

We3F-5

# Millimeter-Wave Substrate-Integrated Waveguide Multiplexer with High Channel Scalability and High Isolation

Pei-Ling Chi<sup>#</sup>, Po-Hua Wang<sup>#</sup>, and Tao Yang<sup>\*</sup>

<sup>#</sup>Department of Electrical and Computer Engineering, National Yang Ming Chiao Tung University, Taiwan

<sup>\*</sup>University of Electronic Science and Technology of China, China  
[peilingchi@nycu.edu.tw](mailto:peilingchi@nycu.edu.tw)

# Outline

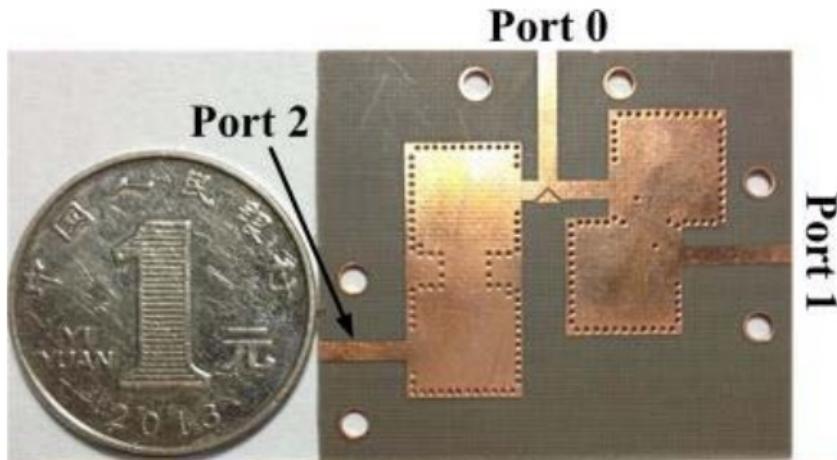
- **Introduction**
- **Proposed Distributed Feeding Technique**
- **Cavity Synthesis and Extraction of External Q & Coupling Coefficient  $M$**
- **Simulation & Measurement**
- **Comparison**

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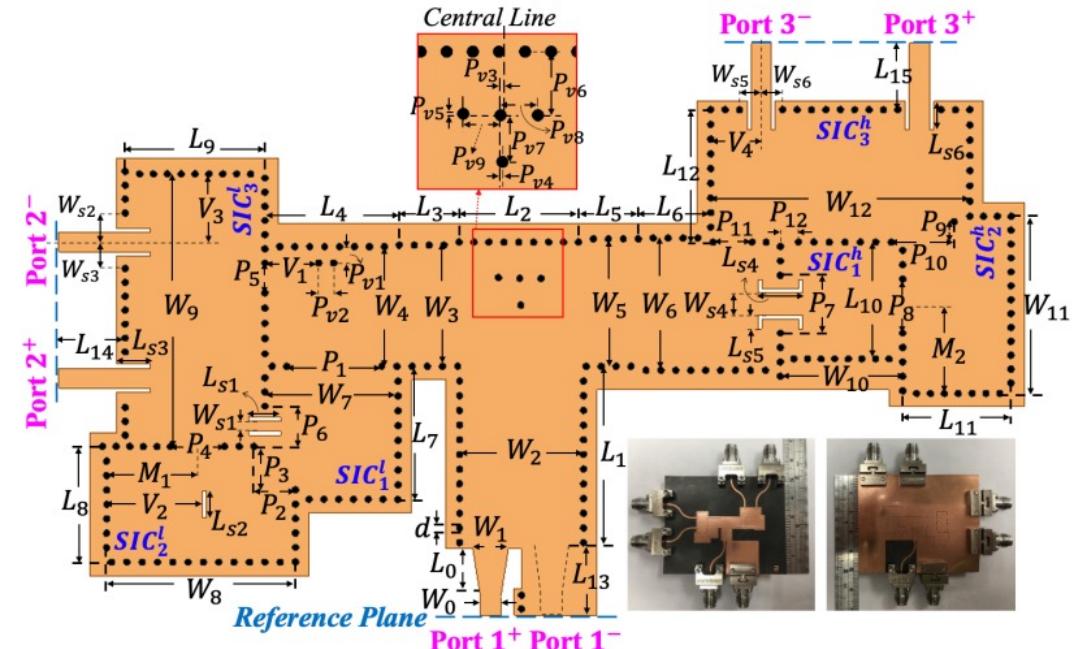
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## 1) Feeding with T-junction

- The capability of expanding channels is highly limited.
- The junction has to be redesigned because the newly introduced channels will impose additional conditions.



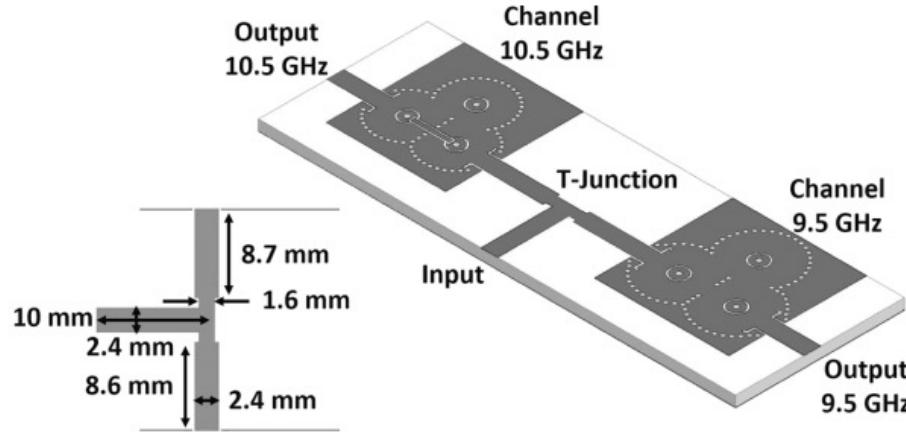
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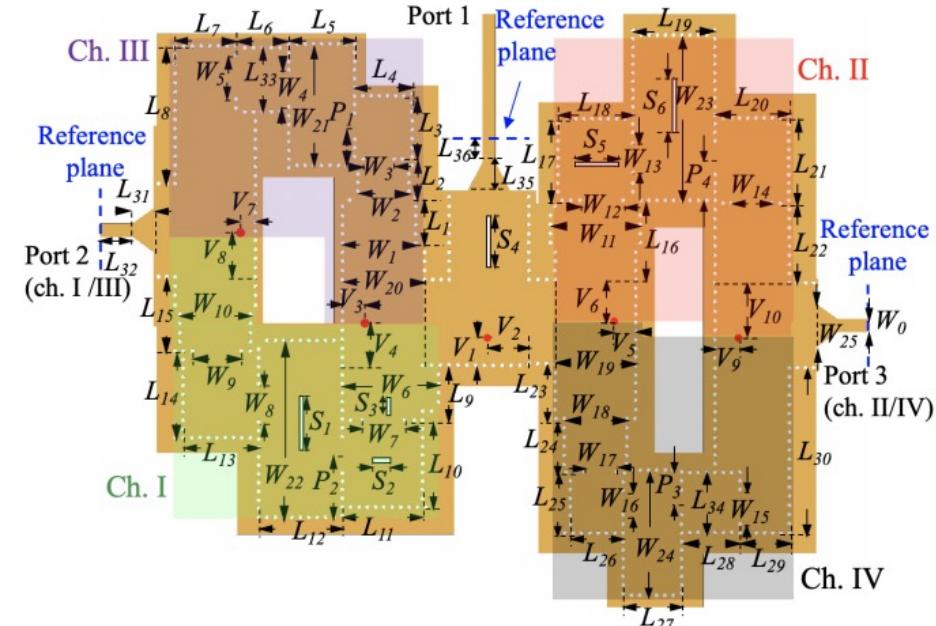
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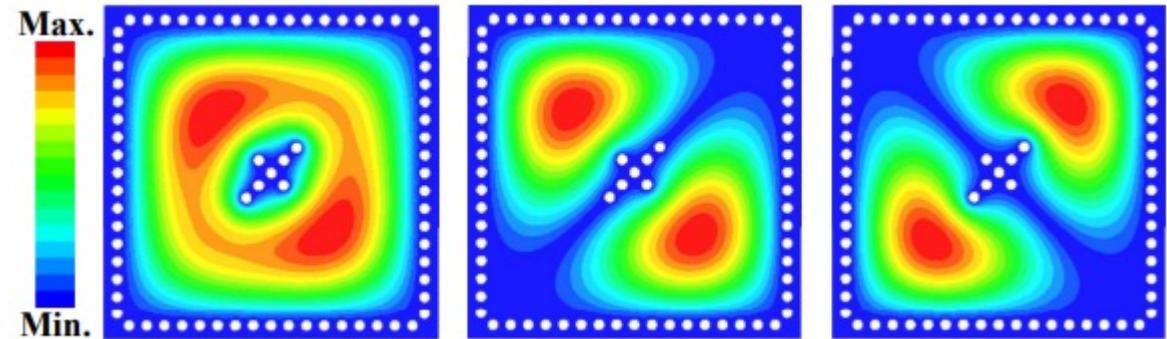
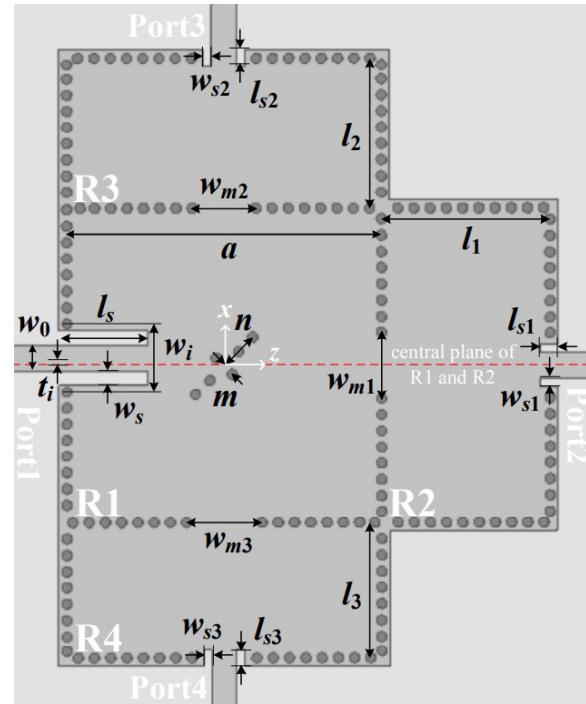
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## 2) Dual/Triple-Mode Cavity Based Scheme

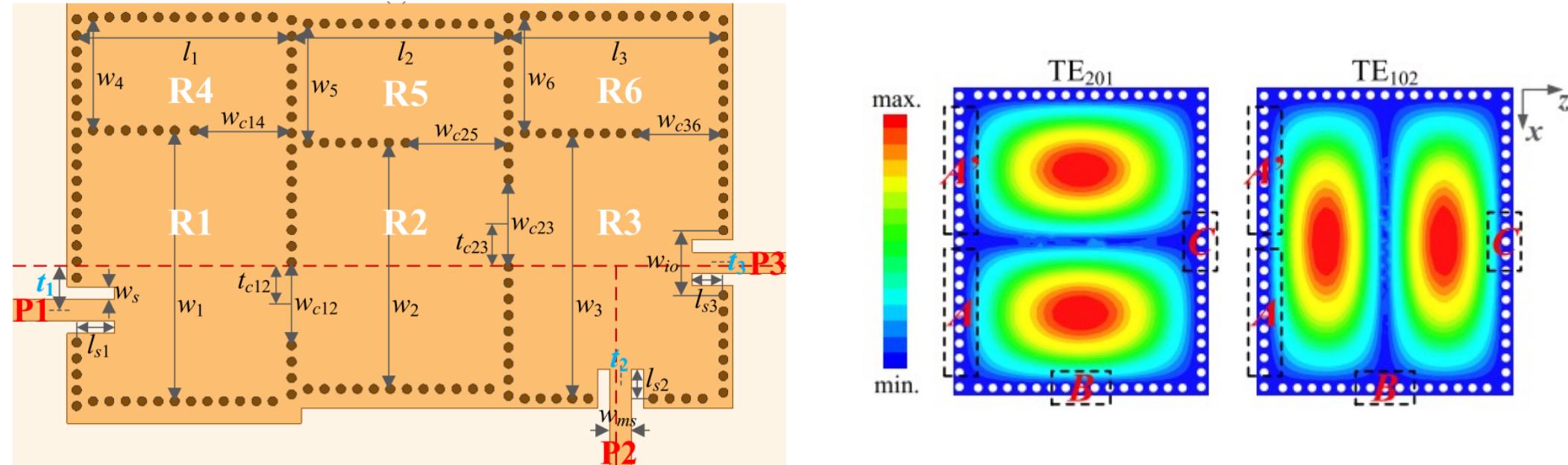
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[5] H. Xie, K. Zhou, C. Zhou, and W. Wu, "Compact substrate-integrated waveguide triplexer based on a common triple-mode cavity," *IEEE MTT-S Int. Microw. Symp. Dig.*, Philadelphia, PA, USA, Jun. 2018, pp. 1072–1075.

