Air-Filled Substrate Integrated Waveguide (AFSIW) Filter with Asymmetric Frequency Response

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Outline

- Motivation
- Air-Filled Substrate Integrated Waveguide (AFSIW)
- Asymmetric Response AFSIW Filter Topology
- Asymmetric Response AFSIW Filter Design
- Asymmetric Response AFSIW Filter Measurement
- Conclusion

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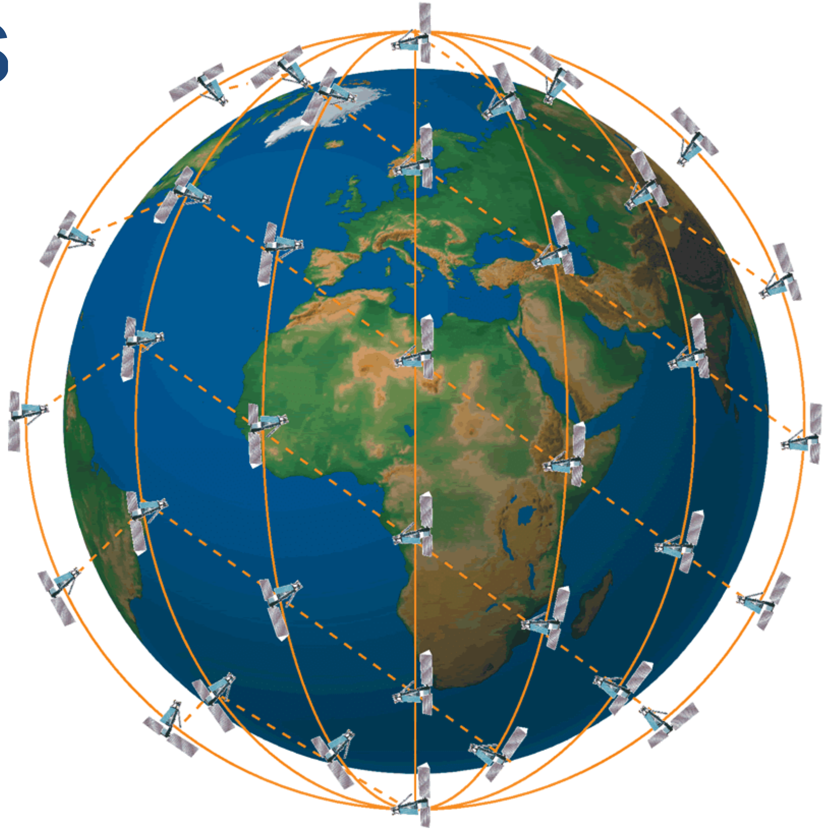
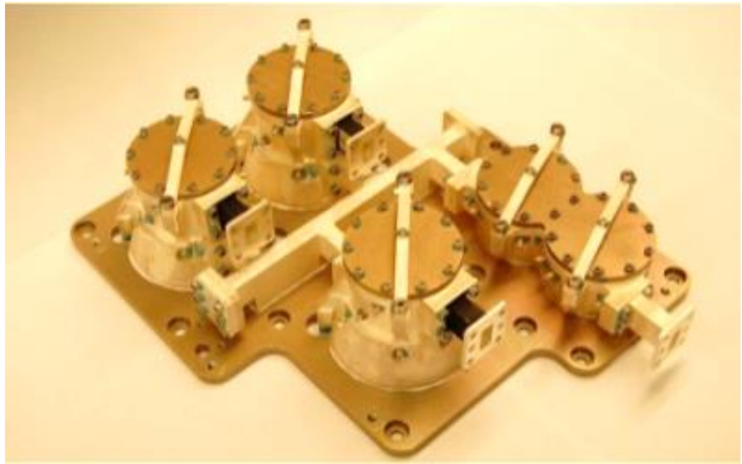
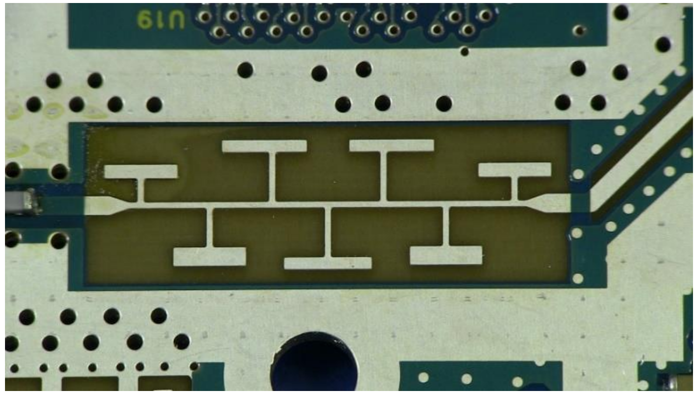
Emerging Space Applications



- Satellite constellations are essential for the new space
- Satellite payload configurations need MUX
- MUX are critical in terms of mass and volume
- Satellite constellations require low SWaP-C MUX
- Major objective is to reduce by 50% mass and volume
- Conventional high performance technologies are not suitable for mass production
- Critical need of an alternative technology



Conflicting Paradigm



Metallic Waveguides (non-planar)

- Low insertion loss
- High quality factor
- Self shielded
- High power handling

- High cost
- Not integrated
- High weight
- Complex manufacturing

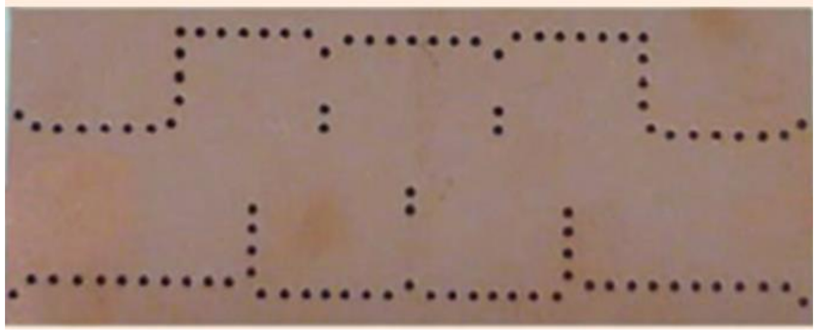
Technological Conflict

Printed Circuit Boards (planar)

- High insertion loss
- Low quality factor
- Shielding is mandatory
- Low power handling

- Low cost
- High integration density
- Low weight
- Standard manufacturing

SIW and AFSIW (High-Q SIW)

