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Metal-Dielectric Coaxial (MDC) Dual-mode Resonator for Compact Inline Bandpass Filter

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Outline

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- MDC Dual-mode Resonator
- Inline Quadruplet and Triplet Sections
- Design Examples
- Summary

Introduction

The metallic coaxial filter still dominates existing market for 5G BTS due to its:

- Mature production process (low cost)
- Relatively high *Q*-factor (low loss)
- Flexibility in realizing cross-couplings

Few effective solutions for its:

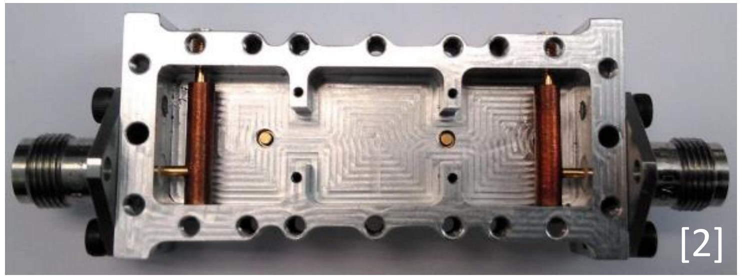
- Further miniaturization
- Inline configuration for layout simplicity

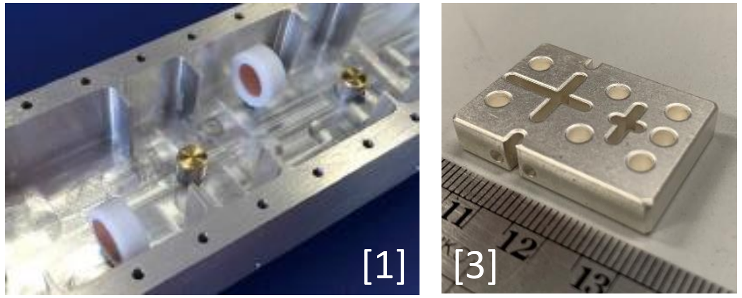
Metallic coaxial filter for BTS with “mushroom” structure

Introduction

Except for degenerate multi-mode resonator, employing two or more dissimilar modes in one physical cavity was developed recently.

- The size reduction can be maximized (if the dissimilar modes are all fundamental modes)
- The high-order resonances related to each dissimilar mode can be staggered to achieve a improved spurious performance[4]





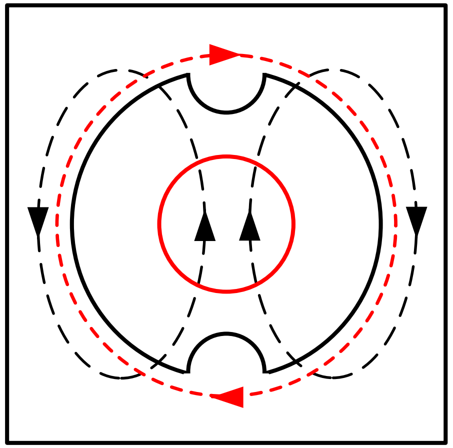
Miniature resonators with dissimilar modes[1]-[3]

[1] C. Tomassoni, S. Bastioli, and R. V. Snyder, "Propagating waveguide filters using dielectric resonators," *IEEE Trans. Microw. Theory Techn.*, vol. 63, no. 12, pp. 4366–4375, Dec. 2015.
[2] A. A. San-Blas, M. Guglielmi, J. C. Melgarejo, A. Coves and V. E. Boria, "Design procedure for bandpass filters based on integrated coaxial and rectangular waveguide resonators," *IEEE Trans. Microw. Theory Techn.*, vol. 68, no. 10, pp. 4390-4404, Oct. 2020.
[3] Y. Chen, Y. Zhang, and K.-L. Wu, "A dual-mode monoblock dielectric bandpass filter using dissimilar fundamental modes," *IEEE Trans. Microw. Theory Techn.*, vol. 69, no. 8, pp. 3811–3819, Aug. 2021.
[4] C. Wang, K. A. Zaki, A. E. Atia, and T. G. Dolan, "Conductor loaded resonator filters with wide spurious-free stopbands," *IEEE Trans. Microw. Theory Tech.*, vol. 45, no. 12, pp. 2387–2392, Dec. 1997.

