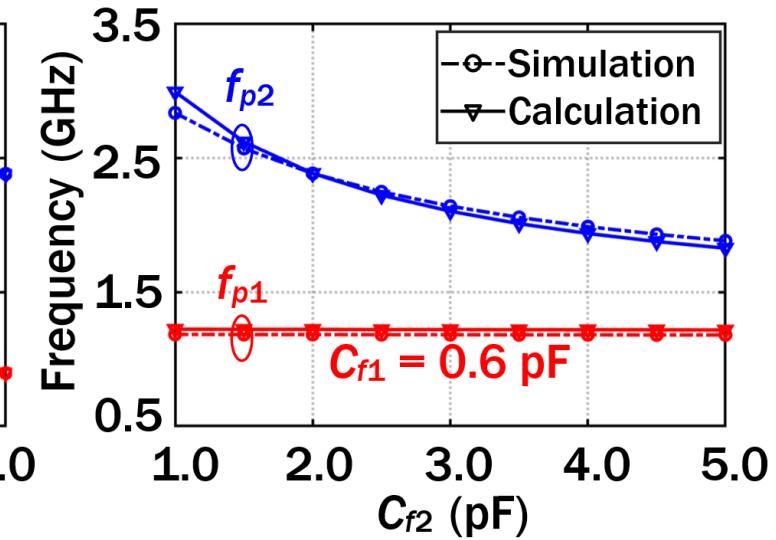
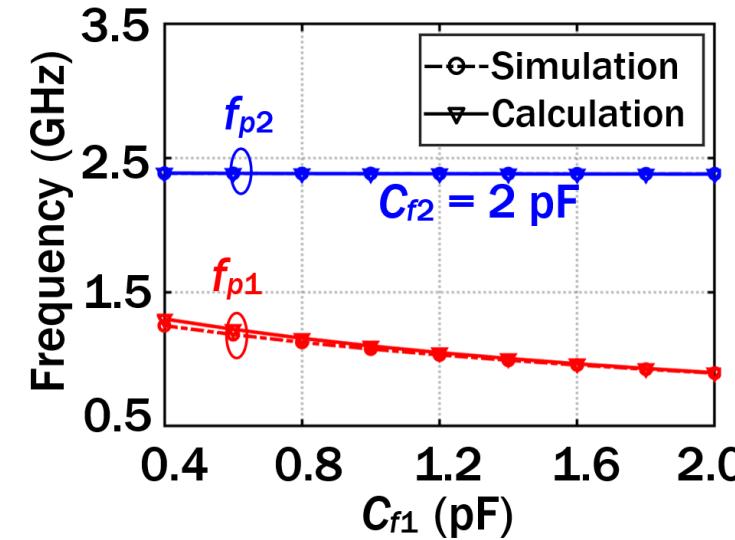


- SIDGS dual-mode resonator

- f_p can be tuned by C_f , $C_f \uparrow$, $f_p \downarrow$

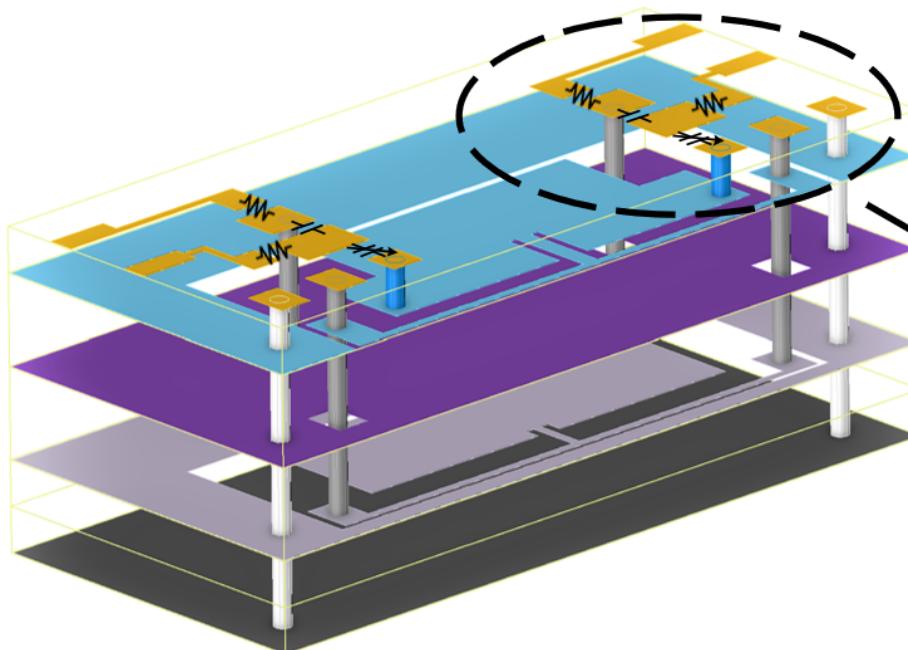


3-D view

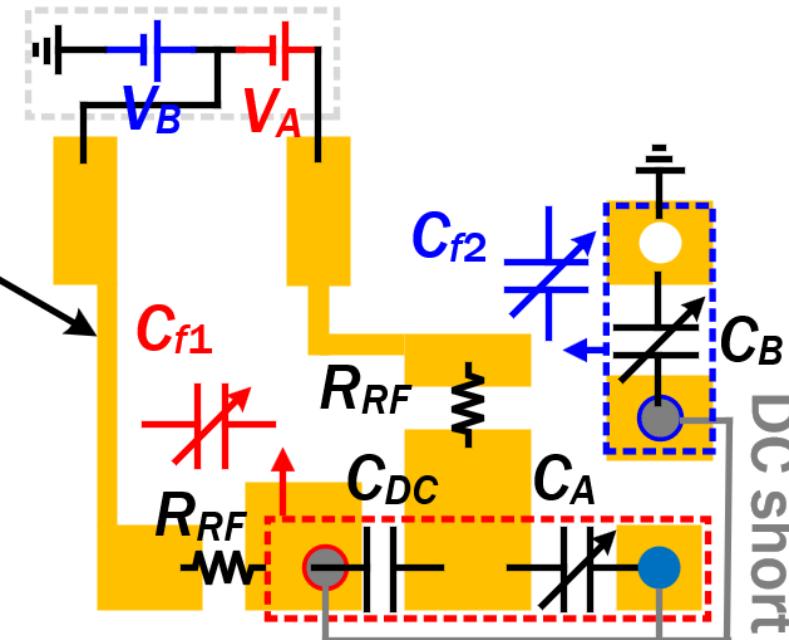


Frequency tuning

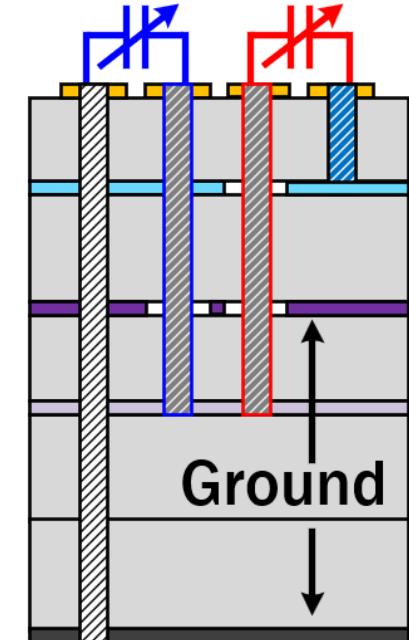
- SIDGS dual-mode resonator
 - Ideal C_f are replaced by varactors and corresponding DC bias circuits