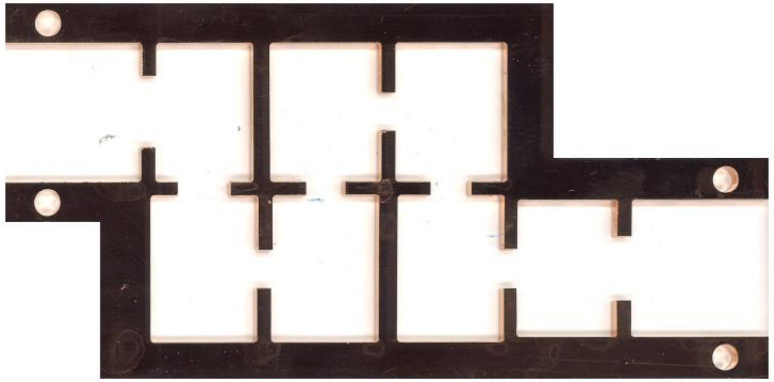


SIW

- Low cost
- High integration density
- Low weight
- Self shielded
- Compact

- Medium insertion loss
- Medium quality factor
- Medium power handling

Technological Alternatives

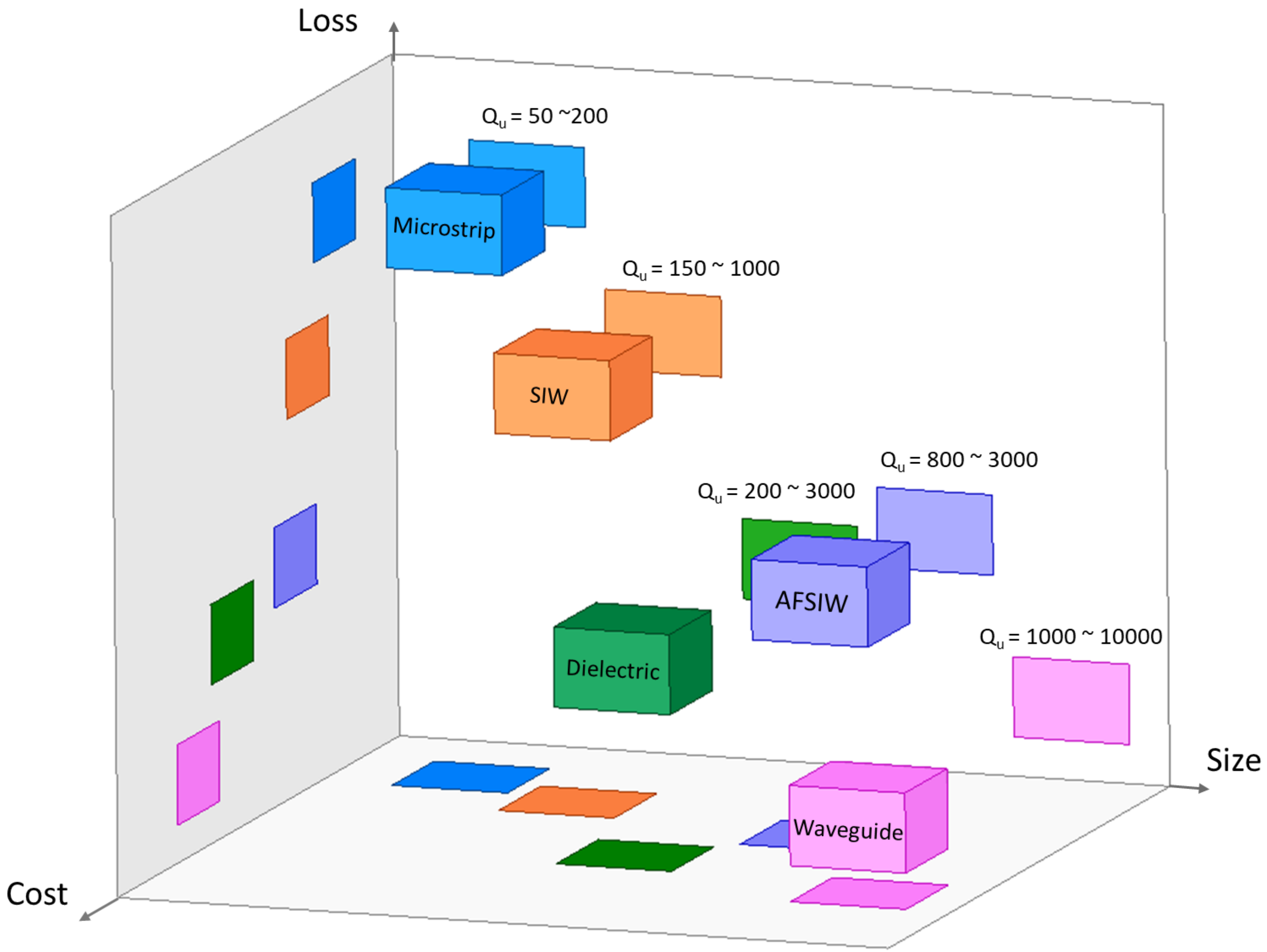


Air-Filled SIW

- Low cost
- High integration density
- Low weight
- Self shielded
- Low insertion loss
- High quality factor
- High power handling

- Less compact

Resonator Technologies



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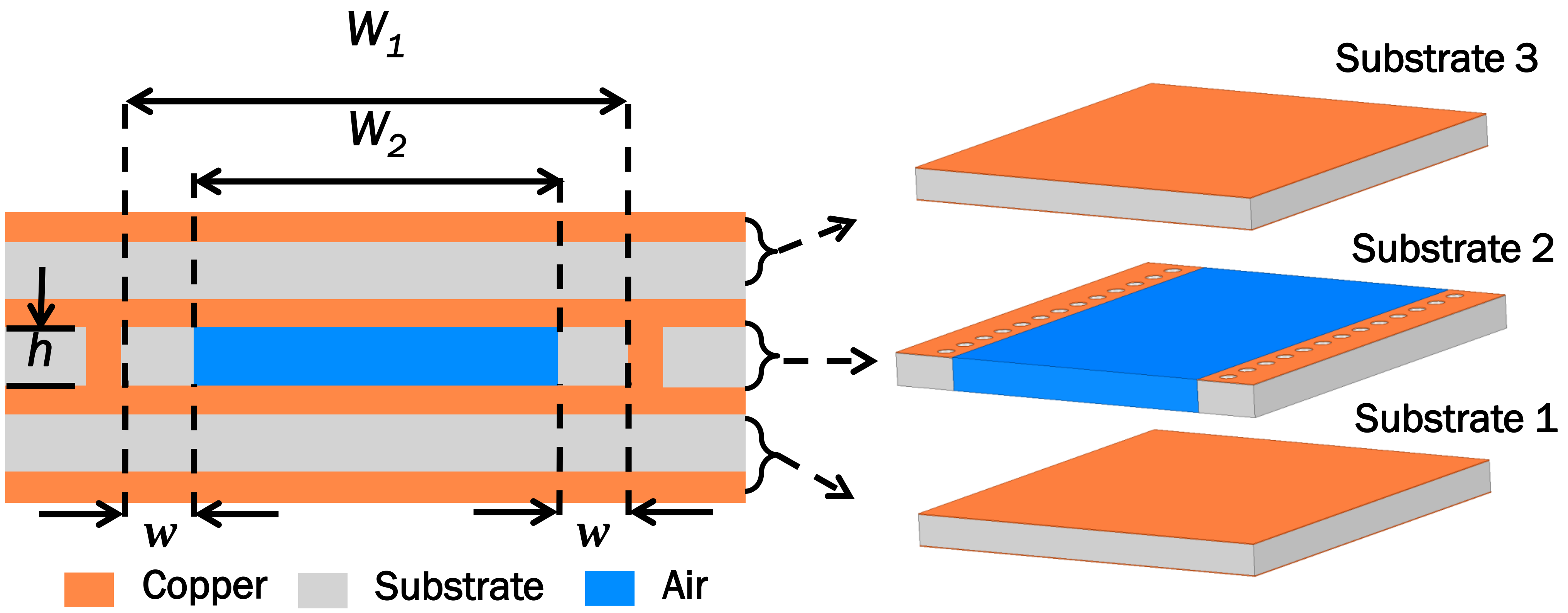
Air-Filled Substrate Integrated Waveguide