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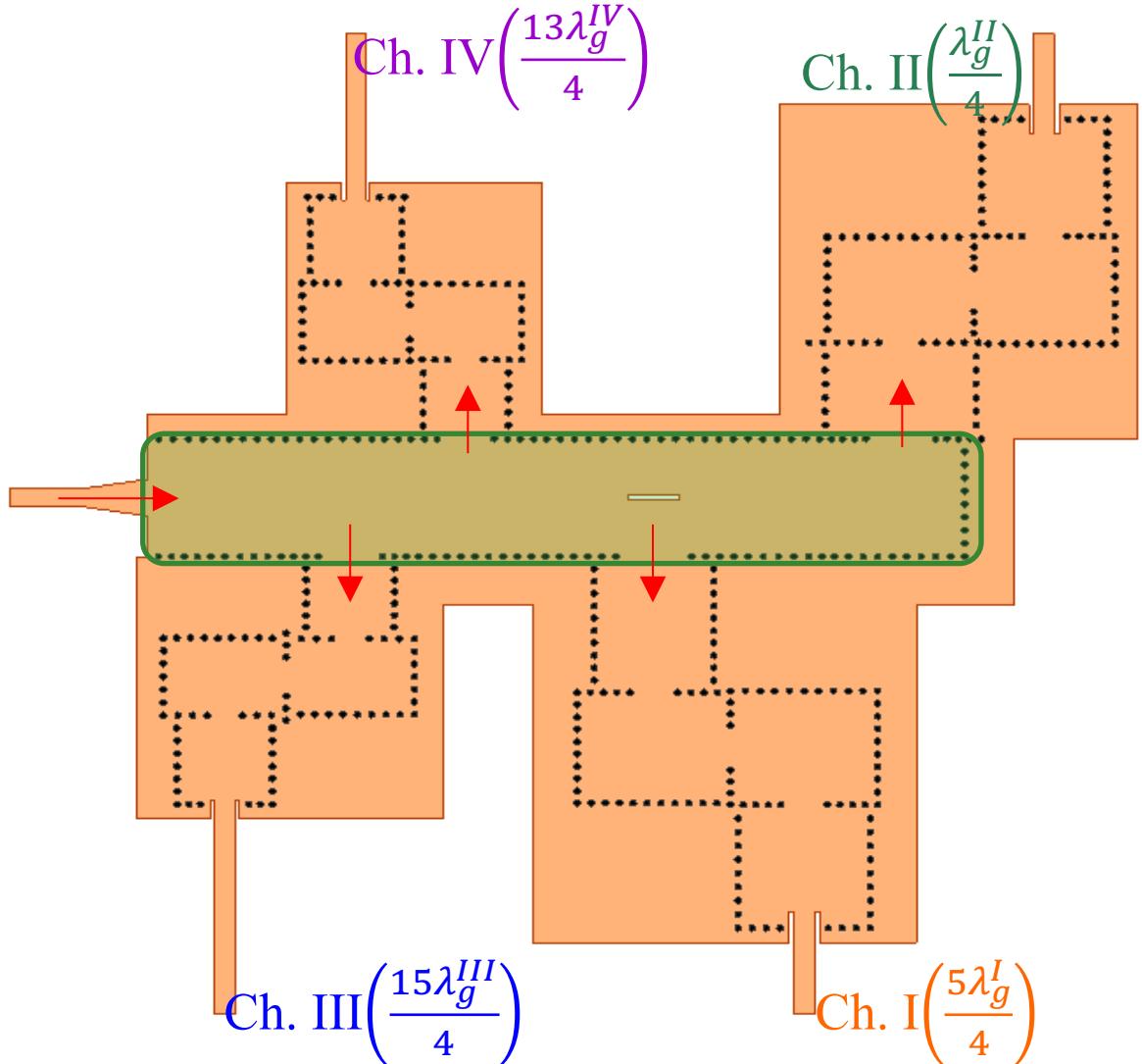
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[6] K. Zhou and K. Wu, "Multichannel substrate integrated waveguide diplexer made of dual-mode cavities and split-type dual-band response," *IEEE MTT-S Int. Microw. Symp. Dig.*, Atlanta, GA, USA, Jun. 2021, pp. 685–688.

# Proposed Feeding Technique

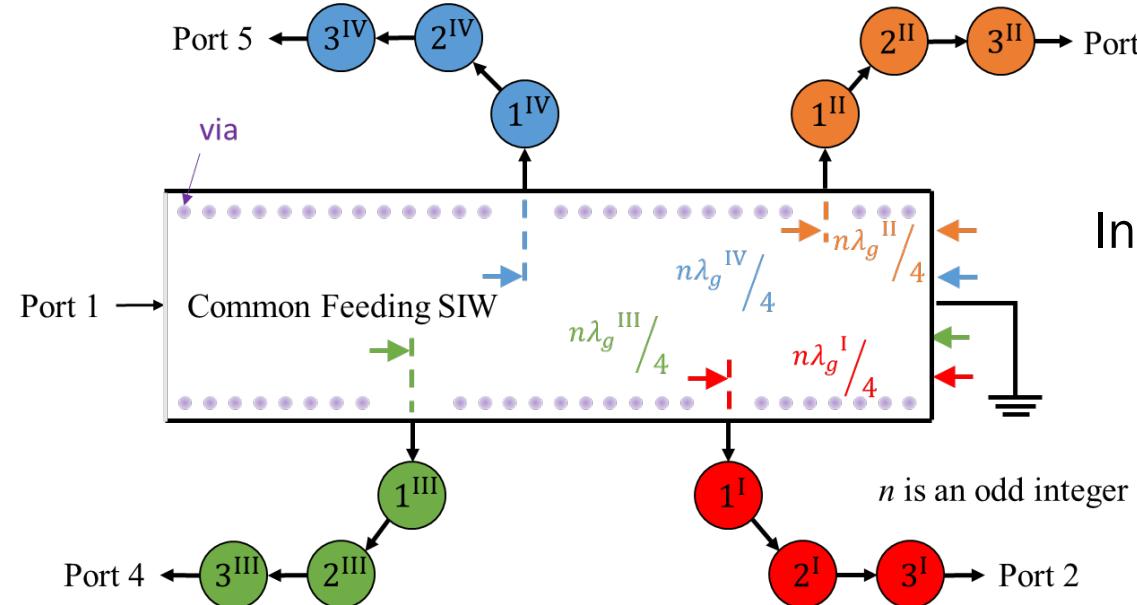
- A common feeding SIW to load each channel filter
- Isolation enhancement by reducing loading effect and staggering higher-order resonances
- Applied to the fifth-generation (5G) millimeter-wave applications



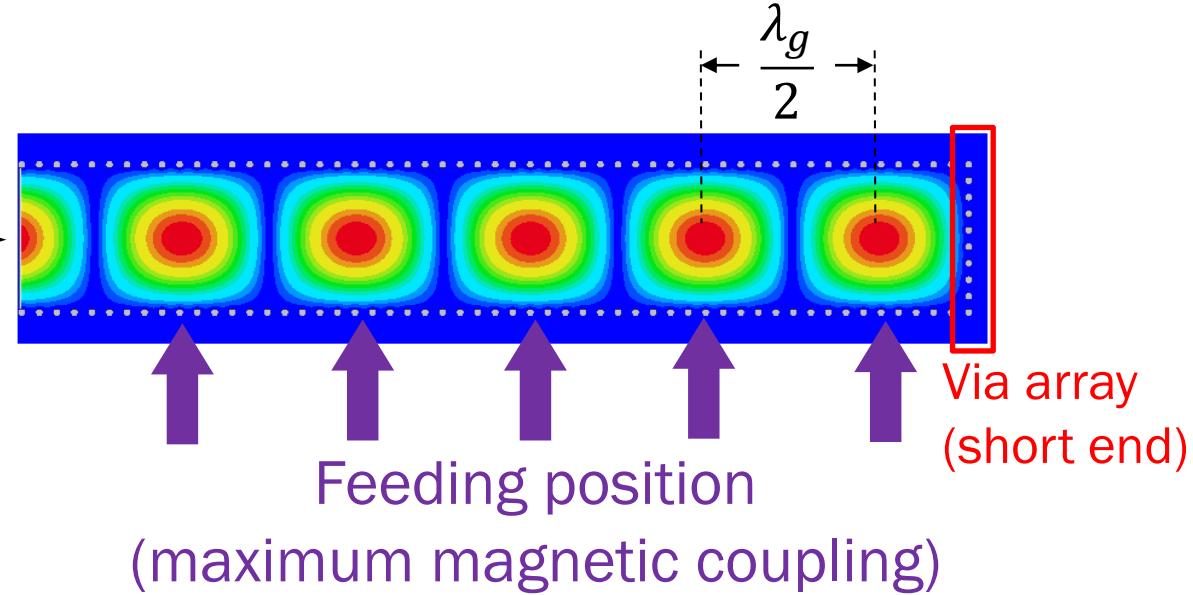
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- SIW is terminated by a short circuit.
- Loading position is chosen at the maximum magnetic field intensity through sidewall aperture coupling.