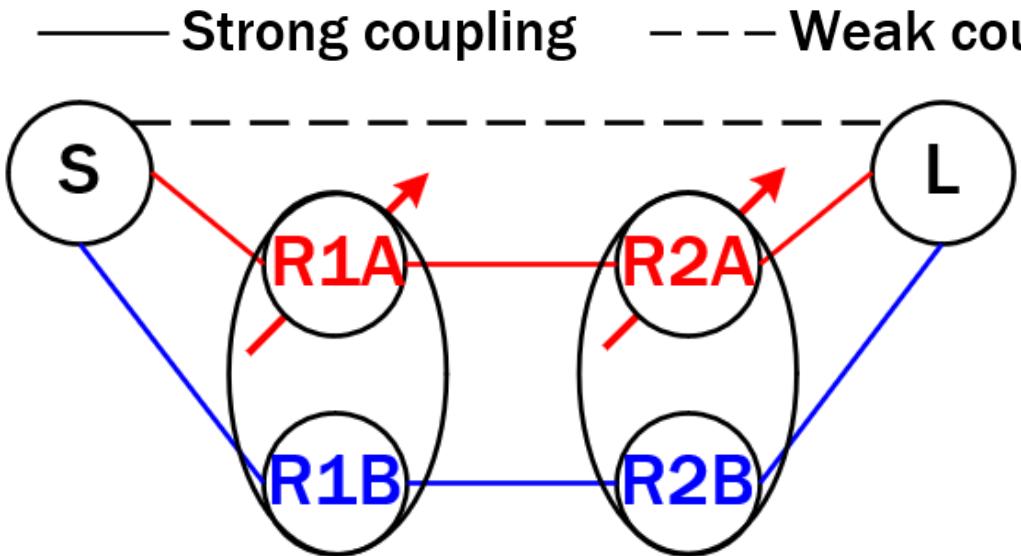
3-D view



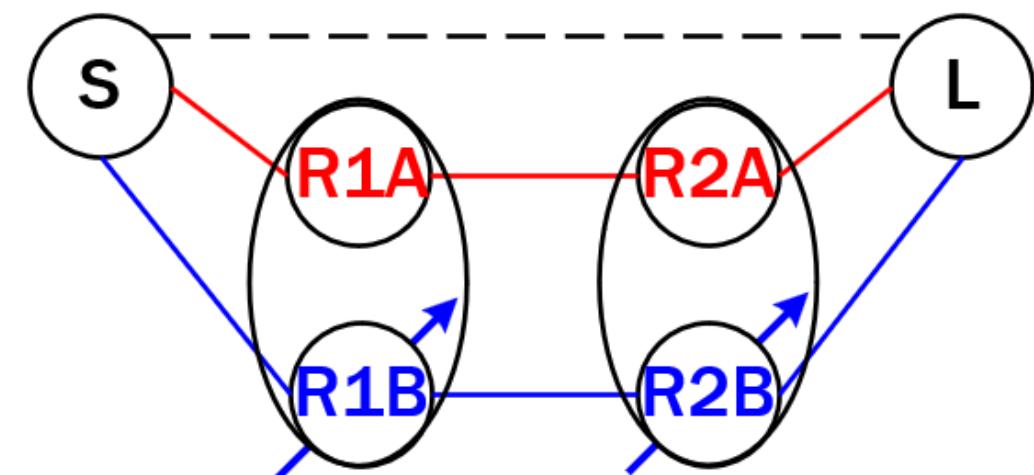
Details of frequency-tuning unit



- Passband
 - Coupling scheme



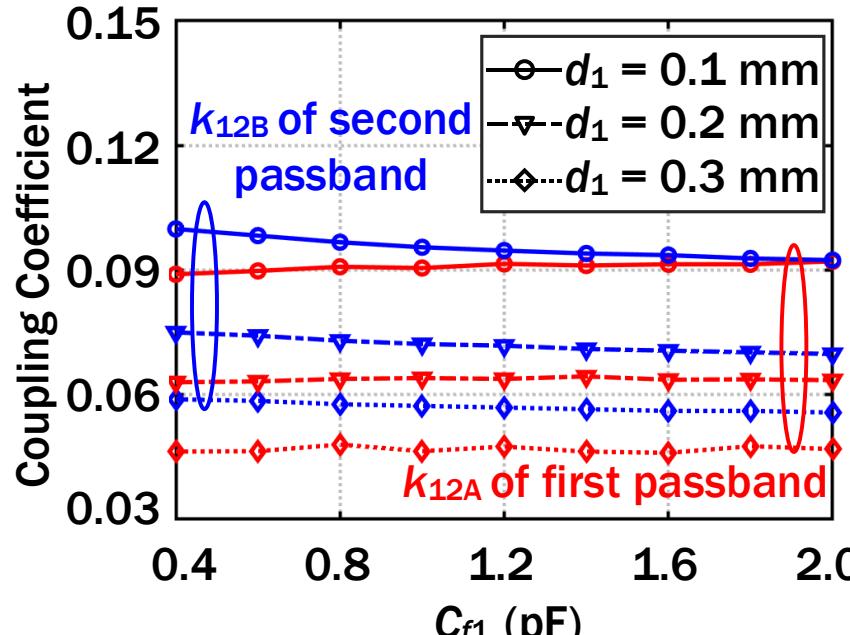
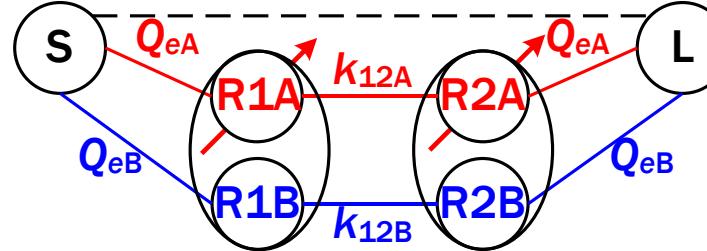
Tuning first passband



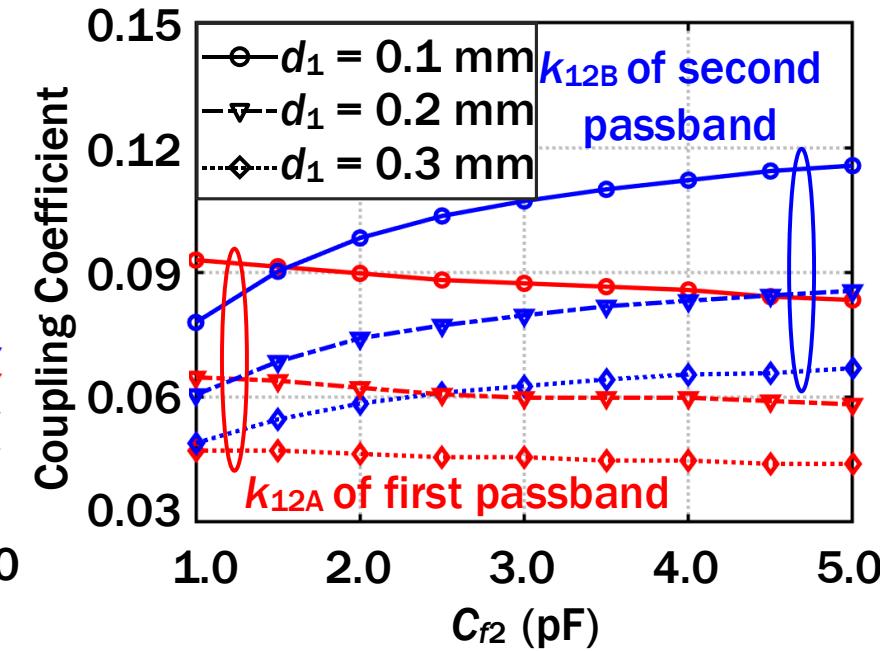
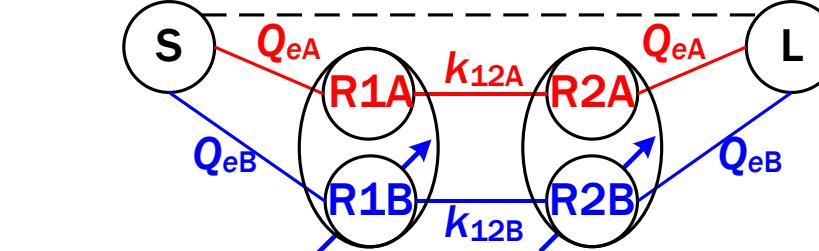
Tuning second passband