AFSIW structure with discontinuous electric walls



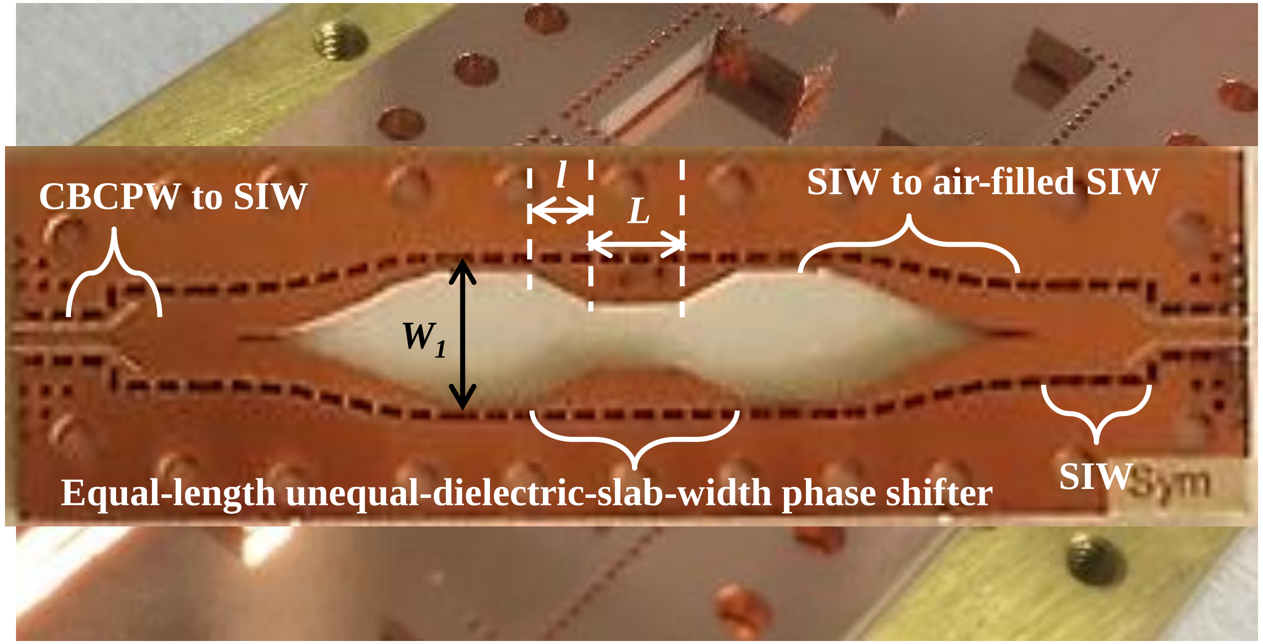
High degrees of freedom leading to creative designs

[1] F. Parment, A. Ghiotto, T.P. Vuong, J.M. Duchamp, and K. Wu, “Broadband transition from dielectric-filled to air-filled substrate integrated waveguide for low loss and high power handling millimeter-wave substrate integrated circuits,” in *Proc. IEEE MTT-S Int. Microw. Symp.*, pp. 1-4, Jun. 2014.

AFSIW Flexibility

Examples of creative designs taking advantage of the dielectric slab sidewalls

- Phase shifter [2]
- Compensated phase shifter [3]
- Thermally compensated filter [4]



[2] F. Parment, A. Ghiotto, T.P. Vuong, J.M. Duchamp, K. Wu, "Air-filled SIW transmission line and phase shifter for high performances and low-cost U-band integrated circuits and systems," *8th IEEE Global Symposium on Millimeter-Waves*, Montreal, 25-27 May. 2015.

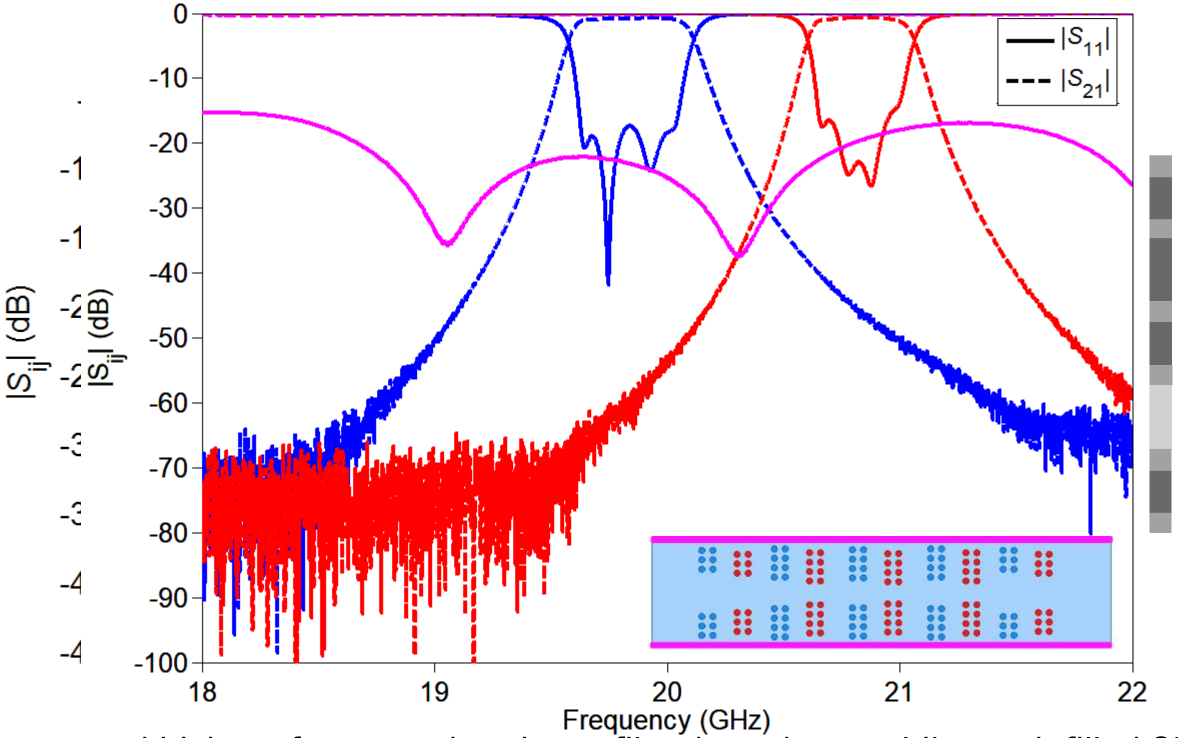
[3] F. Parment, A. Ghiotto, T.P. Vuong, J.M. Duchamp, and K. Wu, "Double dielectric slab-loaded air-filled SIW phase shifters for high-performance and low-cost millimeter-wave integration," *IEEE Transactions on Microwave Theory and Techniques*, vol. 64, no .9, pp. 2833-2842, Sept. 2016.