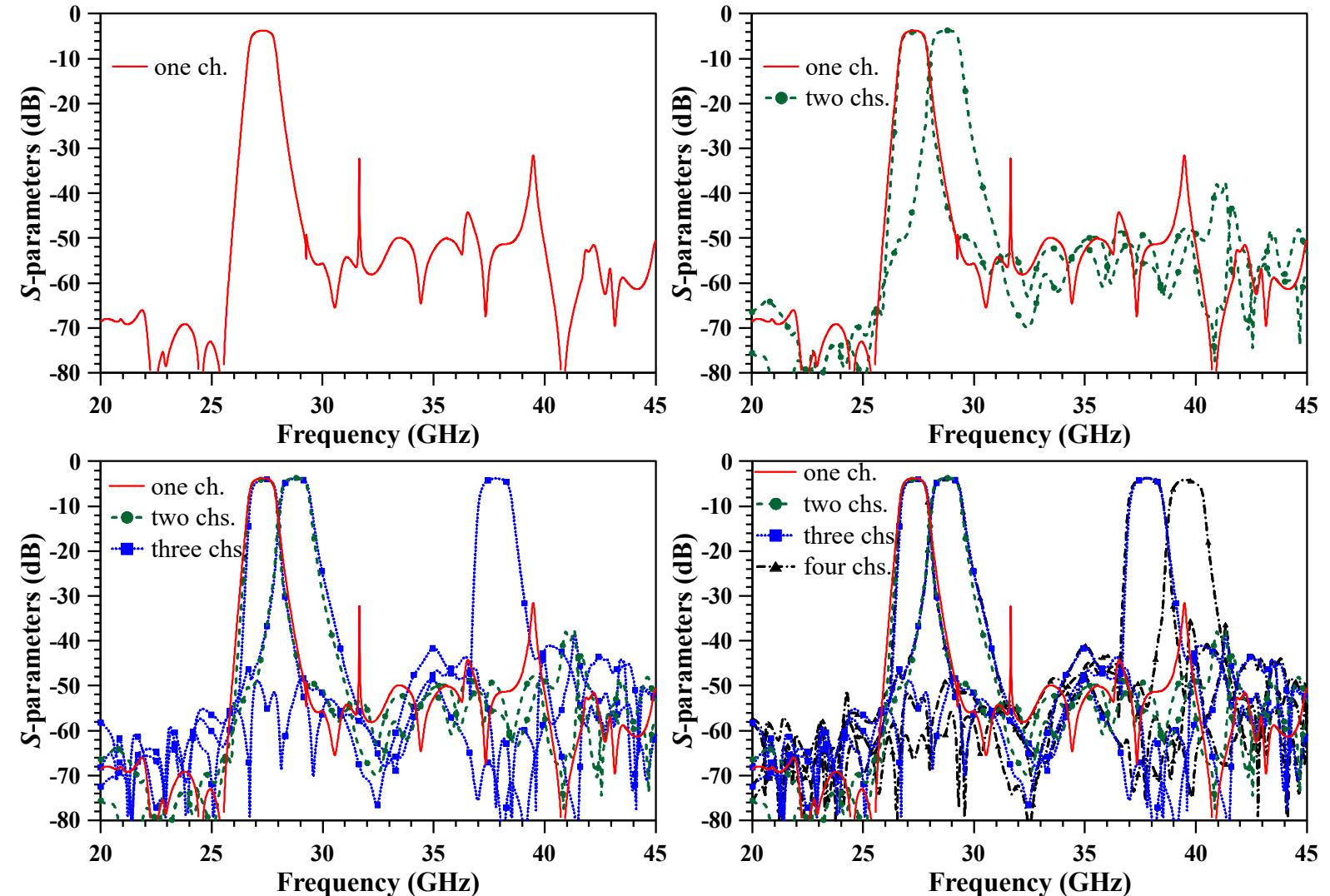


Input Port



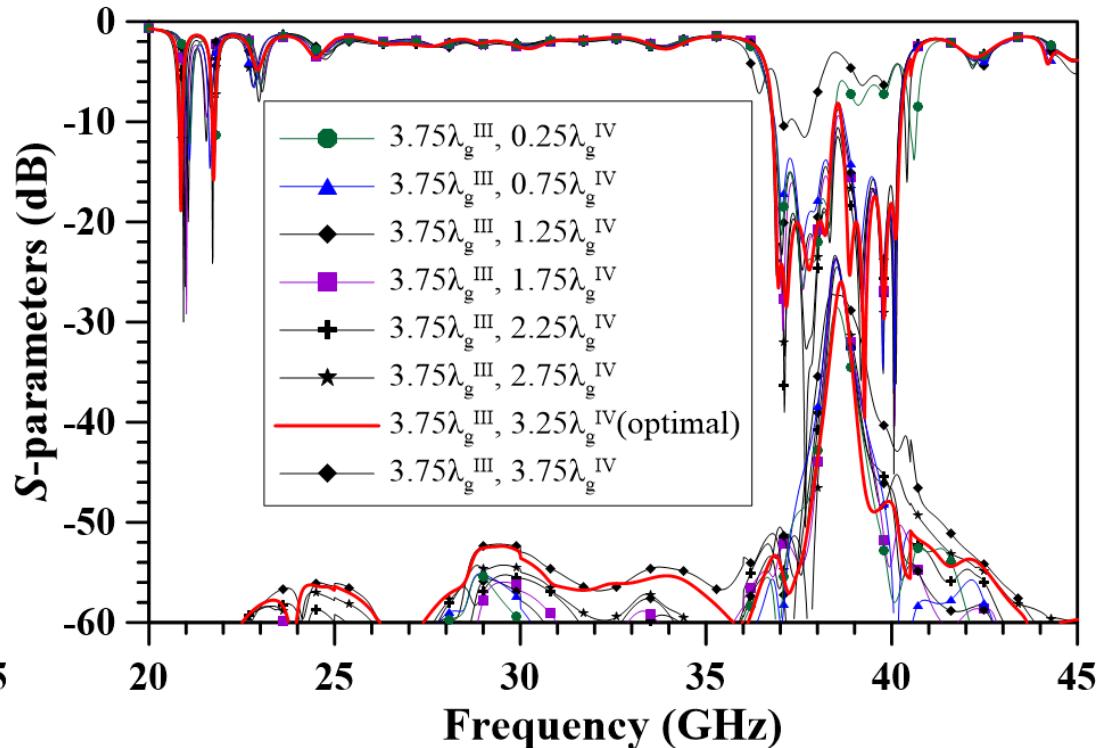
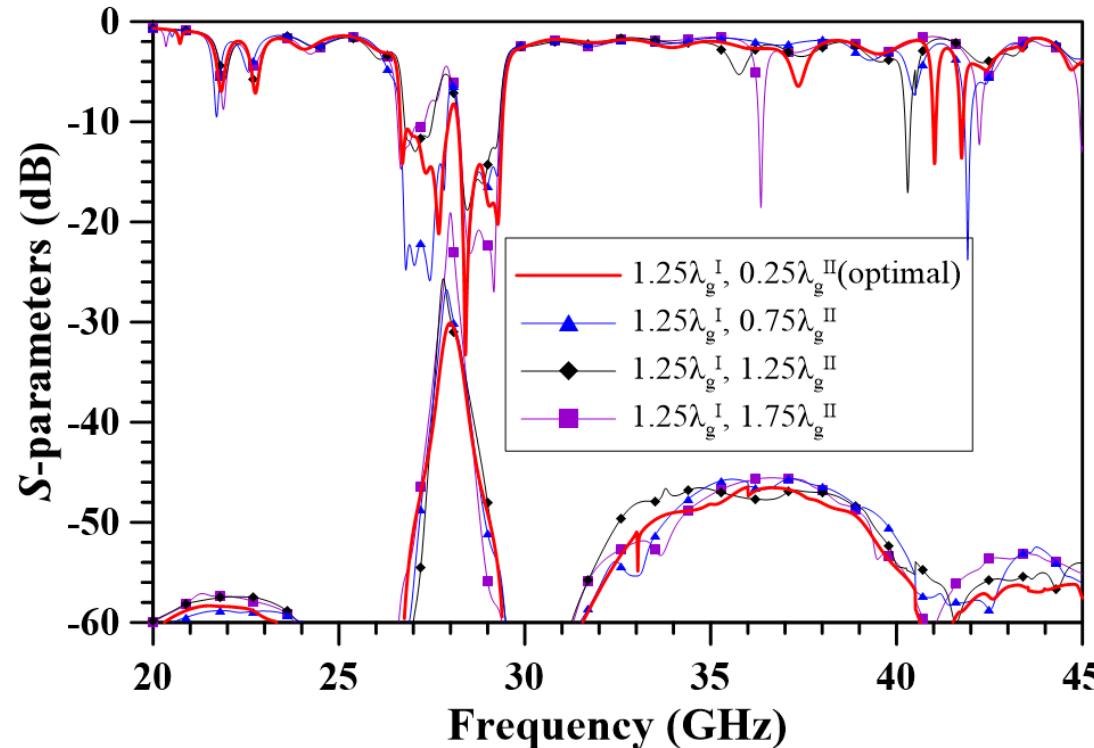
# Independent Design

- Passbands overlap very well with those in the previous responses.



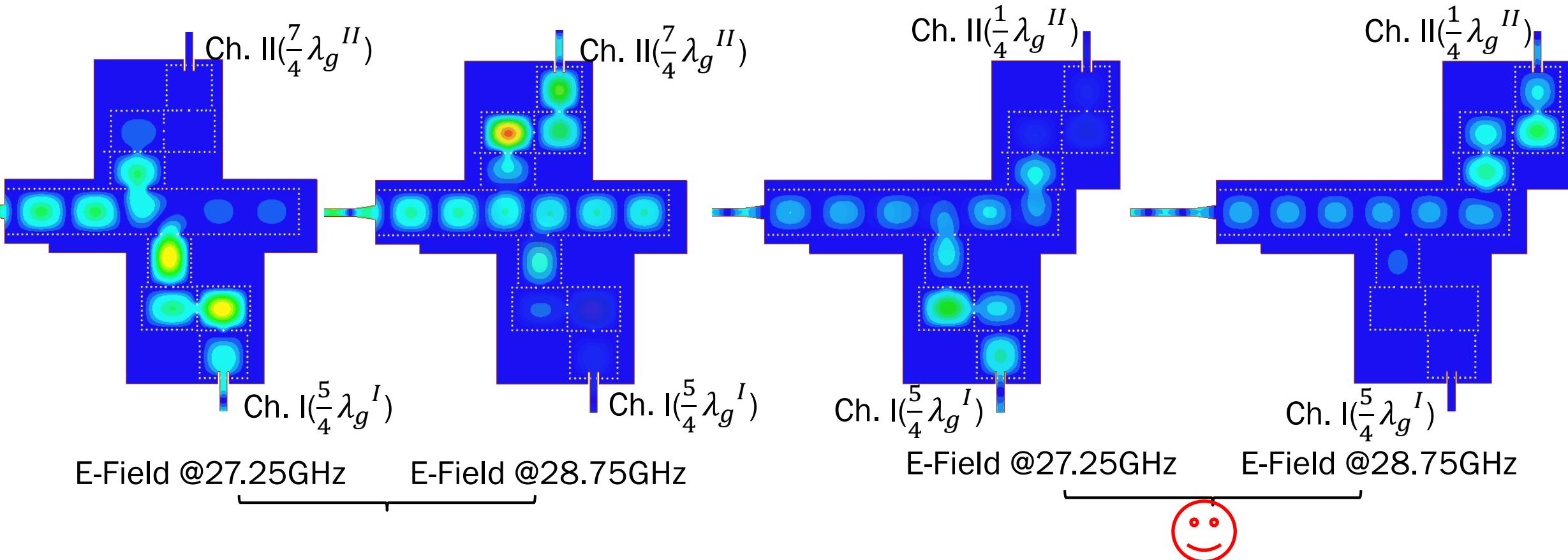
# Two Channels

- For channels that are **close to each other**
  - The higher/lower channels will be placed close/far to/from the short circuit.