Filter Design

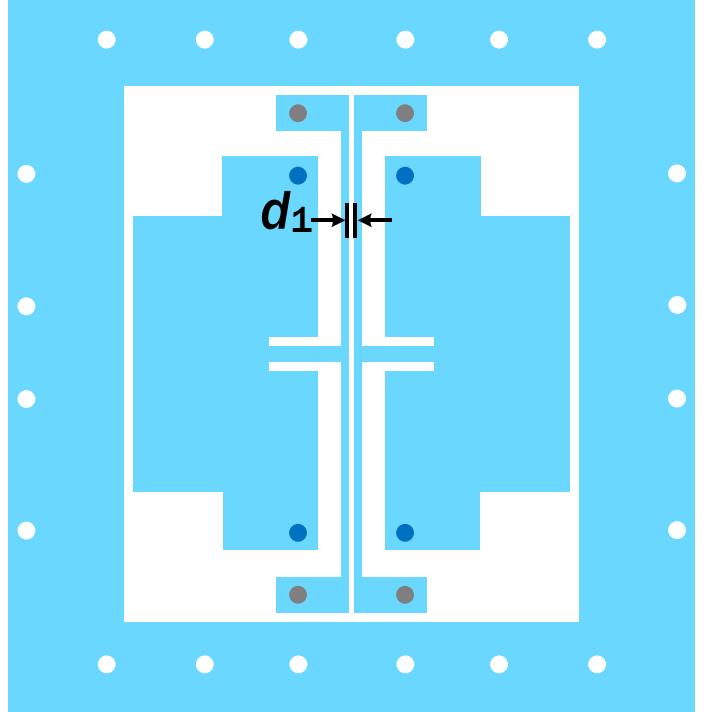
- Passband



Tuning first passband

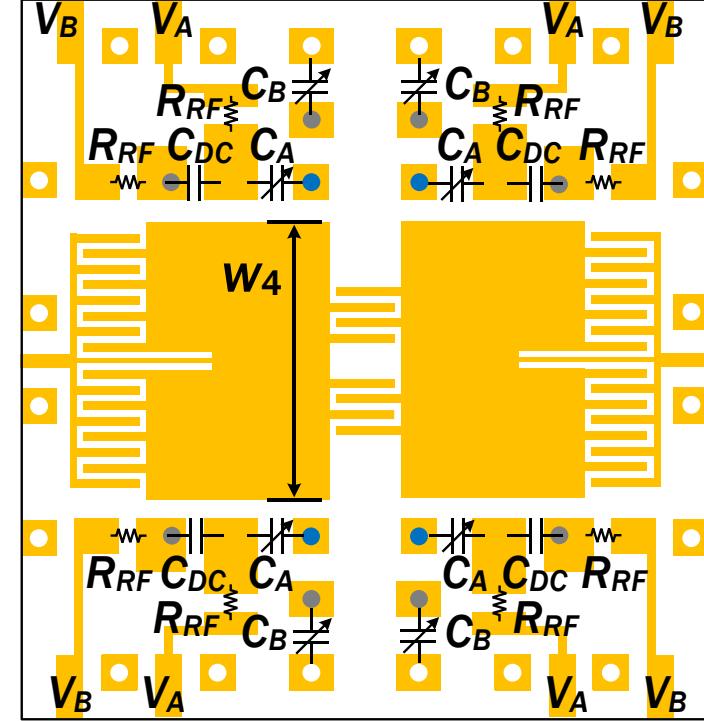
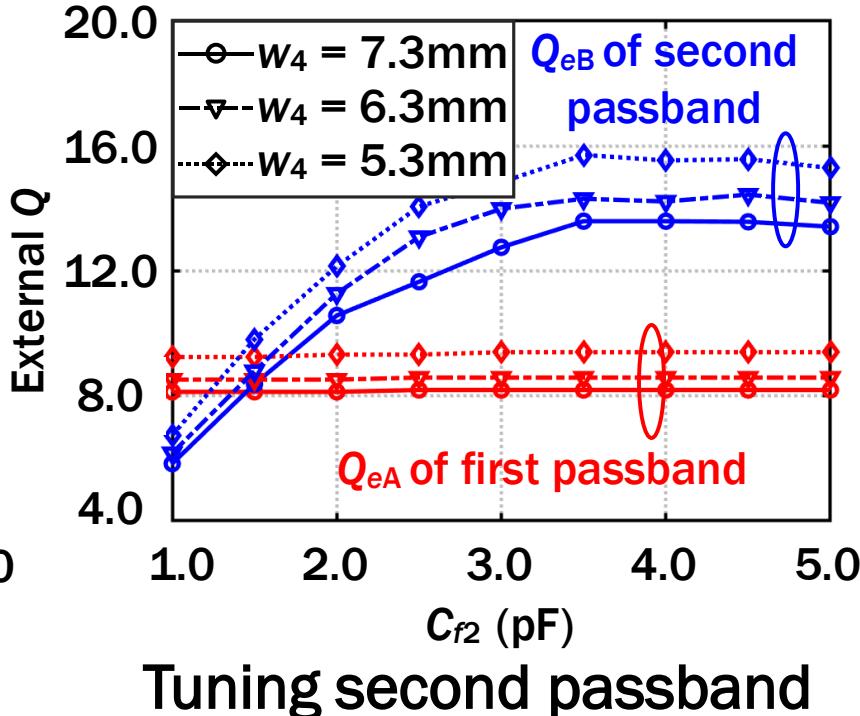
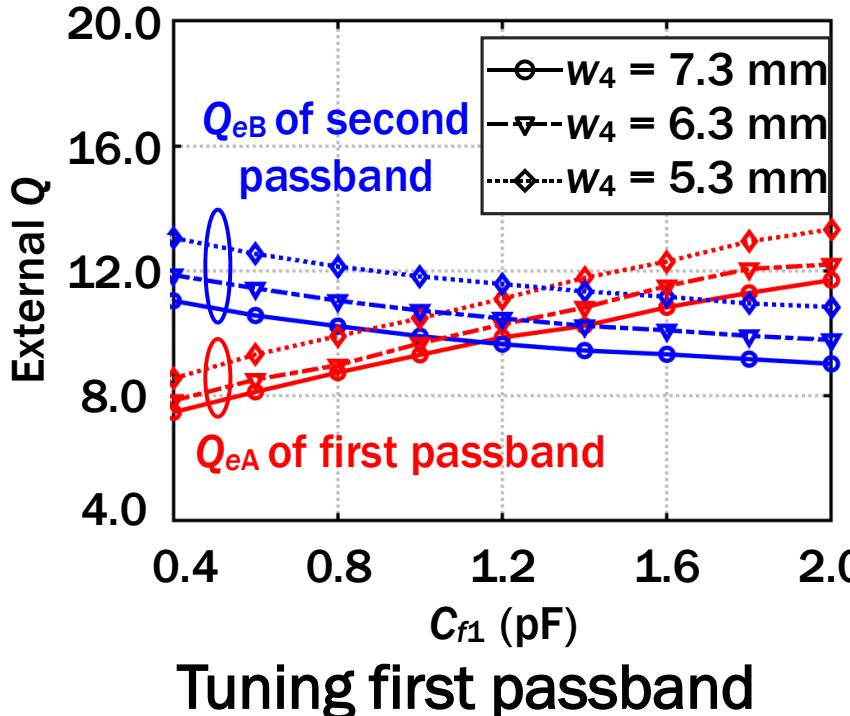
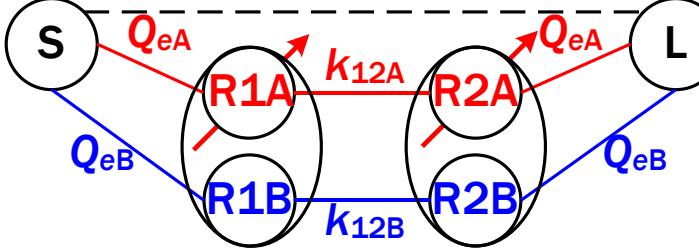