[4] T. Martin, A. Ghiotto, T. Vuong and F. Lotz, "Self-temperature-compensated air-filled substrate integrated waveguide cavities and filters," *IEEE Transactions on Microwave Theory and Techniques*, vol. 66, no. 8, pp. 3611-3621, Aug. 2018.

AFSIW Flexibility

Examples of creative designs taking advantage of the multilayer characteristic

- Compact bandpass filter [5]
- Post-process tuning [6]
- Configurable transmission line [7]



[5] F. Parment, A. Ghiotto, T.P. Vuong, J.M. Duchamp, and K. Wu, “Ka-band compact and high performance bandpass filter based on multilayer air-filled SIW,” in *IET Electronics Letters*, vol. 53, no .7, pp. 486-488, Mar. 2017.

[6] T. Martin, A. Ghiotto, T.P. Vuong, F. Lotz and P. Monteil, “High performance air-filled substrate integrated waveguide filter post-process tuning using capacitive post,” 2017 *IEEE MTT-S International Microwave Symposium*, Hawaii, Honolulu, 4-9 Jun. 2017, pp. 196-199.

[7] T. Martin, A. Ghiotto, F. Lotz and T. Vuong, “Fabrication-tolerant reconfigurable AFSIW filters based on through-hole mounted metallic posts for versatile high performance systems,” *2018 IEEE/MTT-S International Microwave Symposium - IMS*, Philadelphia, PA, 2018, pp. 319-322.

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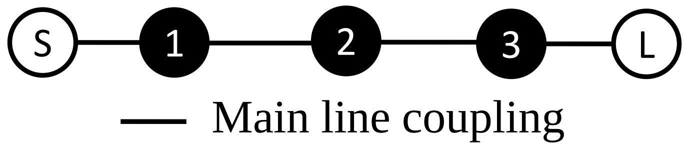
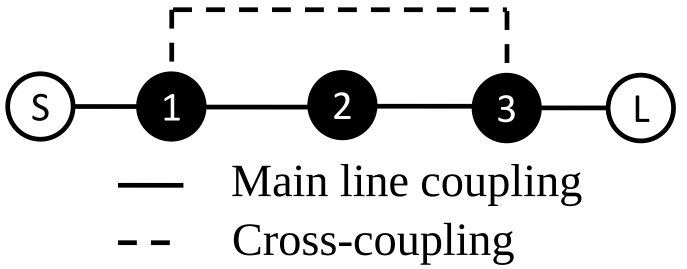
Asymmetric Response Filter