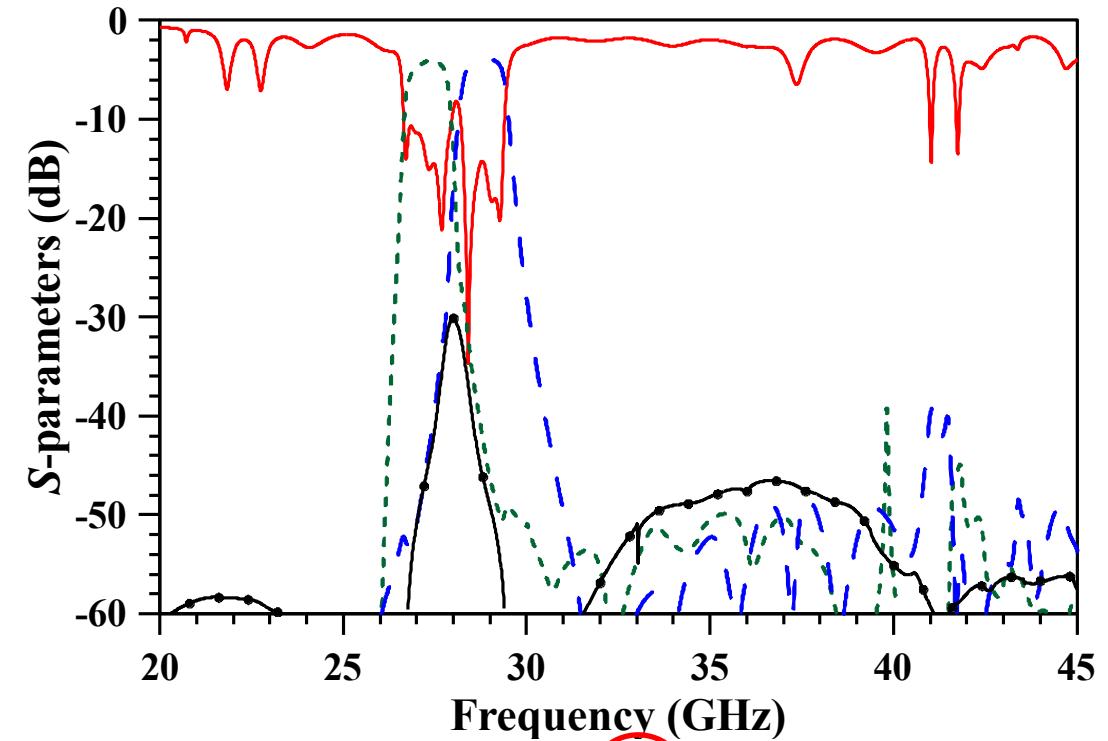
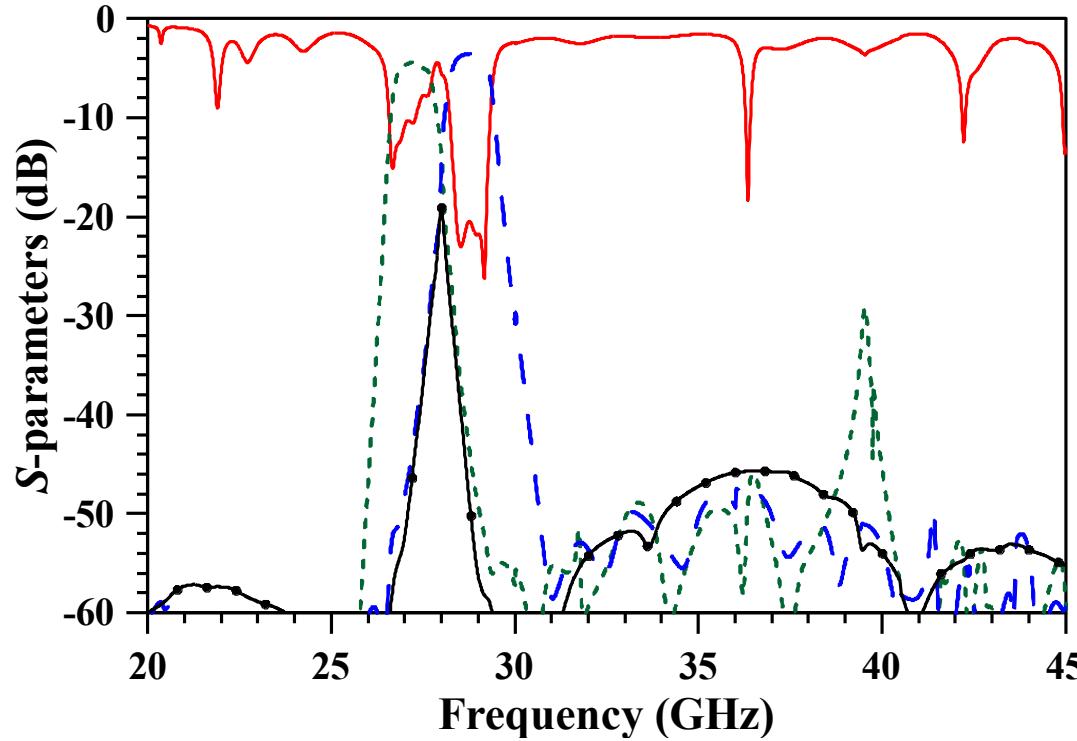
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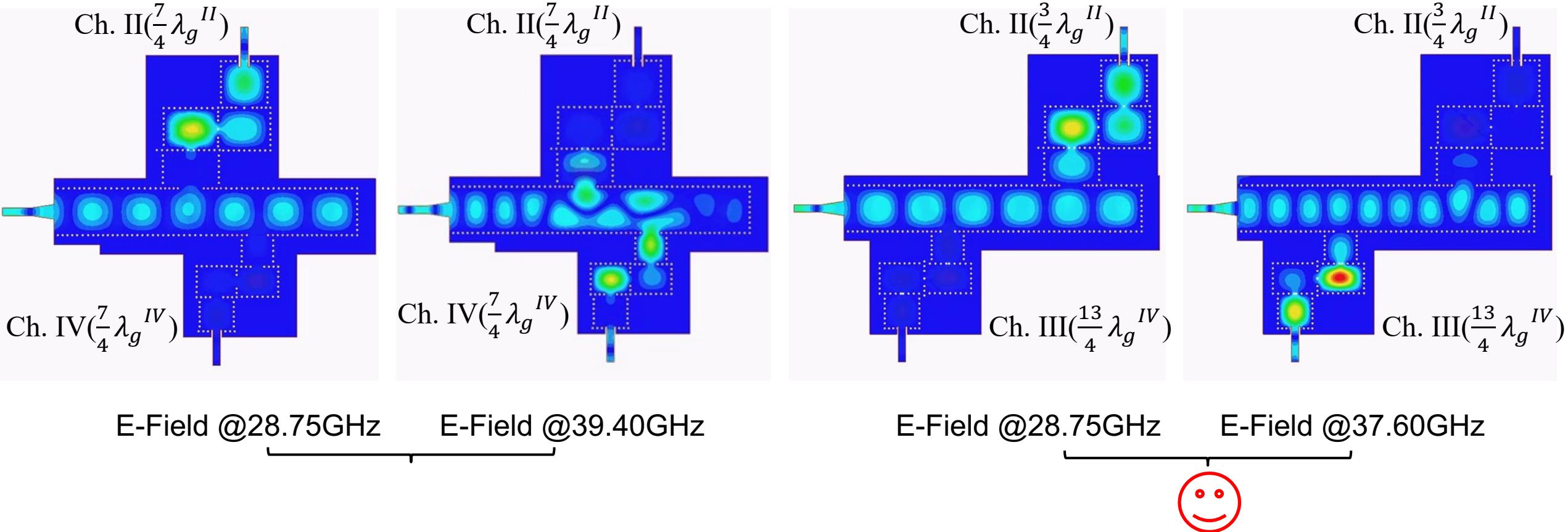
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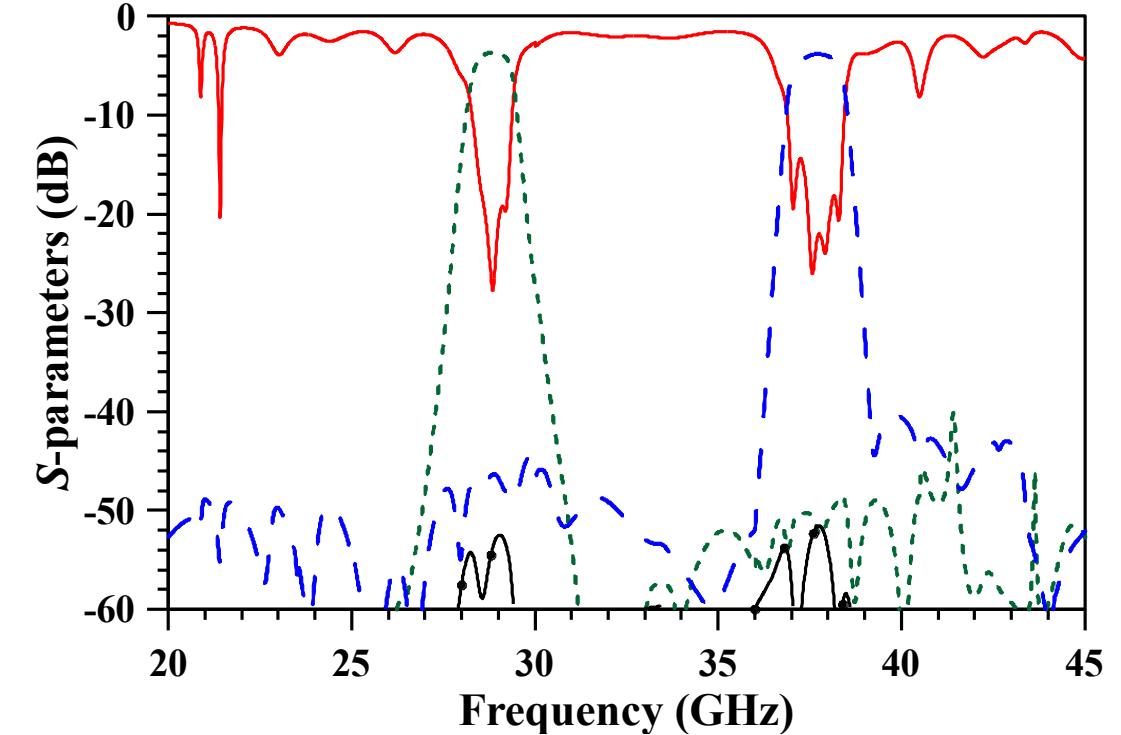
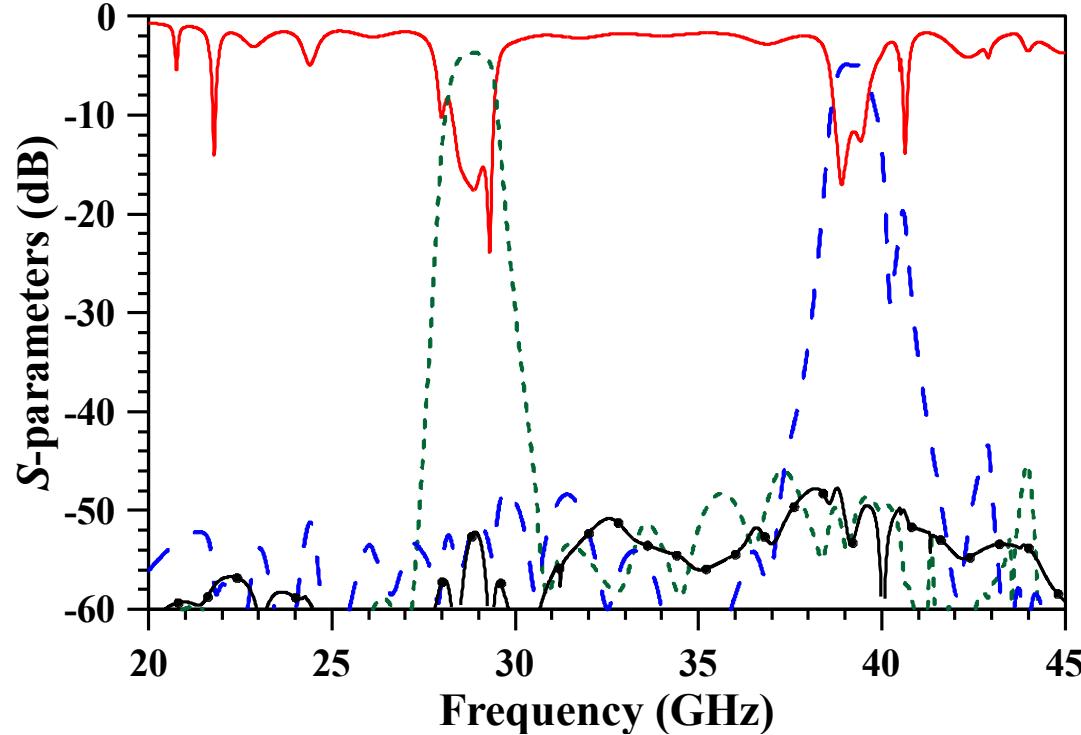
# Two Channels (cont'd)

- For channels that are **distant**
- The higher/lower channels will be placed far/close from/to the short circuit.



# Two Channels (cont'd)

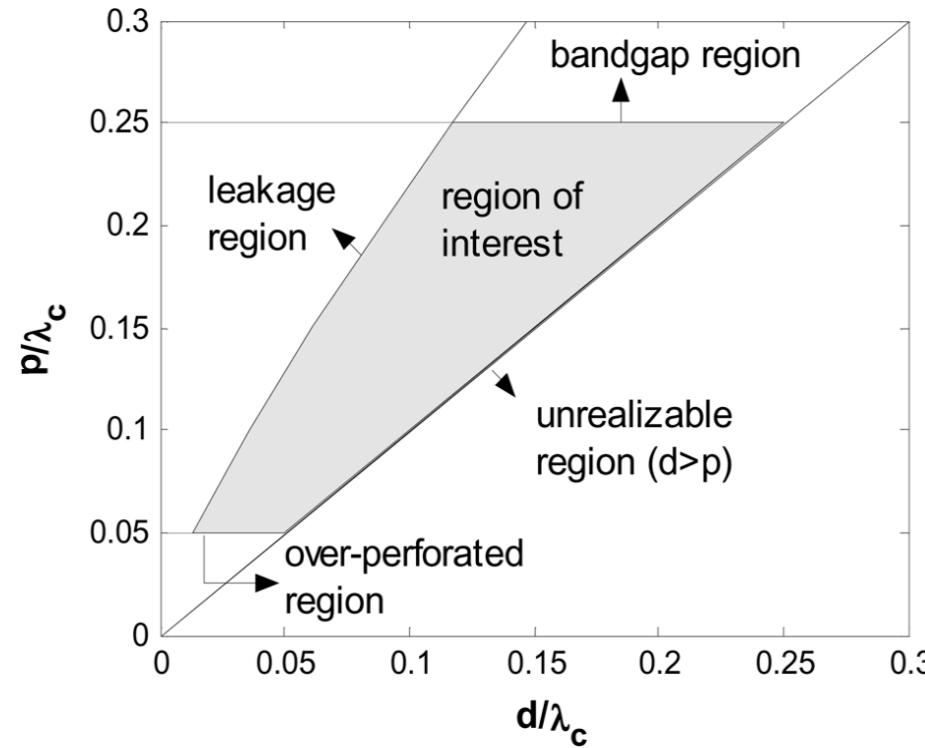
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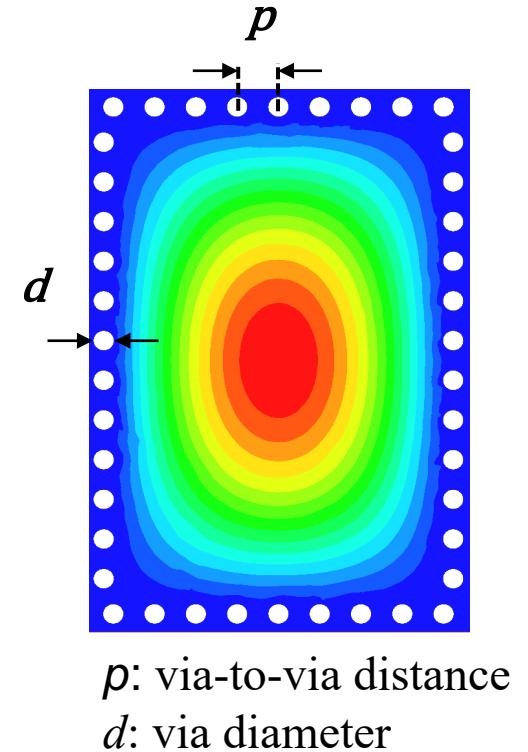
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- Determine the suitable via-to-via distance ( $p$ ) and via diameter ( $d$ )