Tuning second passband



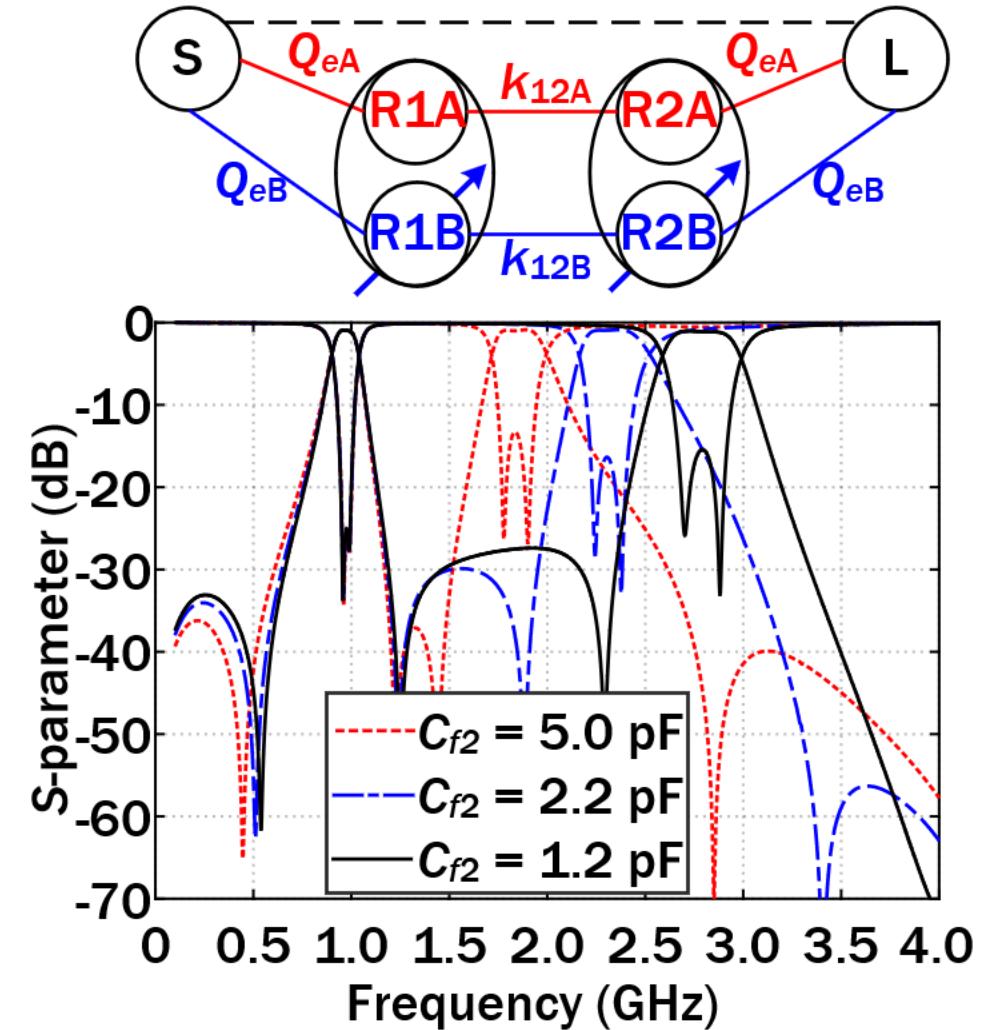
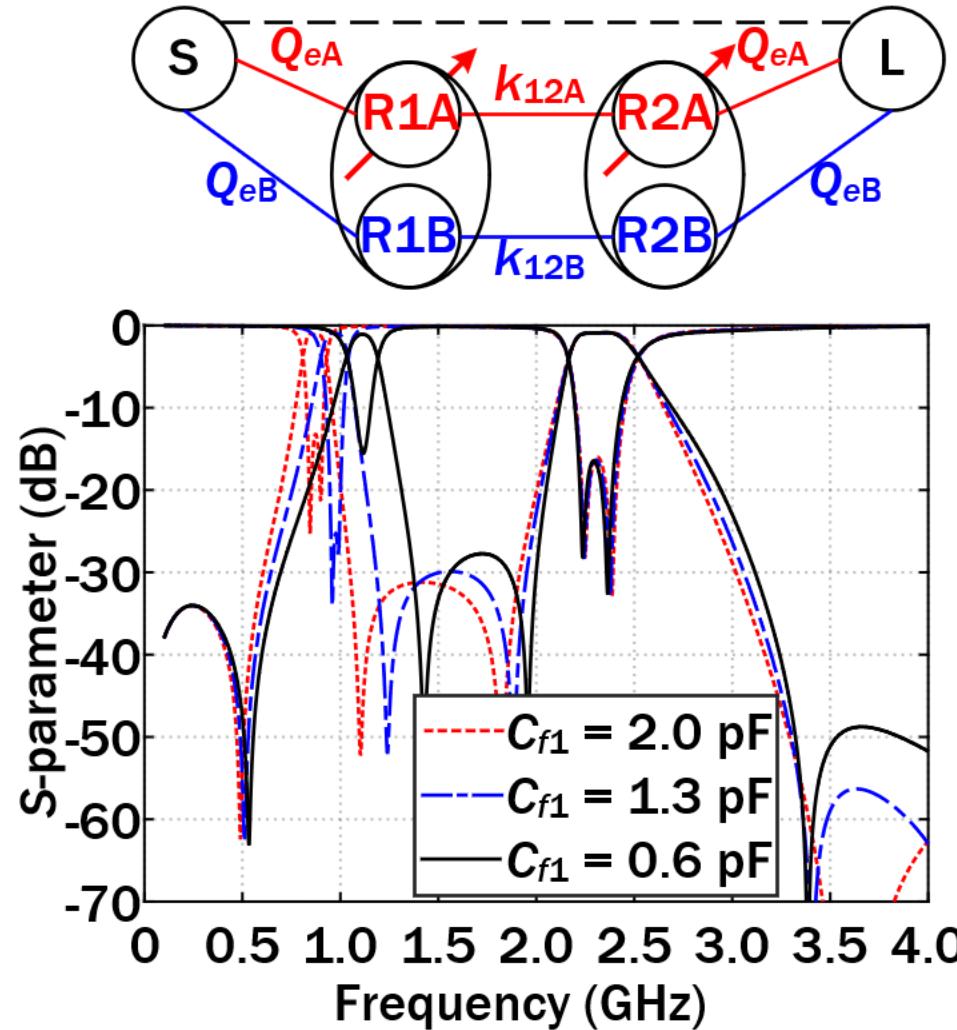
Filter Design