3rd Order Pseudo-Elliptic Filter Response

Conventional Chebyshev response



Pseudo-elliptic response

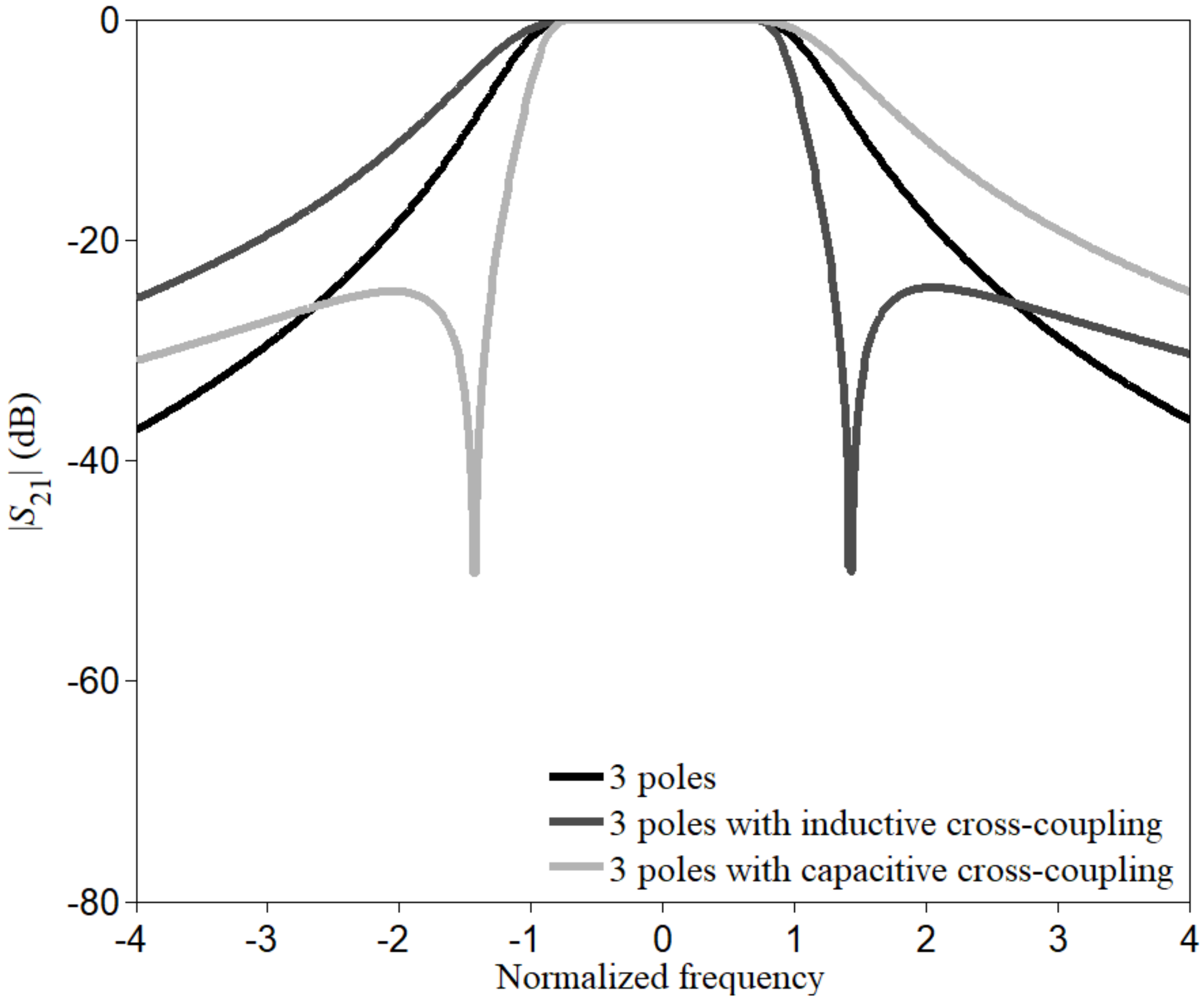


Inductive cross-coupling

- Rejection above passband is increased
- Rejection below passband is increased

Capacitive cross-coupling

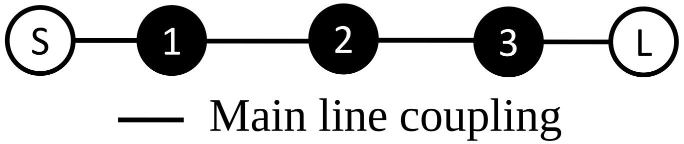
- Rejection below passband is increased
- Rejection above passband is increased



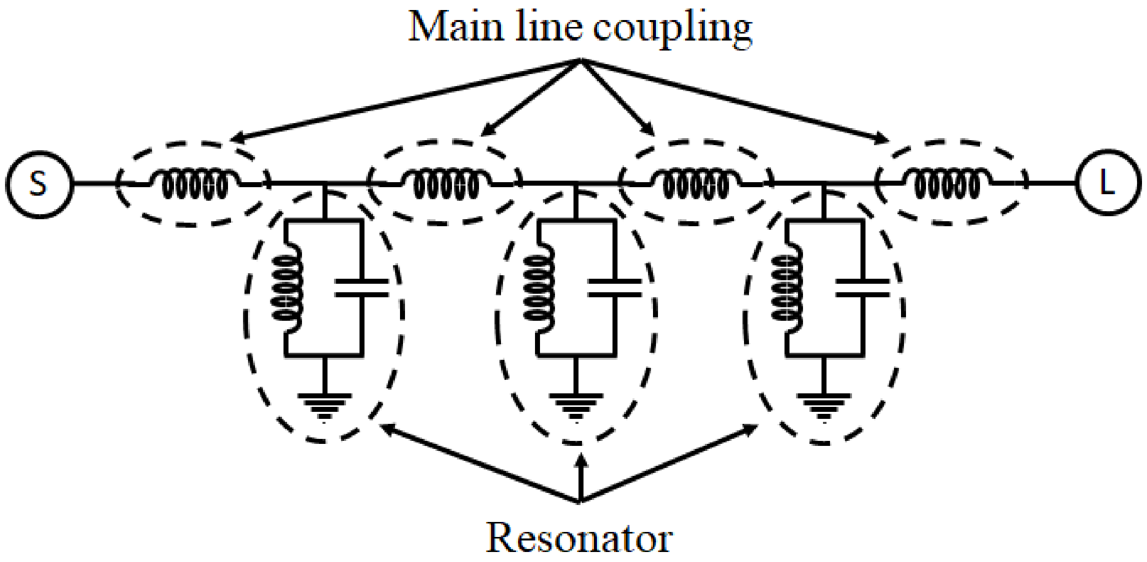
Asymmetric Response Filter

3rd Order Pseudo-Elliptic Filter Response

Coupling scheme

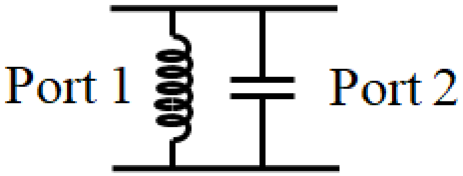


Topology using AFSIW



Phase relationships

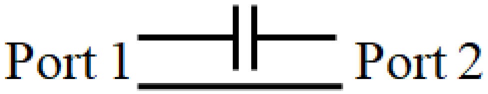
φ_{21} represents the phase of S_{21}



$\varphi_{21} \approx +90\,°$ (below resonance)

$\varphi_{21} \approx -90\,°$ (above resonance)

$\varphi_{21} \approx -90\,°$

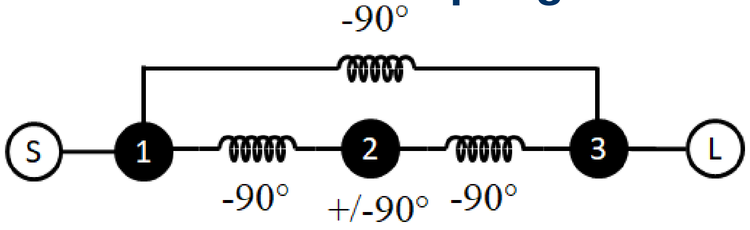


$\varphi_{21} \approx +90\,°$

Asymmetric Response Filter

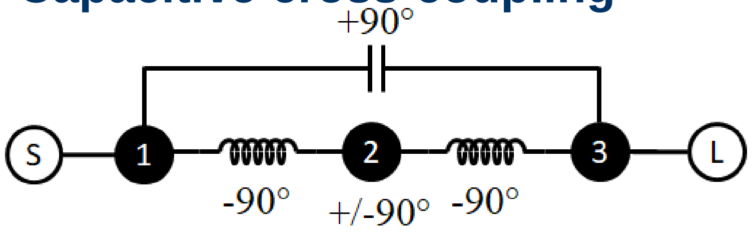
3rd Order Pseudo-Elliptic Filter Response Coupling Diagram