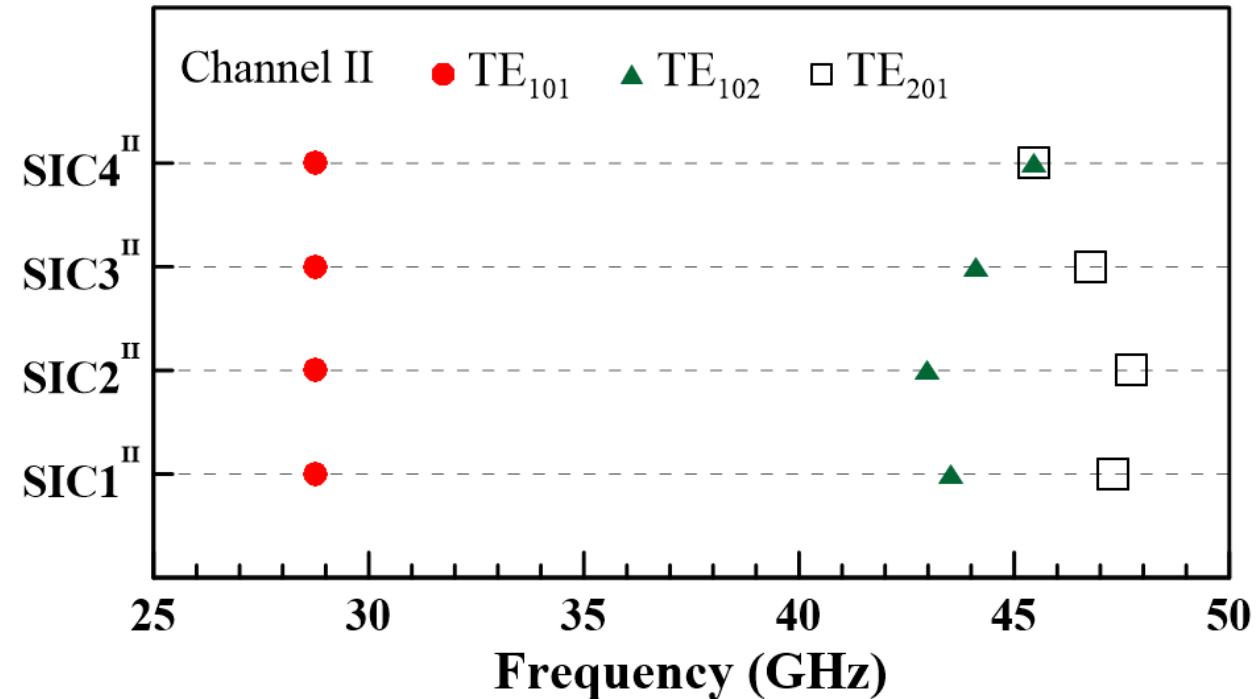
$$W_{eff} = W_{SIC} - 1.08 \times \frac{d^2}{p} + 0.1 \times \frac{d^2}{w_{SIC}}$$

$$L_{eff} = L_{SIC} - 1.08 \times \frac{d^2}{p} + 0.1 \times \frac{d^2}{L_{SIC}}$$



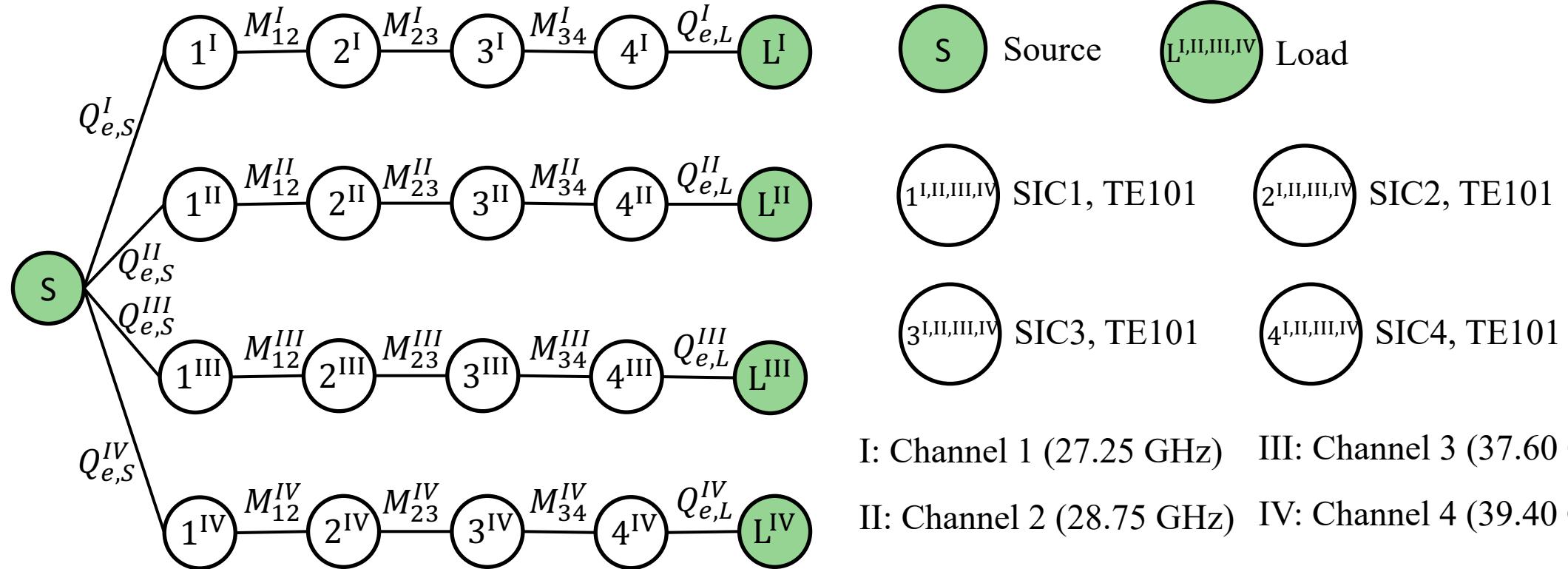
# Spurious Passband Suppression

- Use dissimilar SICs in each channel filter to suppress spurious passbands and enhance isolation (Take the channel-II of four single-mode SICs as an example)



# Coupling Topology

- Coupling topology



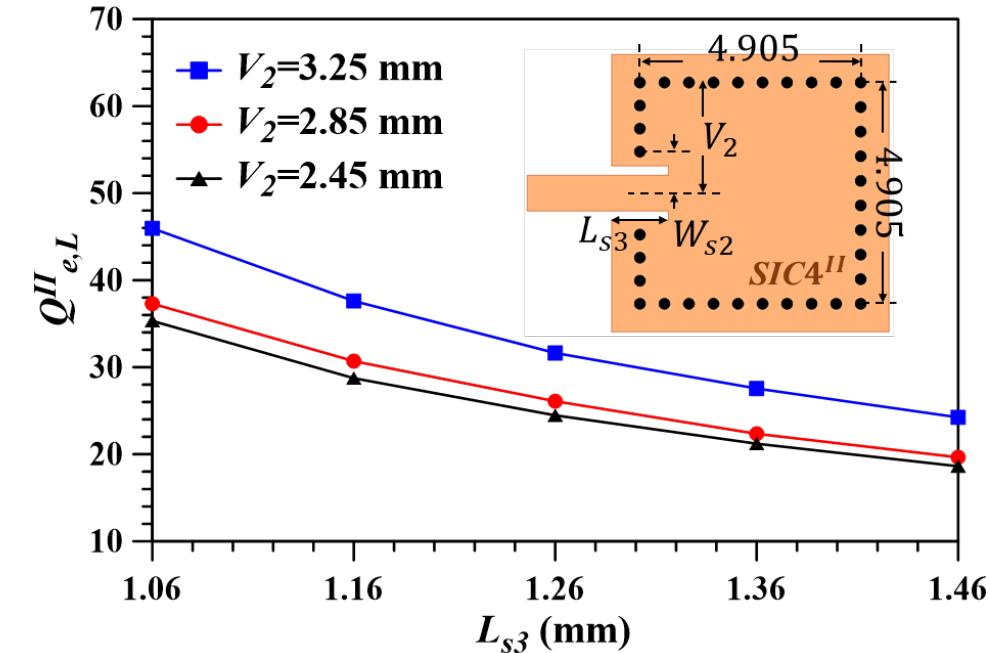
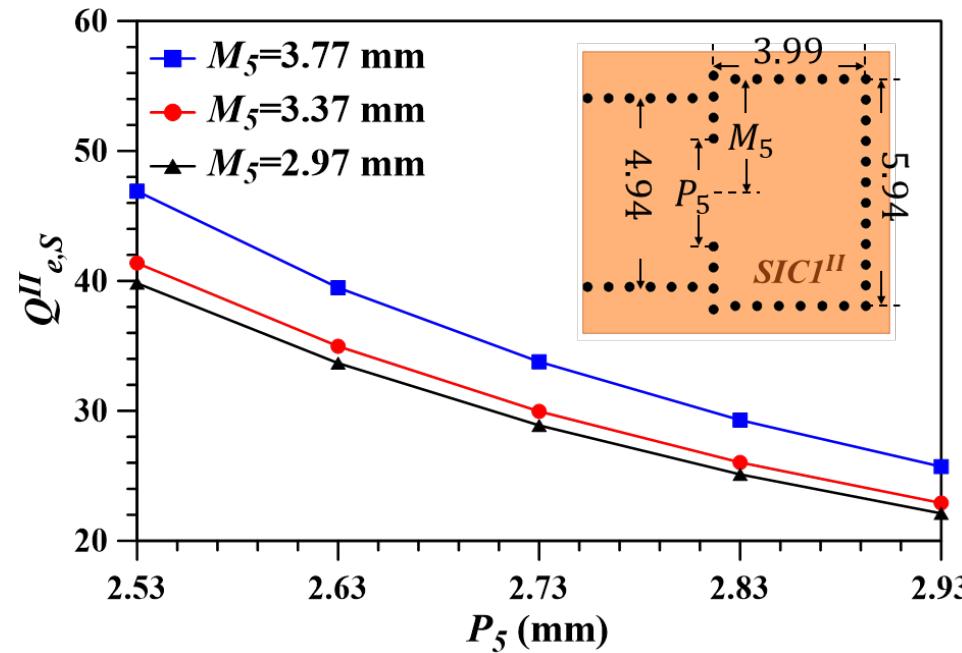
# Channel Specifications

- Fourth-order Chebyshev lowpass prototype with a passband ripple  $L_{AR} = 0.1 \text{ dB}$

<b>N=4</b>	<b>27.25 GHz (Channel I)</b>	<b>28.75 GHz (Channel II)</b>	<b>37.60 GHz (Channel III)</b>	<b>39.40 GHz (Channel IV)</b>
BW (FBW)	1.09 GHz (4%) (26.71~27.80 GHz)	1.15 GHz (4%) (28.18~29.33 GHz)	1.50 GHz (4%) (36.85~38.35 GHz)	1.57 GHz (4%) (38.61~40.18 GHz)
$Q_{ei}$	27.7	27.7	27.7	27.7
$Q_{eo}$	27.7	27.7	27.7	27.7
$M_{12}$	0.0332	0.0332	0.0332	0.0332
$M_{23}$	0.0263	0.0263	0.0263	0.0263
$M_{34}$	0.0332	0.0332	0.0332	0.0332