- Passband



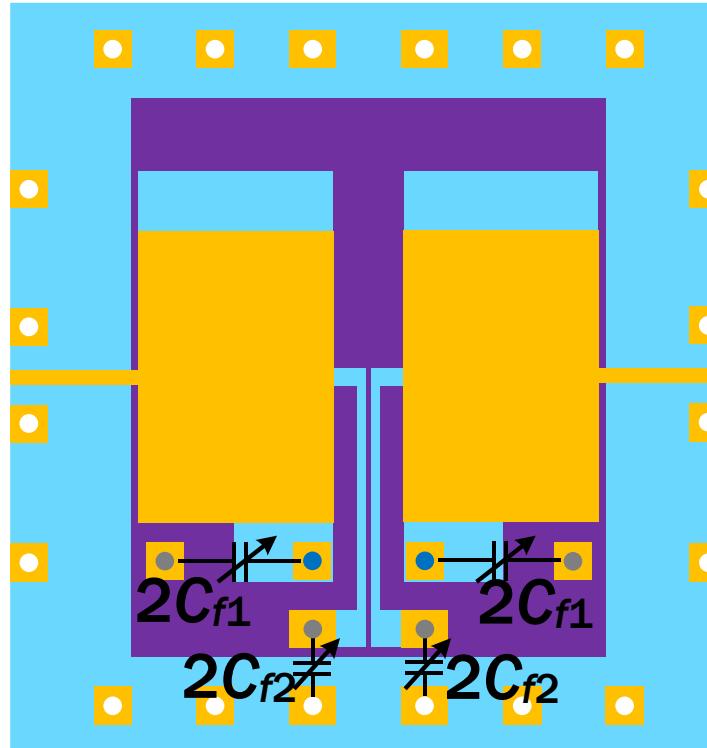
Filter Design

- Passband

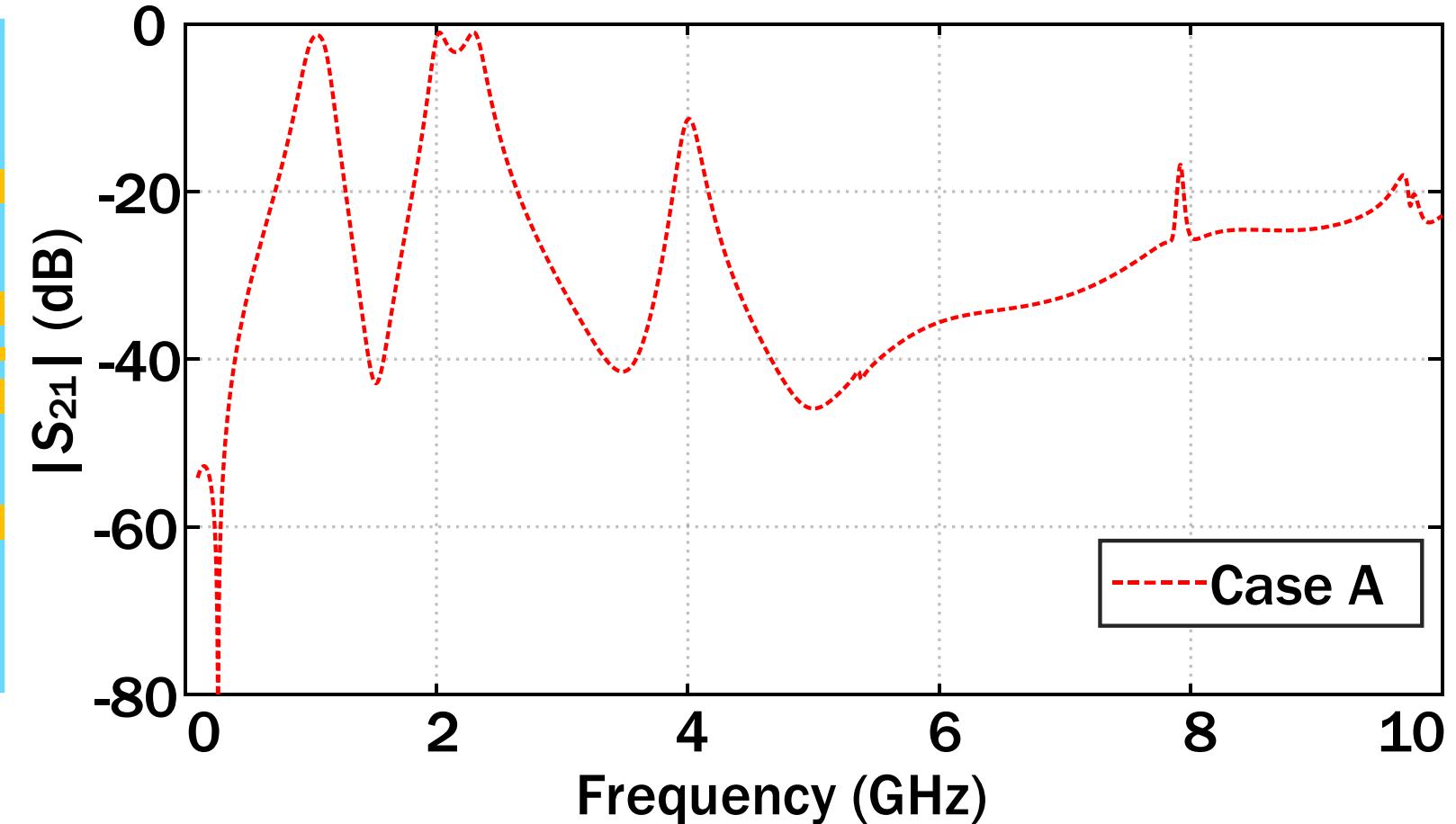


Filter Design

- Stopband

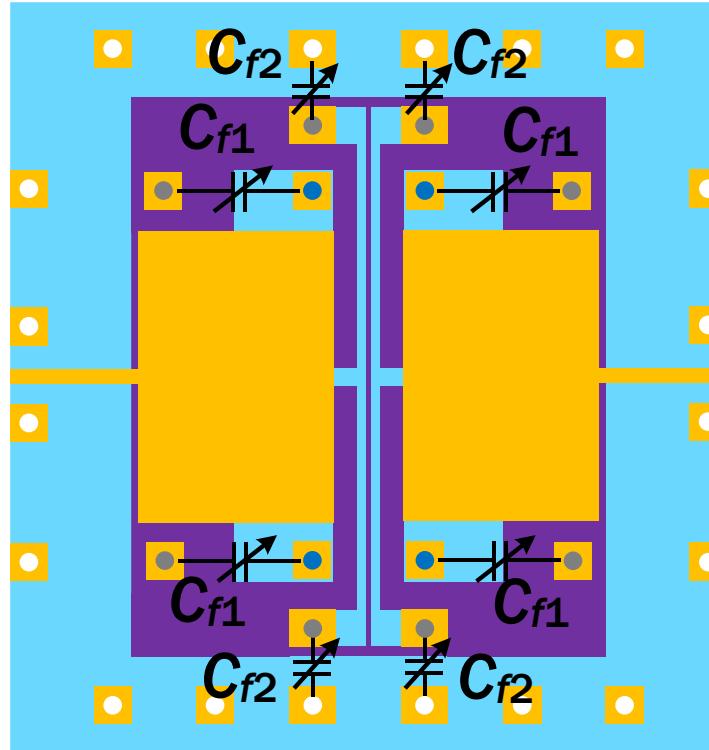


Case A