Inductive cross-coupling

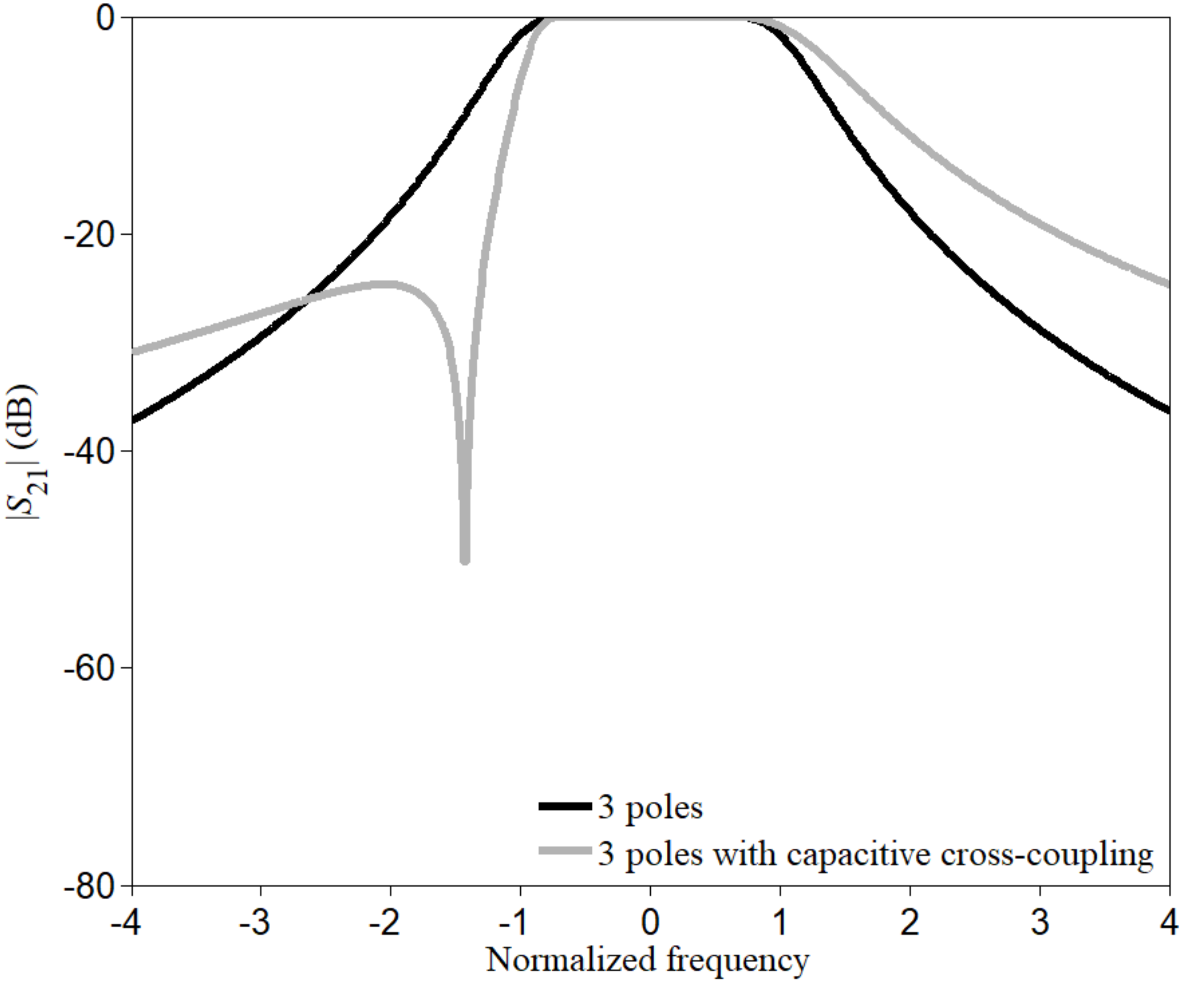


Total phase shift	Below resonance	Above resonance
Path 1-2-3	-90°	-270°
Path 1-3	-90°	-90°
Result	In phase	Out of phase
Tz	No	Yes

Capacitive cross-coupling



Total phase shift	Below resonance	Above resonance
Path 1-2-3	-90°	-270°
Path 1-3	+90°	+90°
Result	Out of phase	In phase
Tz	Yes	No



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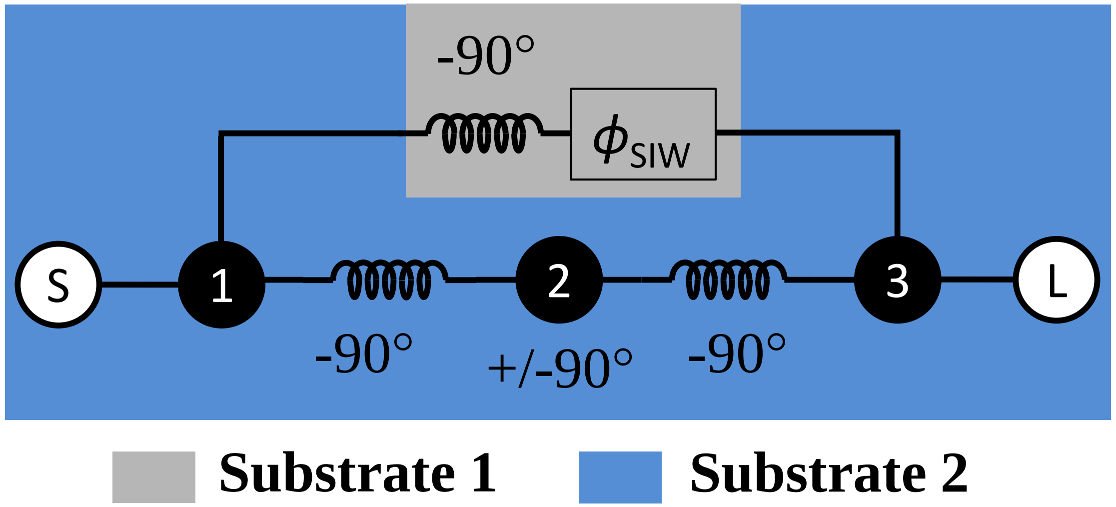
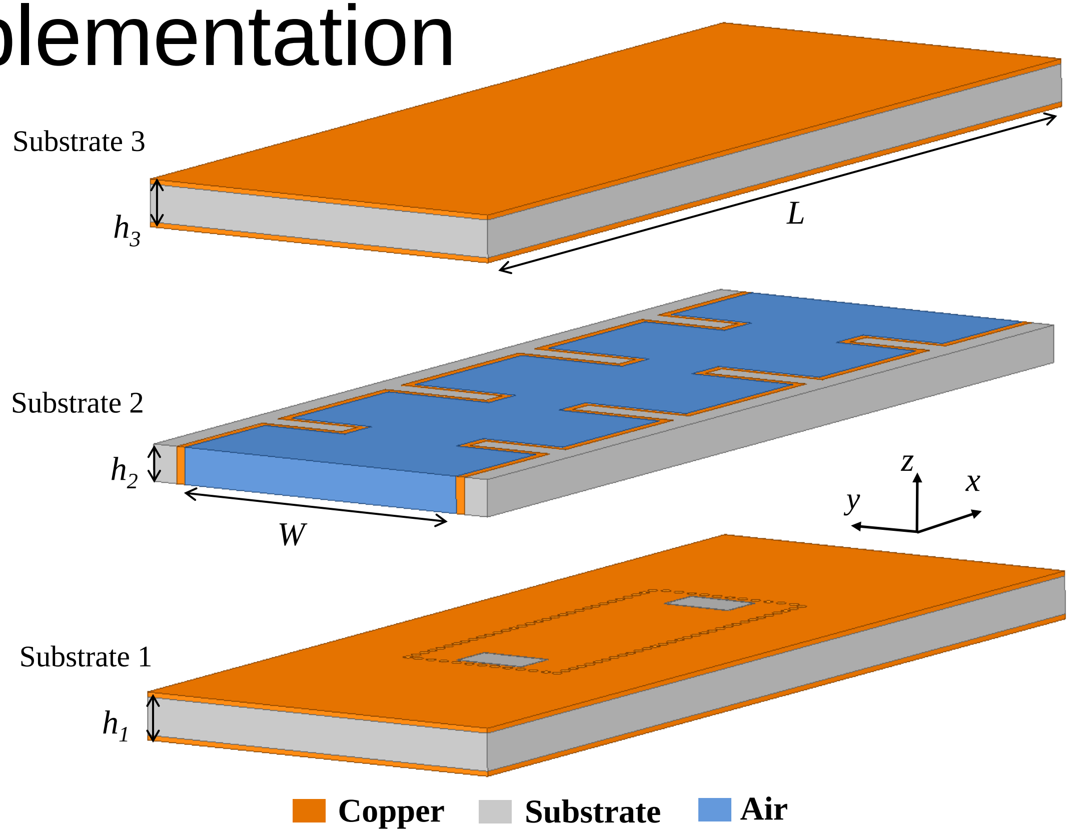
Asymmetric Response Filter