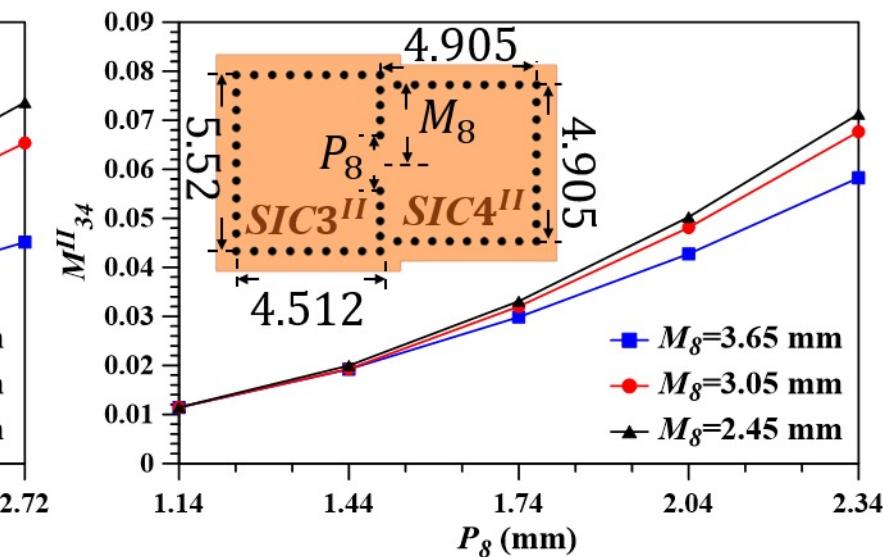
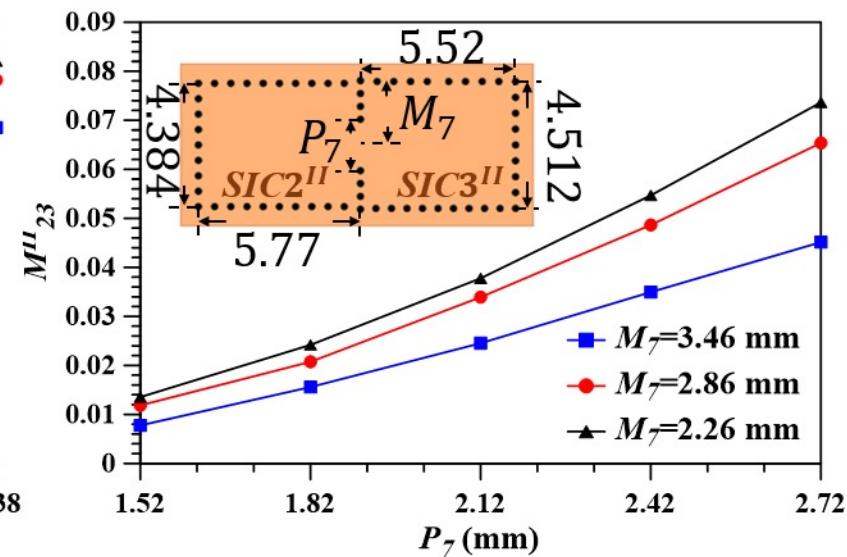
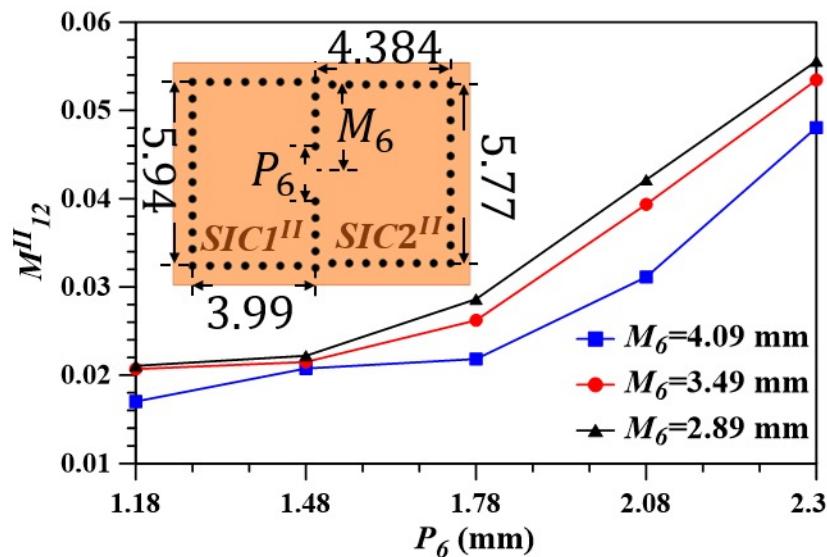
# External Q

- External  $Q_{e,S/L}^{II}$  is controlled by size and location of coupling aperture/slot
- External  $Q_{e,S/L}^{II}$  decrease against coupling aperture ( $P_5$ ) and coupling slot ( $L_{s3}$ )
- Minimum external  $Q_{e,S/L}^{II}$  occur for midplane coupling of  $\text{TE}_{101}$ -mode based input cavity



# Coupling Coefficient $M$

- $M_{12/23/34}^{II}$  is controlled by the width and location of the post-wall iris between SICs
  - $M_{12/23/34}^{II}$  increase with width of iris window ( $P_{6/7/8}$ )
  - Maximum  $M_{12/23/34}^{II}$  occur when the irises are aligned to the midplane of  $TE_{101}$ -mode based cavities



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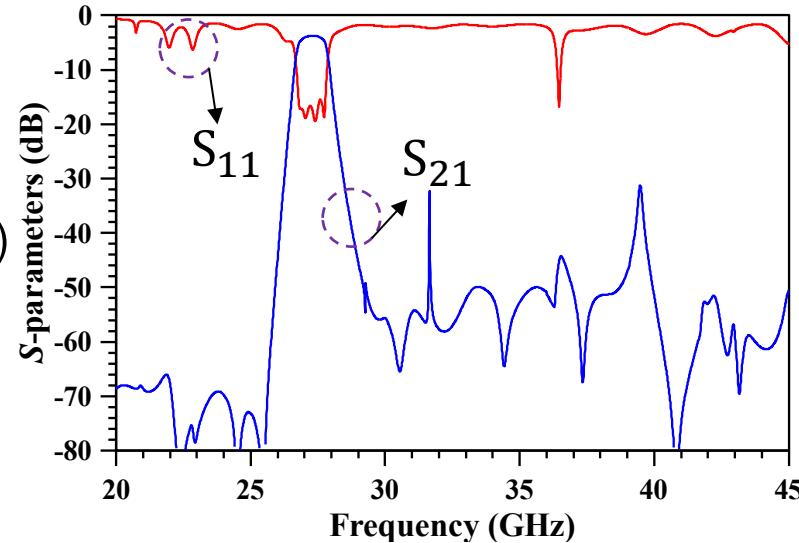
# Simulated Results

## Channel I

CF : 27.25 GHz

BW : 1.09 GHz (4%)  
 (26.71~27.80 GHz)

IL : 2.834 dB

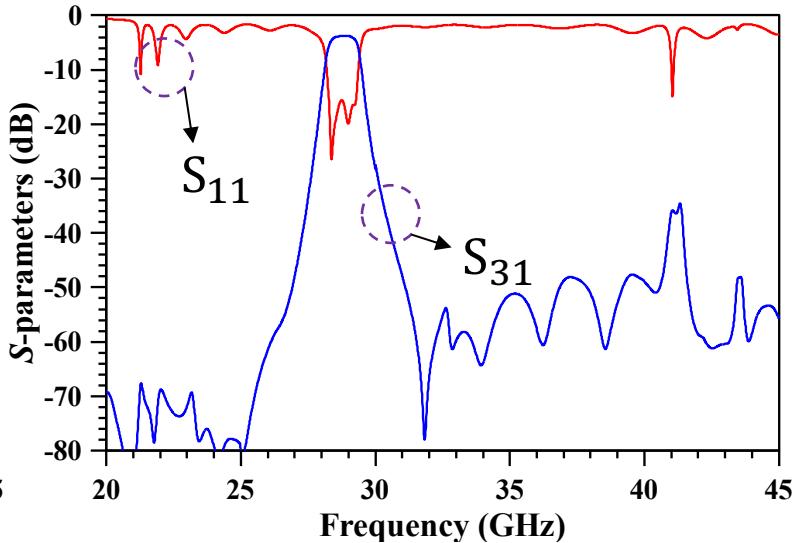


## Channel II

CF : 28.75 GHz

BW : 1.15 GHz (4%)  
 (28.18~29.33 GHz)

IL : 2.773 dB

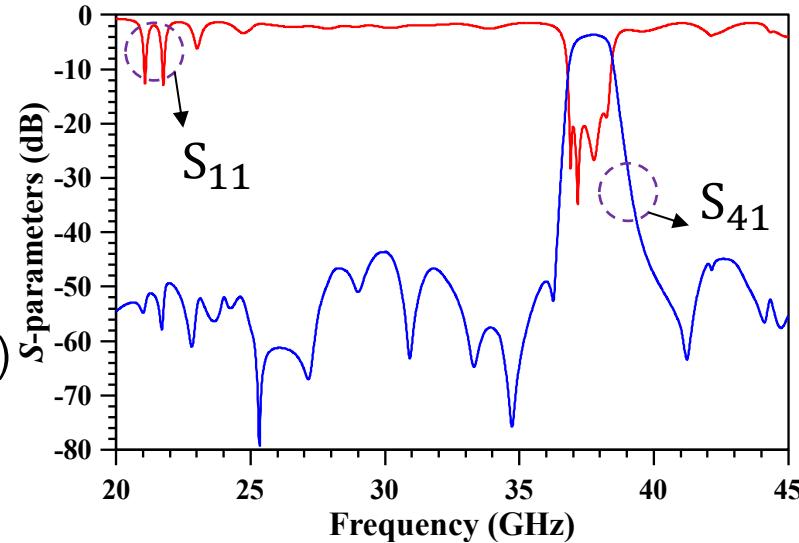


## Channel III

CF : 37.60 GHz

BW : 1.5 GHz (4%)  
 (36.85~38.85 GHz)