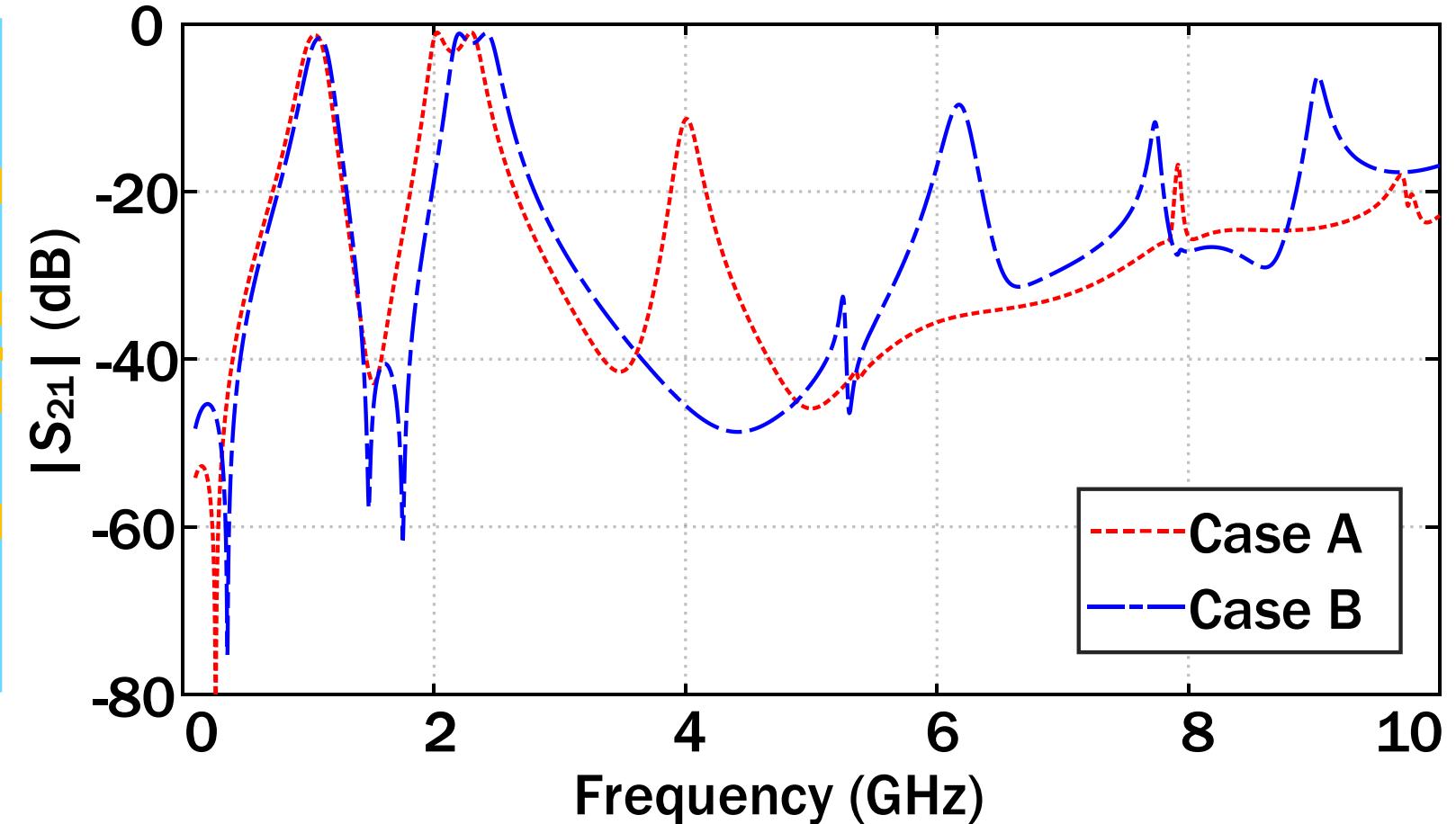


Filter Design

- Stopband

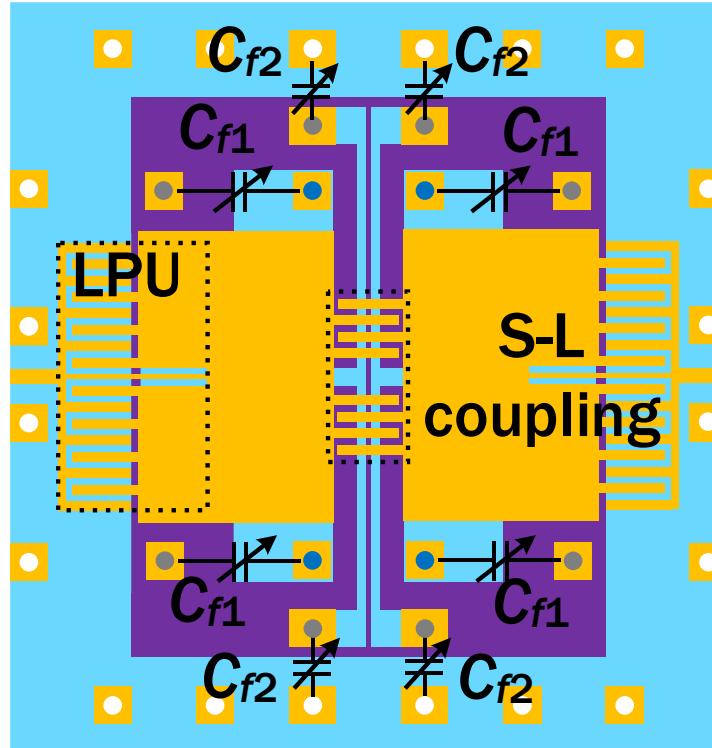


Case B

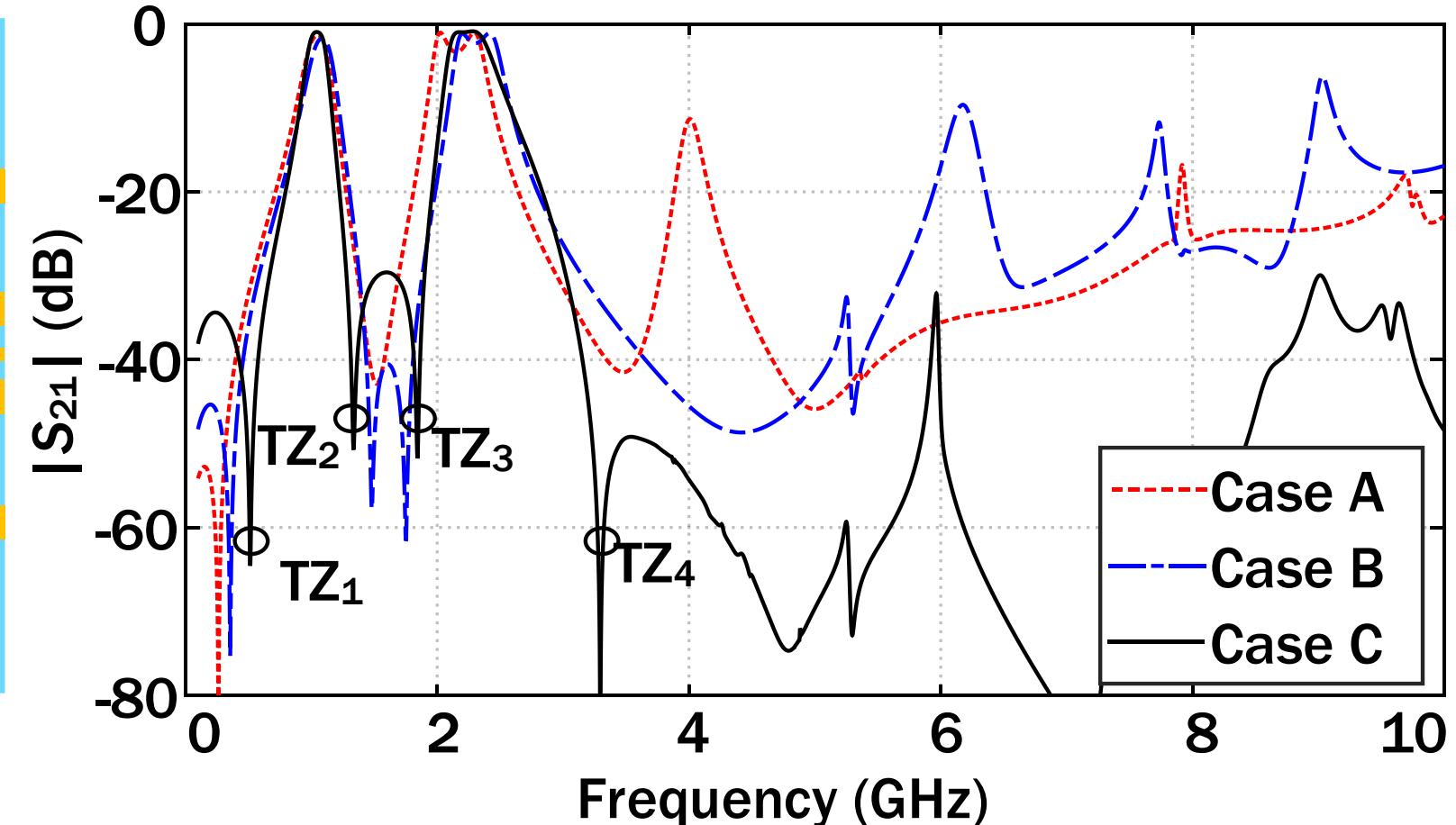


Filter Design

- Stopband

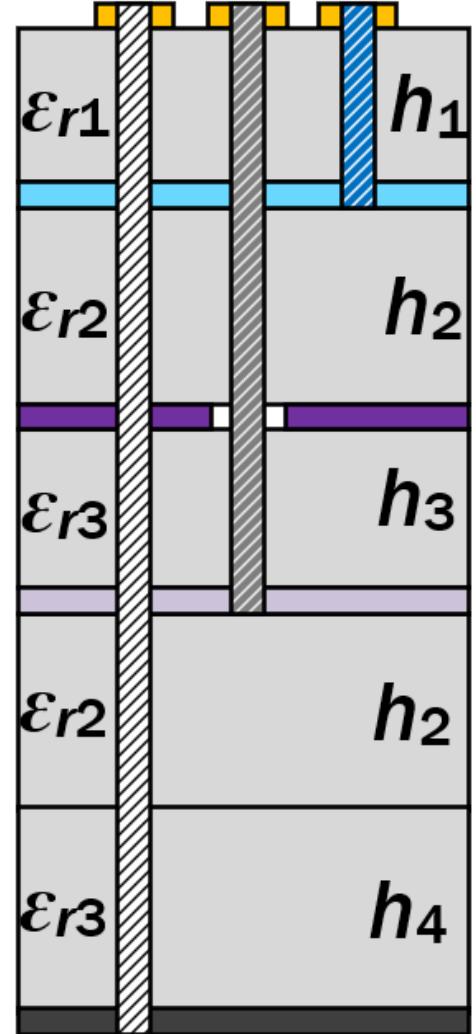