3rd Order Pseudo-Elliptic Filter Implementation

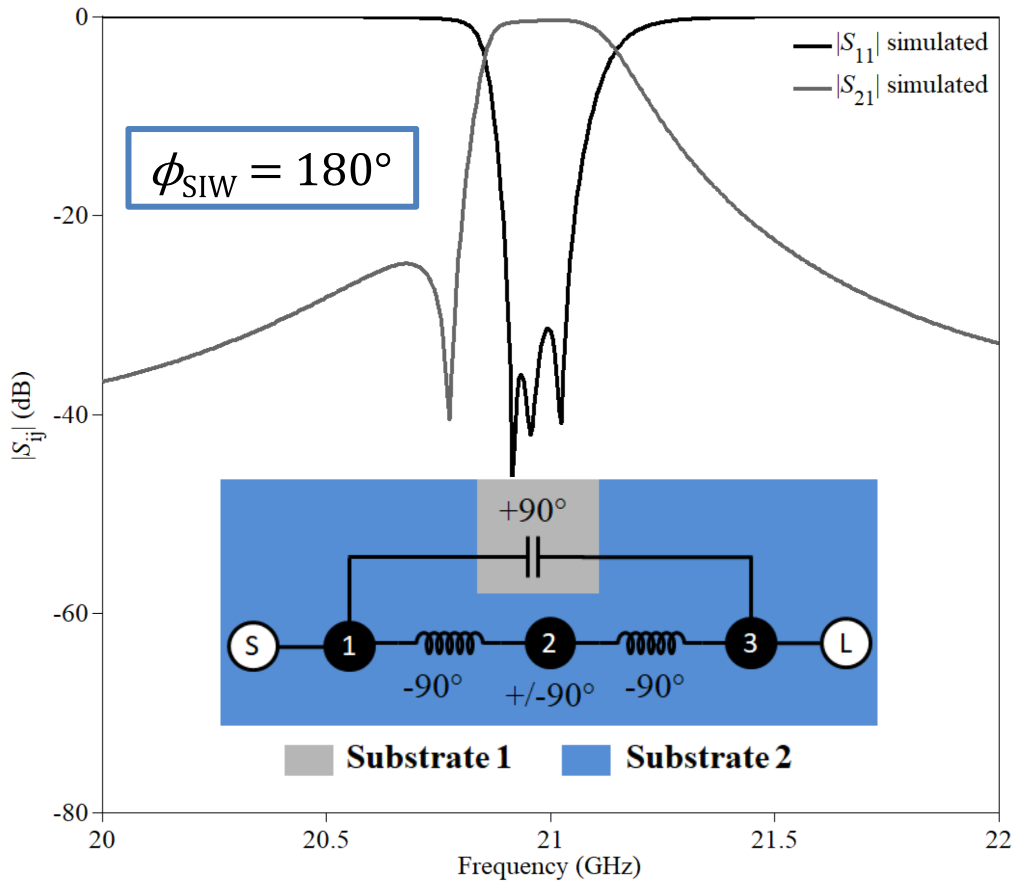


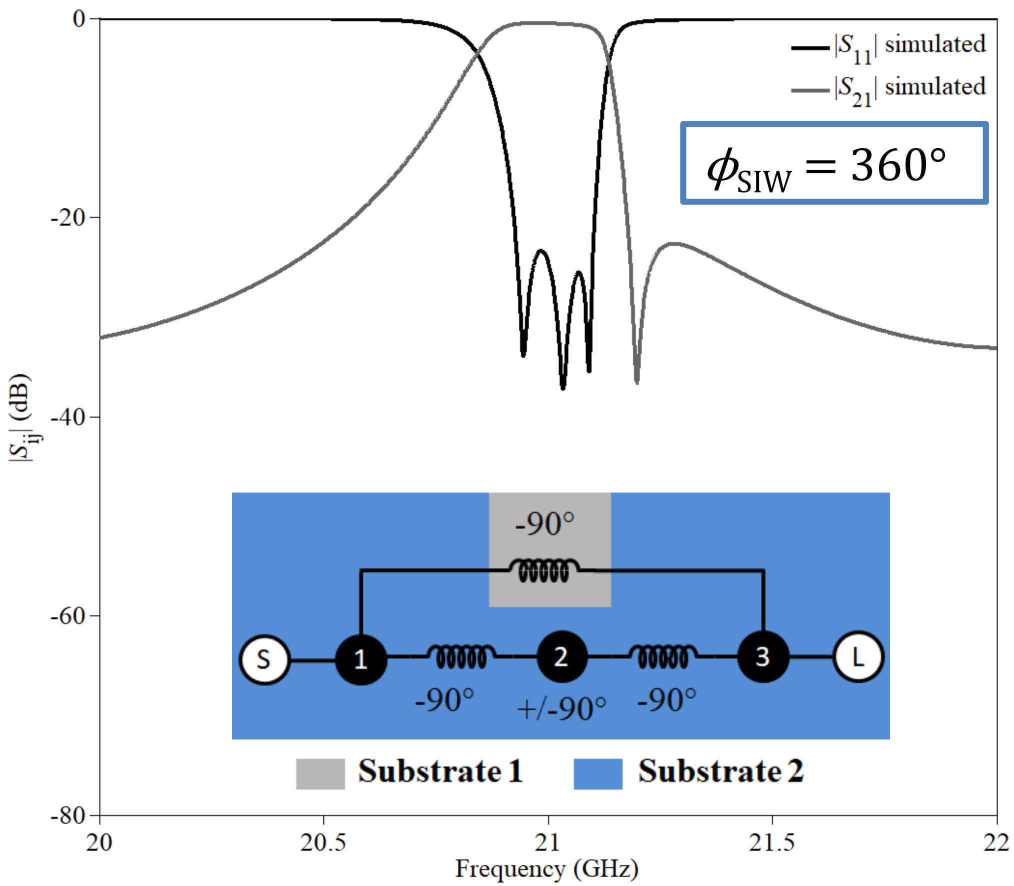


- Primary path implemented in the inner substrate (substrate 2)
- Secondary path implemented in the bottom substrate (substrate 1)
- Cross-coupling implemented through etched inductive iris and SIW transmission line