IL : 2.736 dB

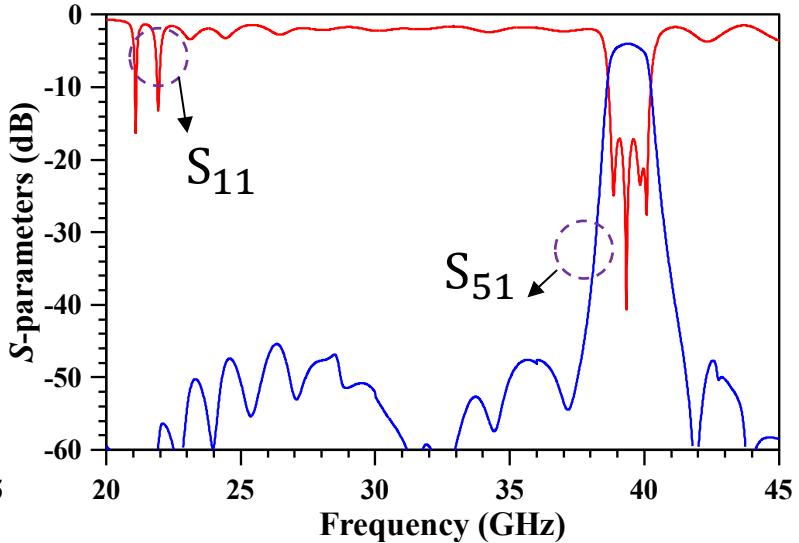


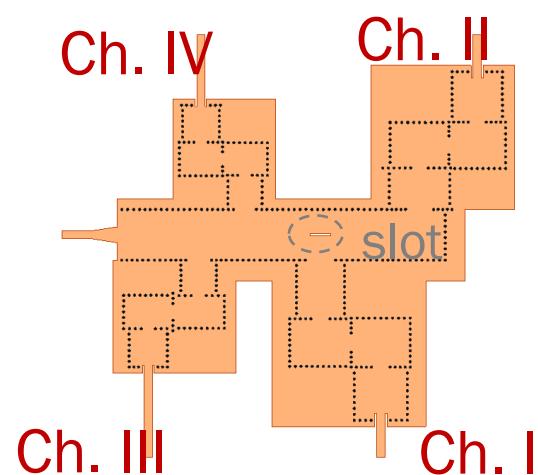
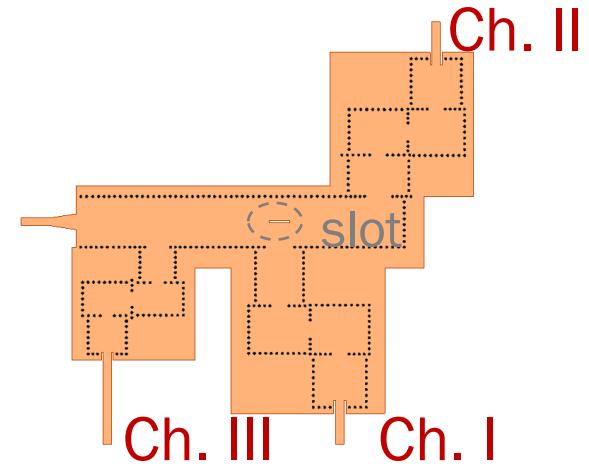
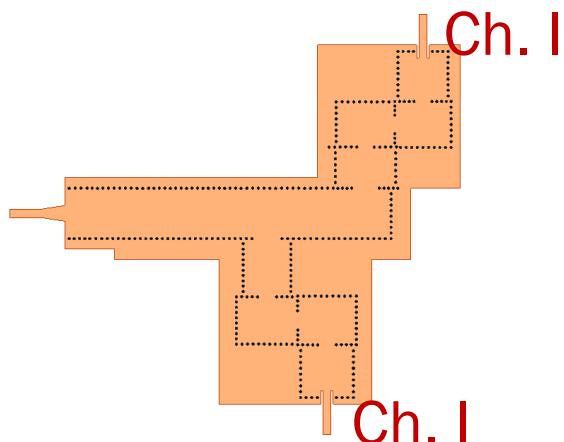
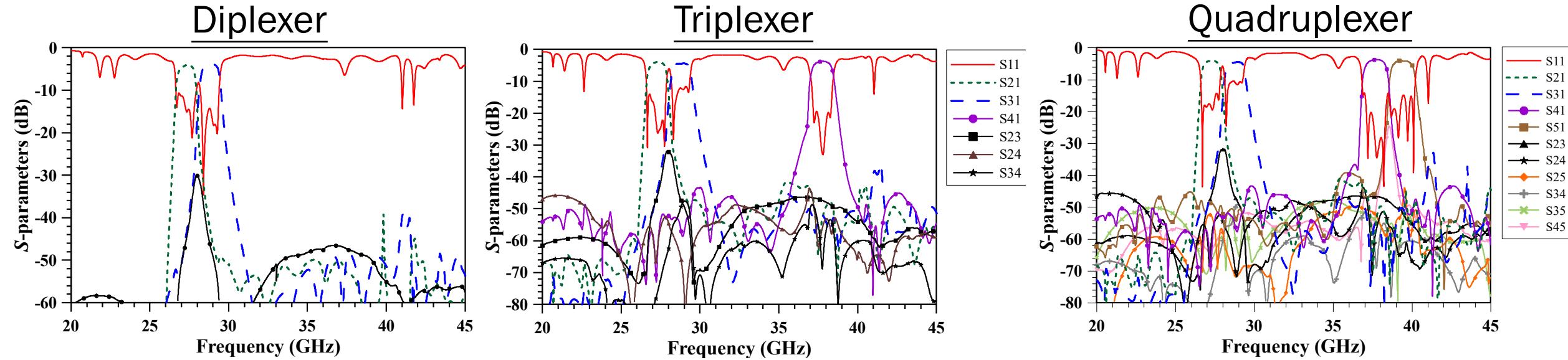
## Channel IV

CF : 39.40 GHz

BW : 1.09 GHz (4%)  
 (36.61~40.81 GHz)

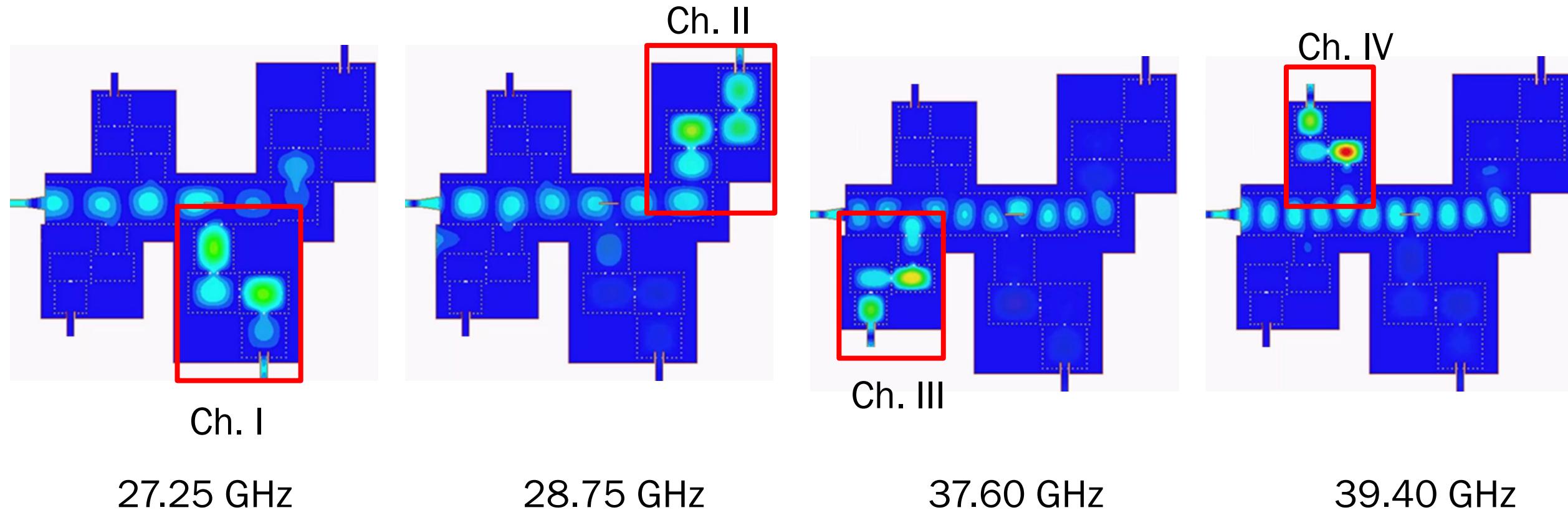
IL : 2.663 dB



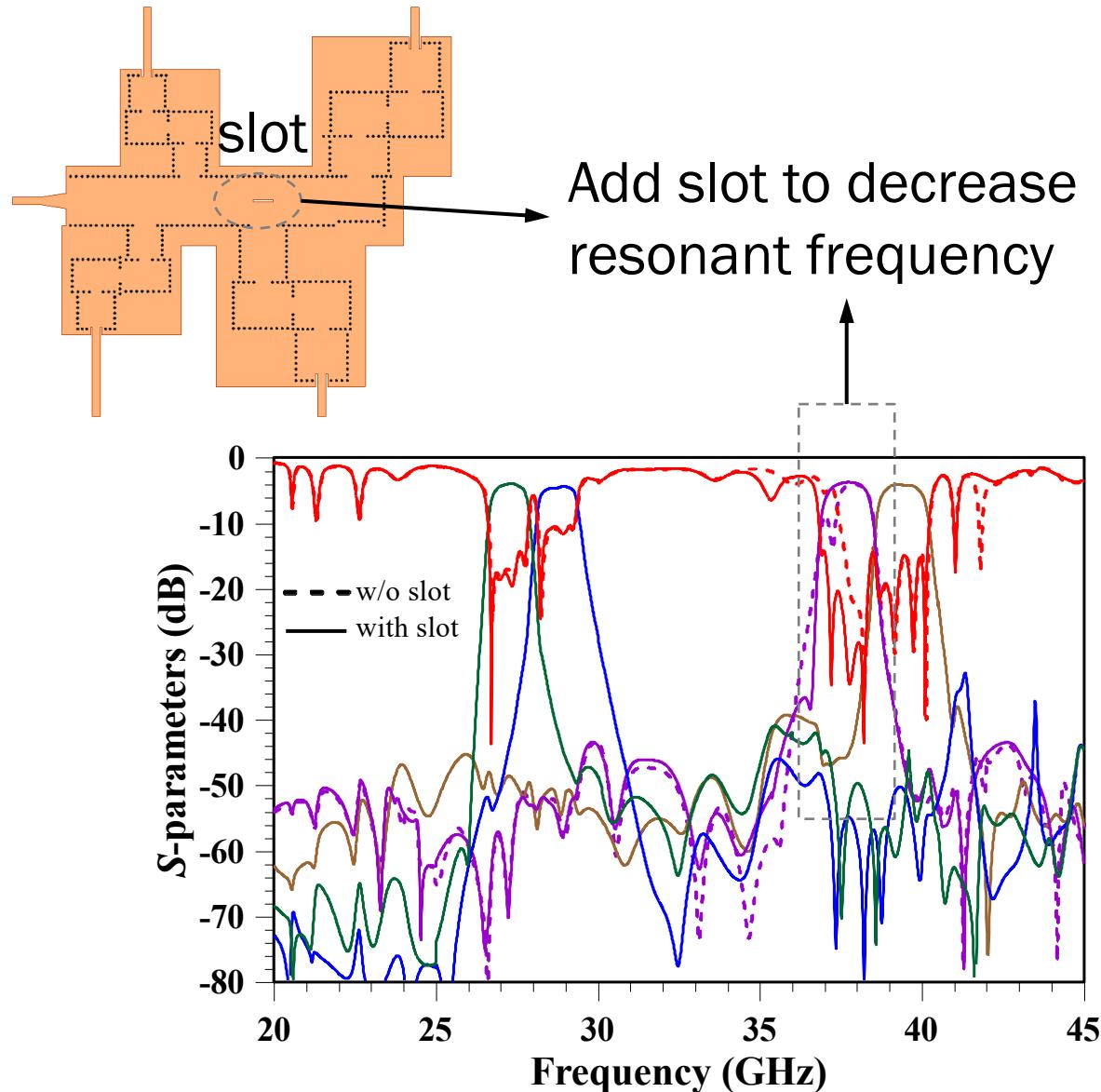


# Field Distribution

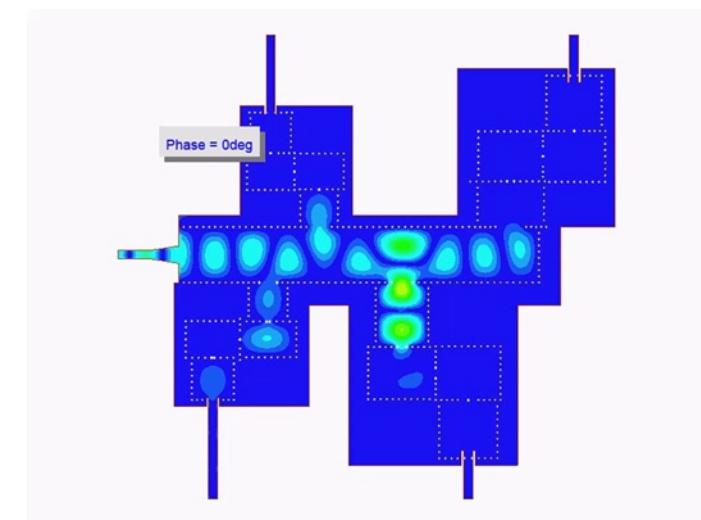
- For every channel



# Slot in SIW

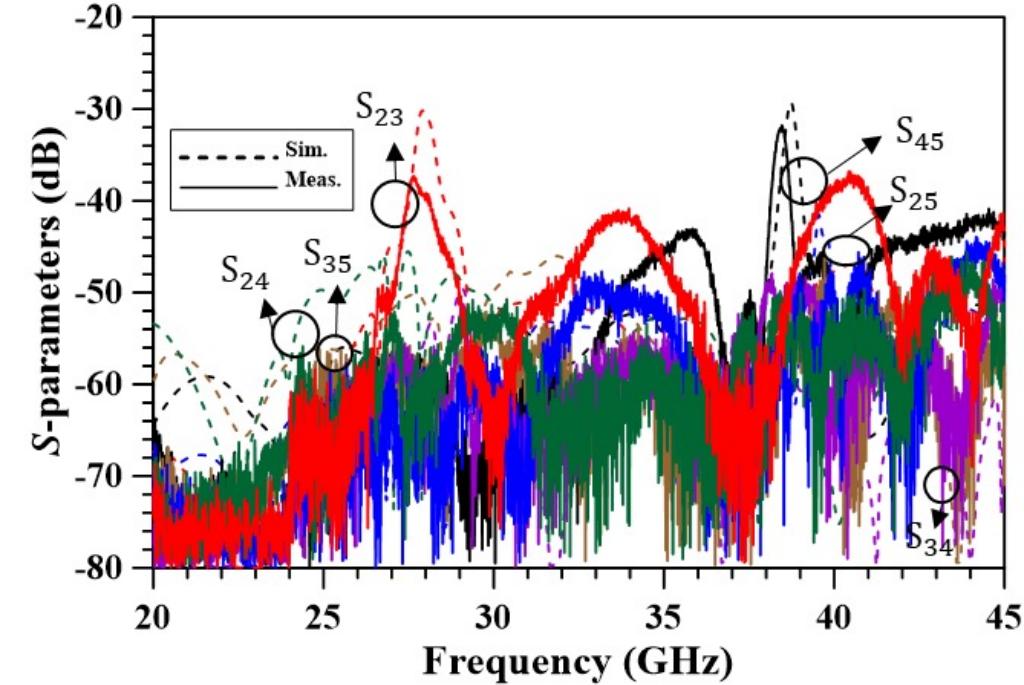
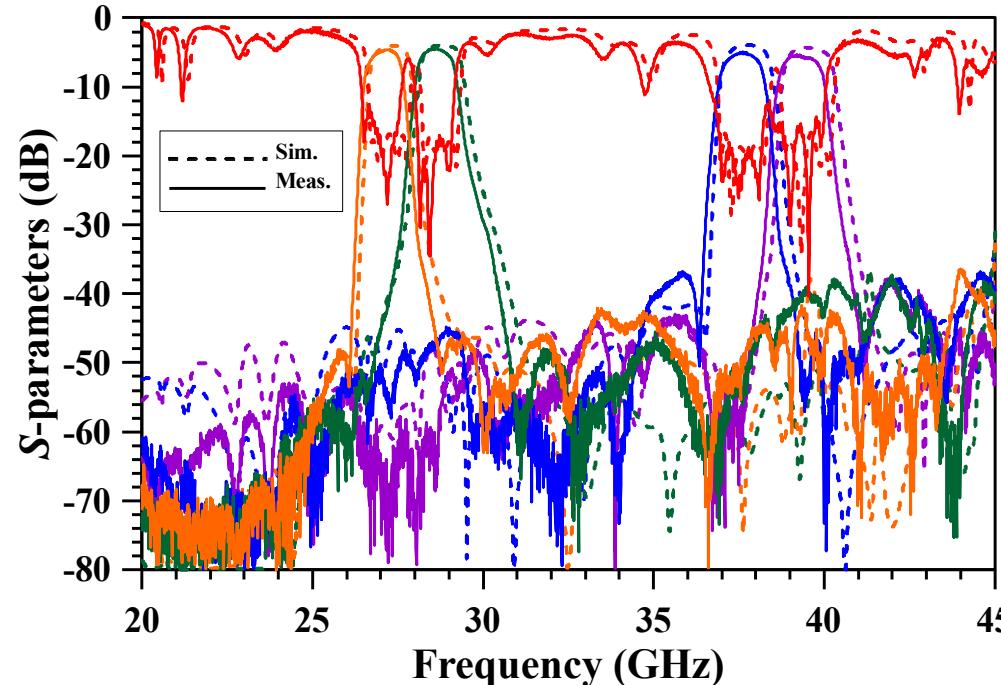