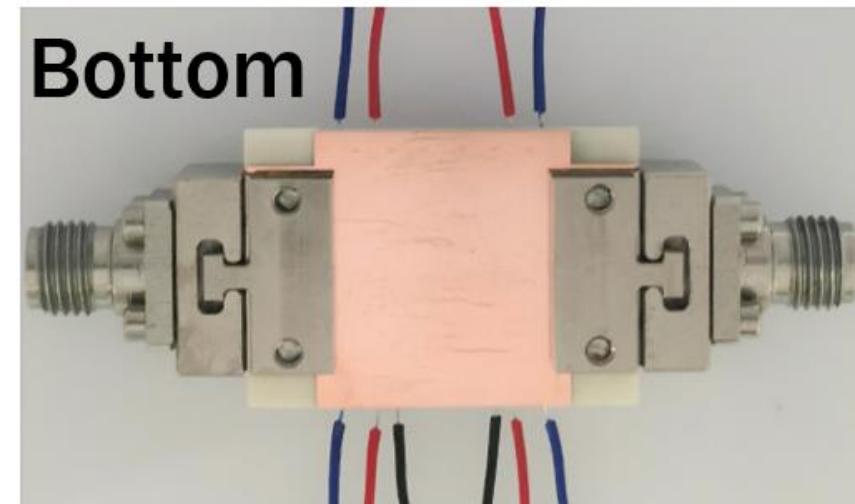
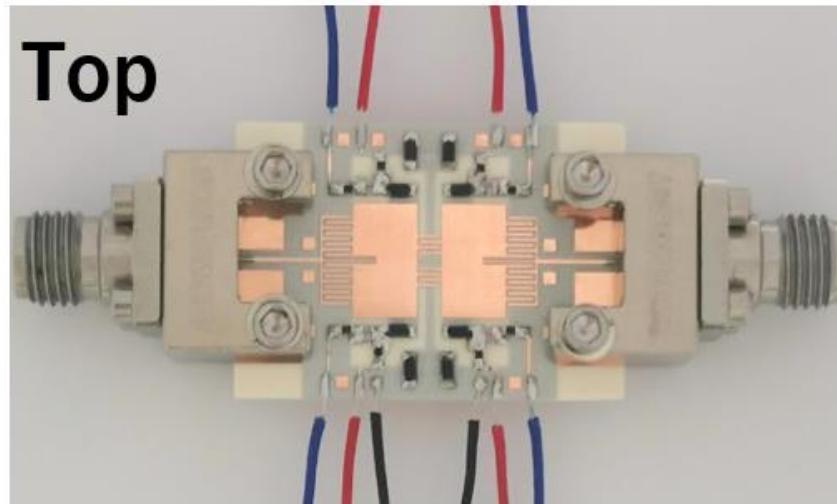


Case C



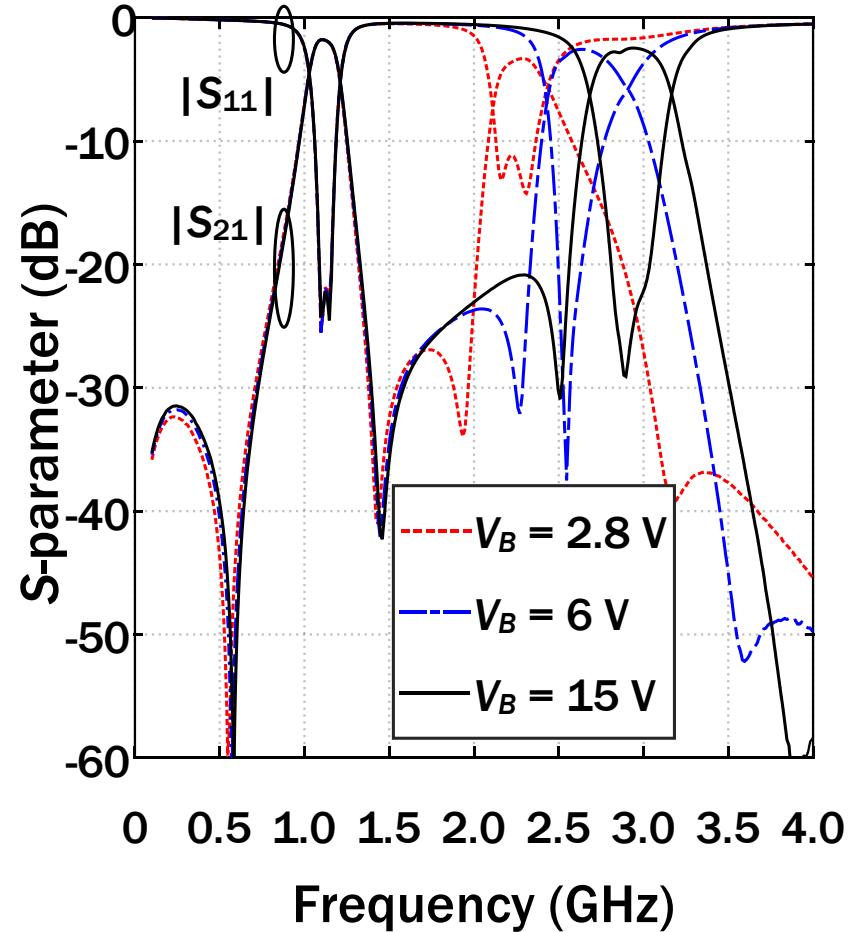
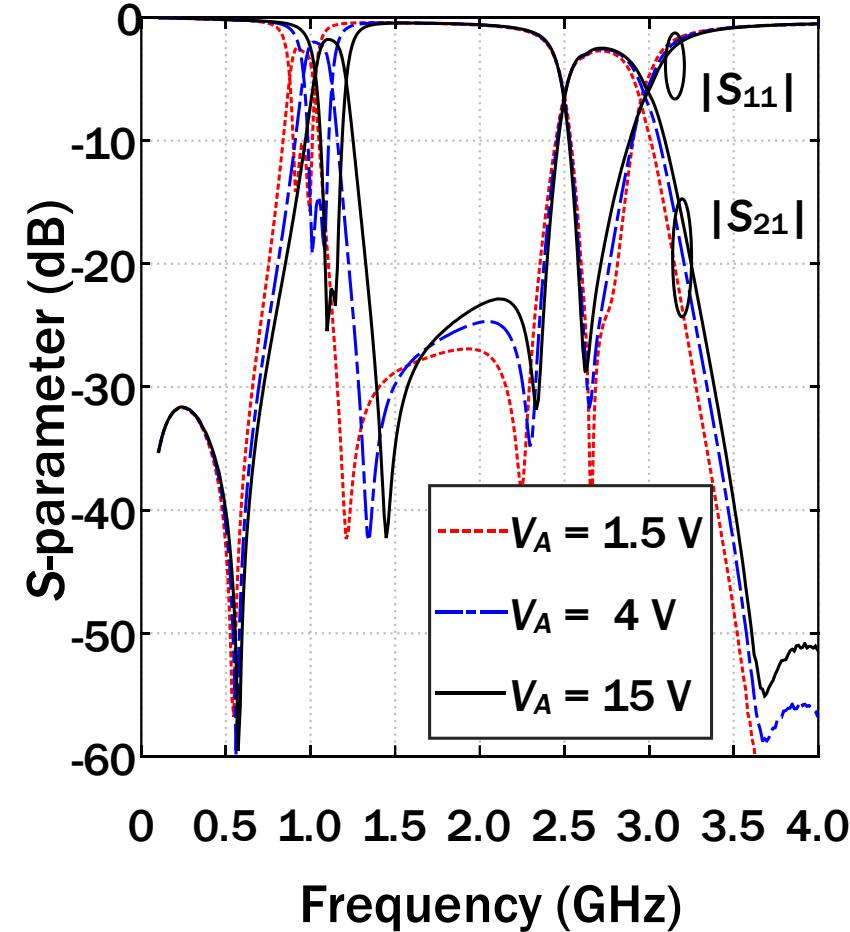
• Photographs