Asymmetric Response Filter

3rd Order Pseudo-Elliptic Filter Flexibility





- Controllable electrical length ϕ_{SIW}
- Flexible response

- Easy Implementation
- PCB standards

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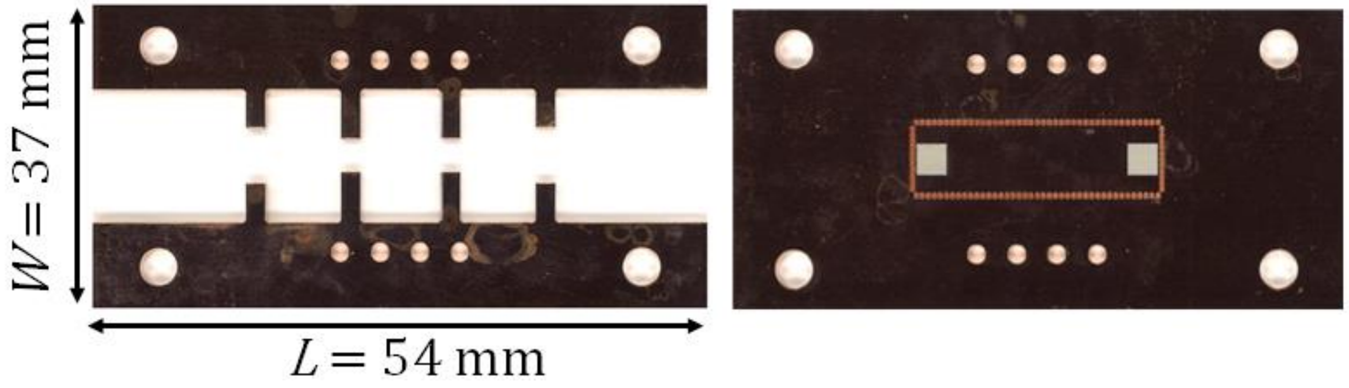
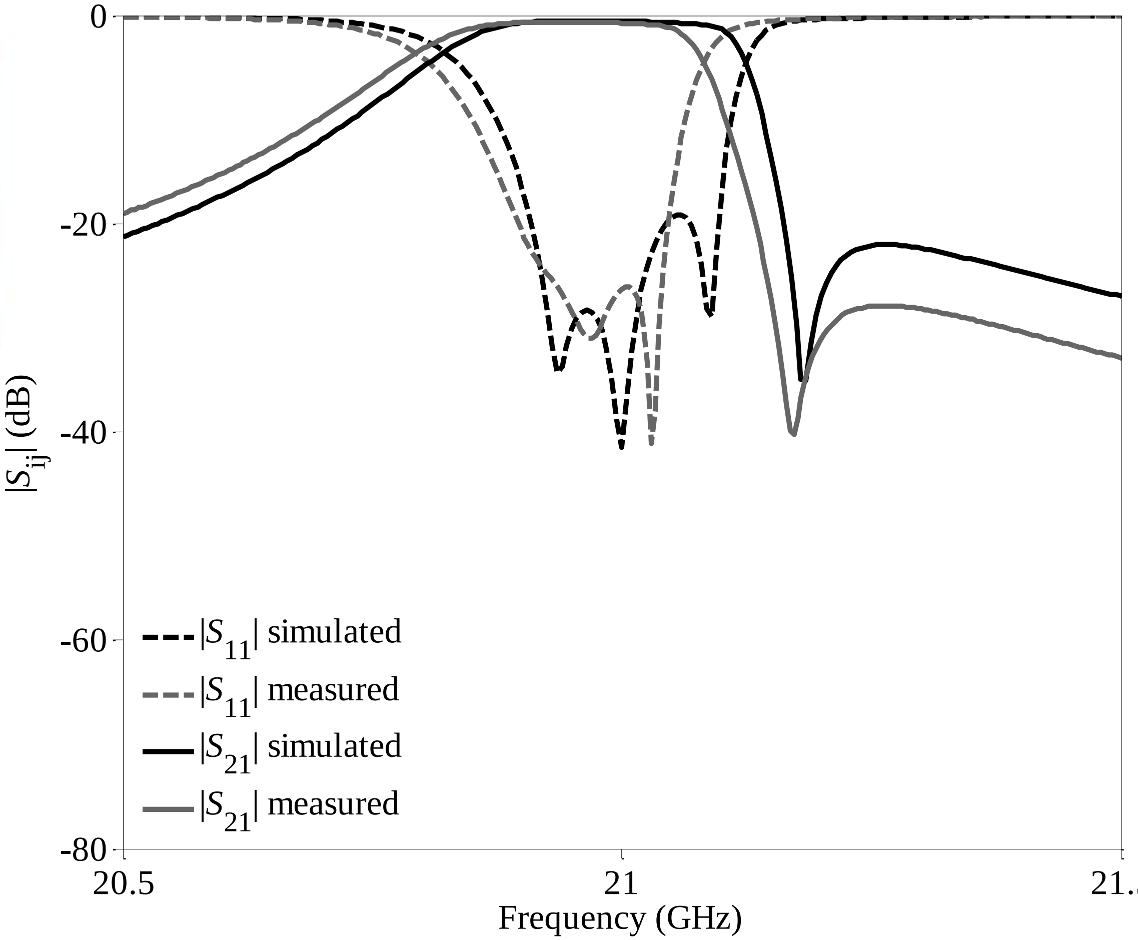
Advanced Filter Responses

Manufactured 3rd Order Pseudo-Elliptic Filter

Capacitive cross-coupling





Characteristics	Simulated (HFSS)	Measured
Return loss (dB)	> 22	> 22
Insertion loss (dB)	0.54	0.66
Center frequency (GHz)	21	20.96
Rejection frequency (GHz)	21.17	21.18
-3 dB bandwidth (MHz)	300	290
-3 dB bandwidth (%)	1.43	1.38
Unloaded *Q*-factor	1689	1429

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Thank you for your attention

Questions?