Resonance produced by SIC1 and waveguide at Channel I



E-Field @ 37.22GHz

# Measurement

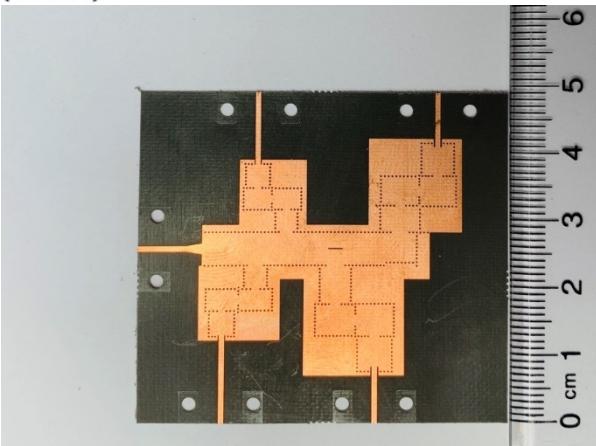
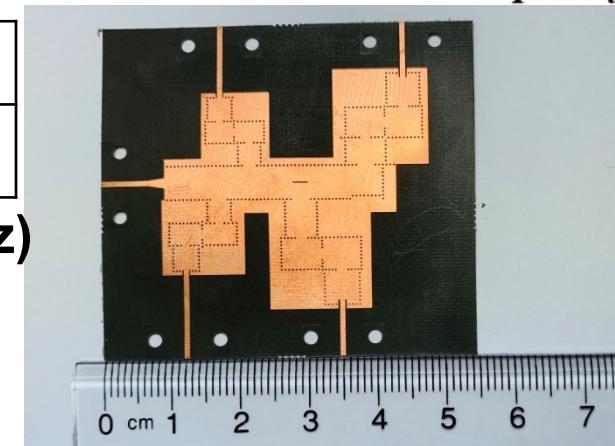


**Center frequency:** 27.10 28.63 37.60 39.33 (GHz)

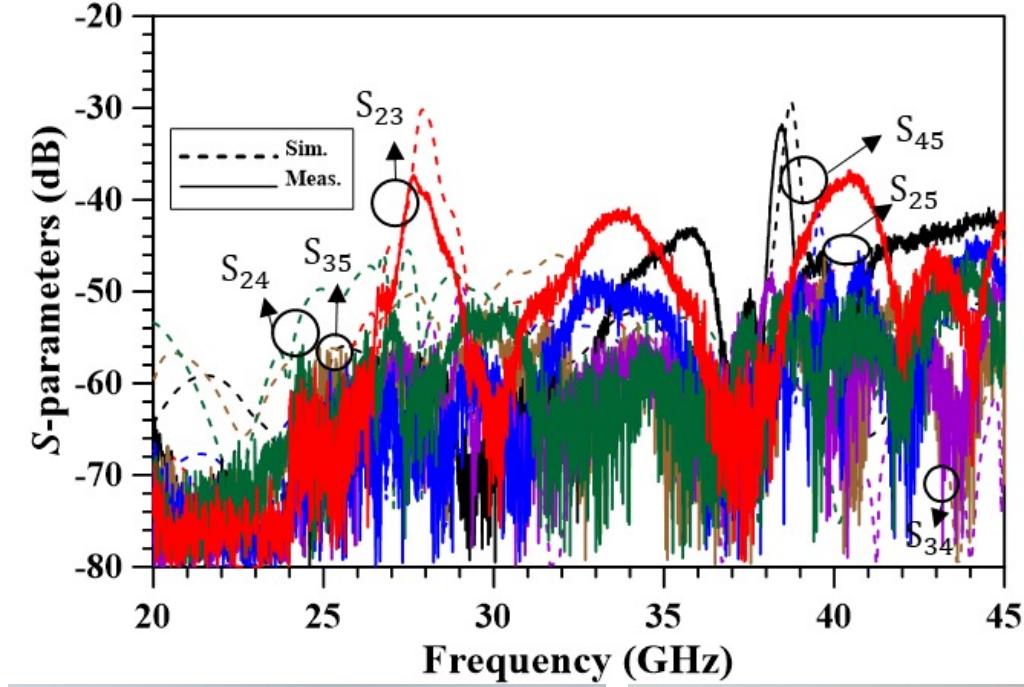
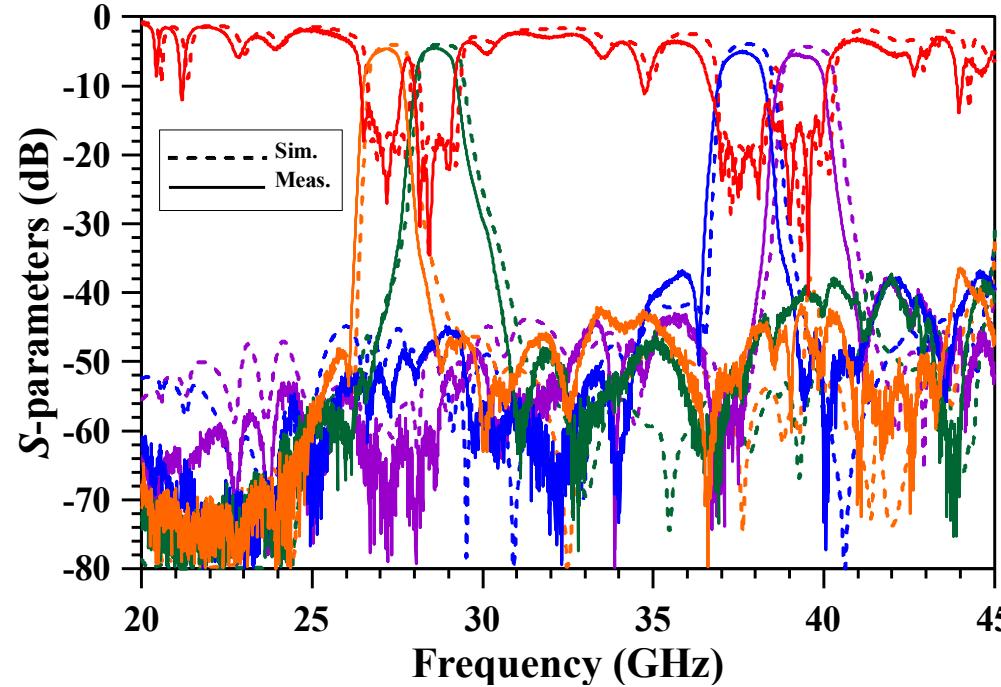
**Min. insertion loss:** 3.99 3.86 3.65 3.96 (dB)

**3-dB FBW:** 3.83% 3.81% 3.22% 3.25%

Without feedline
$5.52 \times 4.71 (\lambda_g^2)$



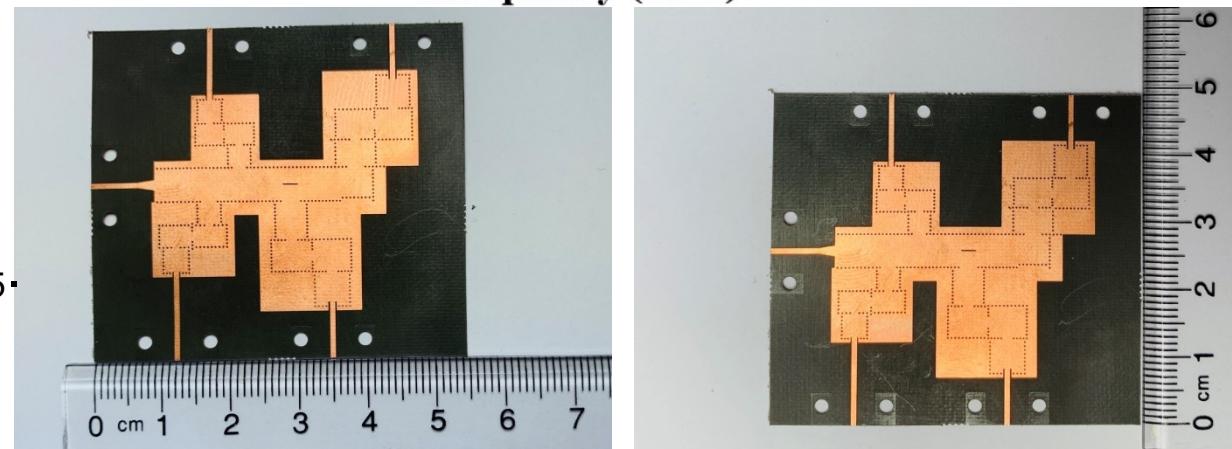
# Measurement



## In-band isolation:

>37.4 dB for  $S_{23}$ , >50.1 dB for  $S_{24}$ , >47.5 dB for  $S_{25}$ ,  
 >47.9 dB for  $S_{34}$ , >46.3 dB for  $S_{35}$ , and >37 dB for  $S_{45}$ .

Wideband isolation: >32 dB (20-45 GHz).



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# Comparison Table

	Feeding	Channels	Passband (GHz)	FBW (%)	IL (dB)	In-band isolation
This Work	Distributed feeding	4, quadruplexer	27.16/28.59/ 37.58/39.14	3.83/3.81/3.22/ 3.25	3.9/3.8/3.6/ 3.9	>37
[1]	T-Junction	2, diplexer	9.5/10.5	400 (MHz)	1.6/2.1	>35
[2]	T-Junction	2, diplexer	26.65/24.97	-	2.5/2	>40
[3]	T-Junction	4, quad-chan. diplexer	26.7/28.39/ 37.31/38.44	4.3/1.7/2.4/1.7	3.5/4.4/5.5/ 6.5	>34.7
[4]	T-Junction	2, diplexer	26.9/28.9	3 (0.1 ripple)	3.1/3	>51.2
[5]	Common triple-mode cavity	3, triplexer	11/12/13	2.62/2.86/3.42	1.82/1.84/1. 74	>20

# Reference

- [1] S. Sirci, J. D. Martínez, J. Vague, and V. E. Boria, "Substrate integrated waveguide diplexer based on circular triplet combline filters," *IEEE Microw. Wireless Compon. Lett.*, vol. 25, no. 7, pp. 430-432, Jul. 2015.
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- [7] N. Sielck, A. Sieganschin, K. Erkelenz, and A. F. Jacob, "A compact K-/Ka-band diplexer with dual-mode folded SIW cavities," *IEEE/MTT-S Int. Microw. Symp. Dig.*, Denver, CO, USA, Jun. 2022, pp. 472-474.

# Thank You!

## Q & A