- Substrate1: R04350B (i.e., $\epsilon_{r1} = 3.66$, $h_1 = 0.101$ mm)
- Substrate2: R04003C(i.e., $\epsilon_{r3} = 3.55$, $h_3 = 0.203$ mm, $h_4 = 0.812$ mm)
- Bounding layer: R04450F (i.e., $\epsilon_{r2} = 3.52$, $h_2 = 0.305$ mm)
- Circuit size: 15.4 mm \times 15.6 mm ($0.081 \lambda_g \times 0.082 \lambda_g$)



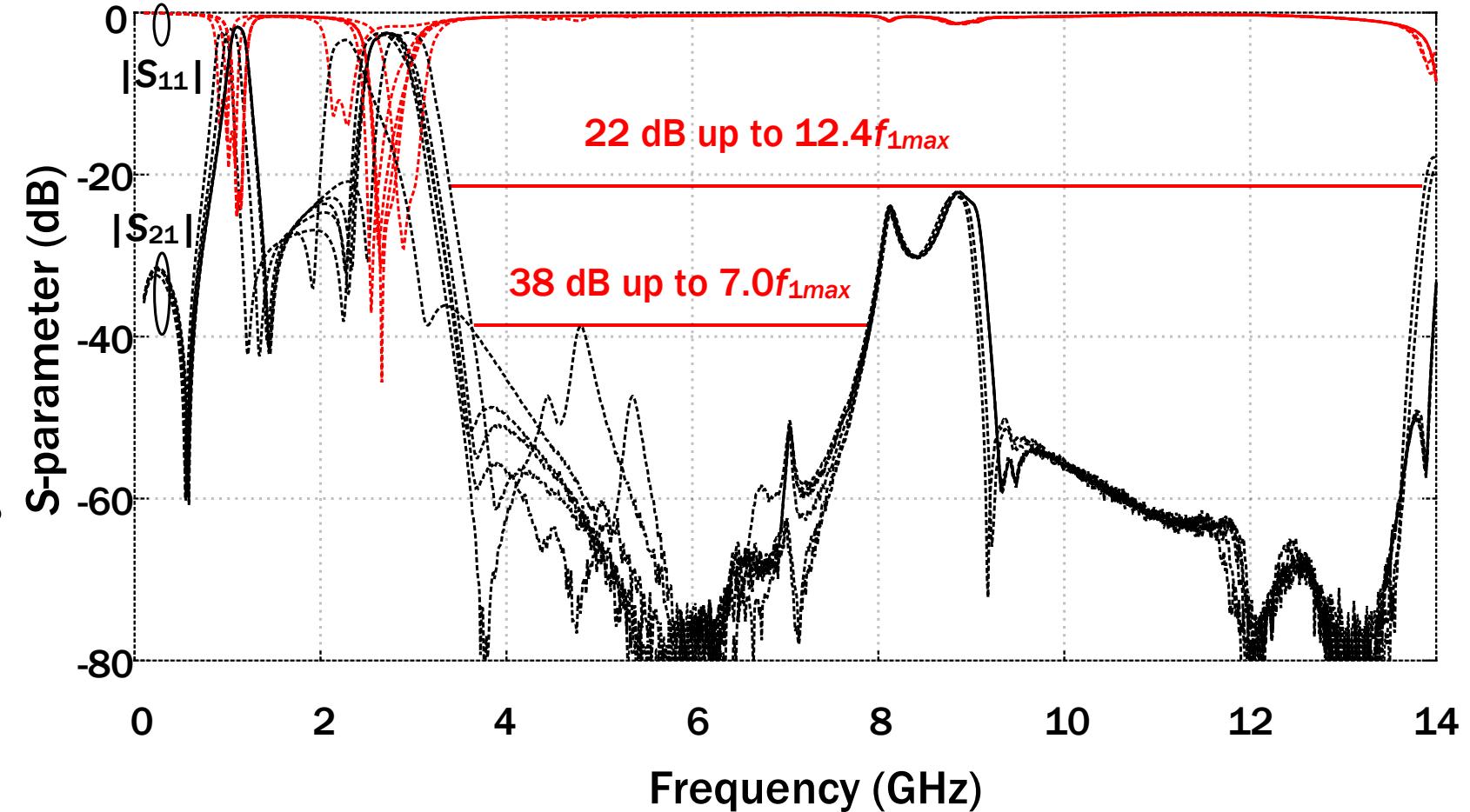
- Measurement

- ◊ Independent tuning
- ◊ Center frequencies:
 $f_1: 0.94\text{--}1.12 \text{ GHz}$
 $f_2: 2.29\text{--}2.92 \text{ GHz}$
- ◊ Insertion losses:
 $f_1: 1.78\text{--}2.46 \text{ dB}$
 $f_2: 2.47\text{--}3.31 \text{ dB}$
- ◊ 2 Controlled DC voltages
- ◊ 4 Transmission zeros
- ◊ Stopband Rejection:
 $>38 \text{ dB up to } 7.0 f_{1\max}$
 $>22 \text{ dB up to } 12.4 f_{1\max}$



- Measurement

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- ◊ Center frequencies:
 f_1 : 0.94–1.12 GHz
 f_2 : 2.29–2.92 GHz
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>38 dB up to $7.0 f_{1\max}$
>22 dB up to $12.4 f_{1\max}$



- Comparison

Ref.	[9]	[11]	[13]	[14]	This Work
Tech.*	Microstrip & DGS	Microstrip	Microstrip	HMSIW	SIDGS
Ind.**	No	Yes	No	Yes	Yes
Freq. (GHz)	f_1	0.85–1.20	0.80–1.02	0.52–0.76	3.26–3.47
	f_2	1.40–2.14	2.02–2.48	0.98–1.36	5.47–6.13
IL \triangle (dB)	f_1	1.32–3.40	1.12–2.93	3.1–3.7	0.2–2.9
	f_2	1.80–3.80	1.45–4.89	1.5–5.0	0.1–2.1
CV \bullet	2	2	4	2	2
TZ	3	6	3	2	4
Stopband Rejection	20dB up to $10f_{2max}$	20dB up to $3.4f_{1max}^\diamond$	20dB up to $2.6f_{1max}^\diamond$	20dB up to $2f_{1max}^\diamond$	22dB up to $12.4f_{1max}$
Size(λ_g^2)	0.033 $^\diamond$	0.045 $^\diamond$	0.010	0.186 $^\diamond$	0.0066

*: Technology. **: Independent tuning. \triangle : Insertion loss.

\bullet : Controlled DC voltages for dual-band tuning. $^\diamond$: Estimated from paper.

- Comparison

Ref.	[9]	[11]	[13]	[14]	This Work
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Ind.**	No	Yes	No	Yes	Yes
Freq. (GHz)	f_1	0.85–1.20	0.80–1.02	0.52–0.76	3.26–3.47
	f_2	1.40–2.14	2.02–2.48	0.98–1.36	5.47–6.13
IL [△] (dB)	f_1	1.32–3.40	1.12–2.93	3.1–3.7	0.2–2.9
	f_2	1.80–3.80	1.45–4.89	1.5–5.0	0.1–2.1
CV•	2	2	4	2	2
TZ	3	6	3	2	4
Stopband Rejection	20dB up to $10f_{2max}$	20dB up to $3.4f_{1max}^\diamond$	20dB up to $2.6f_{1max}^\diamond$	20dB up to $2f_{1max}^\diamond$	22dB up to $12.4f_{1max}$
Size(λ_g^2)	0.033 [◊]	0.045 [◊]	0.010	0.186 [◊]	0.0066

*: Technology. **: Independent tuning. △: Insertion loss.

•: Controlled DC voltages for dual-band tuning. ◊: Estimated from paper.

- High selectivity
- Wide stopband
- Miniaturized size

Conclusion

- **Comparison**

- A **multilayer folded SIDGS resonator** with two independently tunable resonant modes is proposed.
- Based on the proposed resonator, an **independently tunable** dual-band BPF is designed.
- the BPF exhibits the merits of miniaturized size, high selectivity, and wide stopband.
- With good performance, the proposed BPF is attractive for modern communication systems with **versatile and integrated applications**.

Thank you for your attention !