MDC Dual-mode Resonator

Basic structure

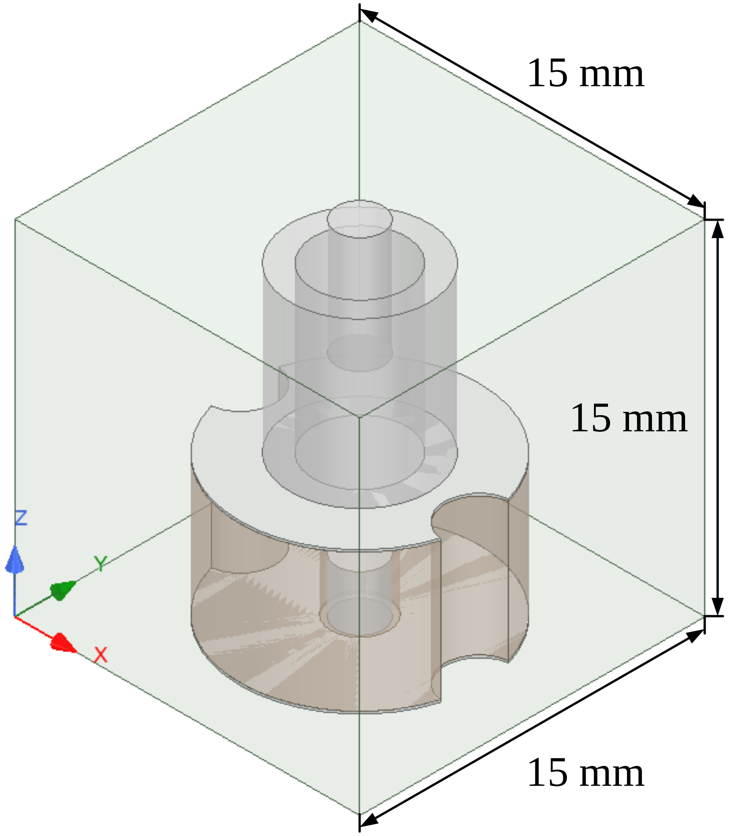
- Metallized air cavity
- Metallic hollow cylinder: supports TEM mode
- Dielectric puck: supports one HE_{11} mode (the other HE_{11} mode is pushed away)



Magnetic field sketch

Eigenmode	Frequency (GHz)	Q	
Mode 1	3.56639 +j 0.00113858	1566.16	HE_{11a}
Mode 2	3.61651 +j 0.00100547	1798.41	TEM
Mode 3	3.91012 +j 0.00110379	1771.22	HE_{11b}
Mode 4	5.55660 +j 0.00130212	2133.67	
Mode 5	5.73910 +j 0.00179335	1600.10	
Mode 6	5.80478 +j 0.00178315	1627.68	
Mode 7	5.97382 +j 0.00119637	2496.64	

EM eigenmode analysis

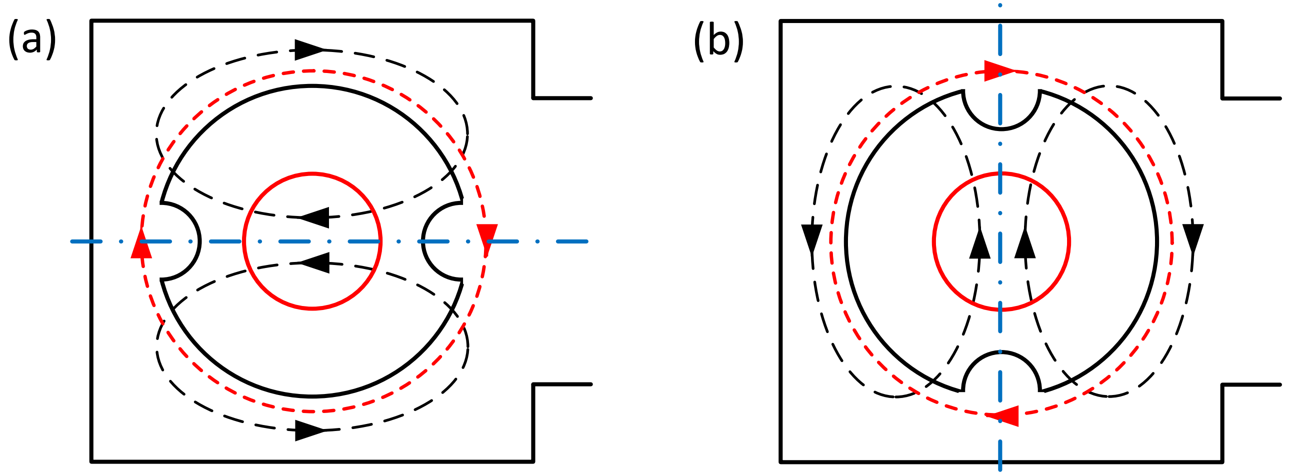


Proposed MDC resonator
(ε_r = 39.5, tan δ = 5e-5, and σ = 2e7 S/m for EM analysis)

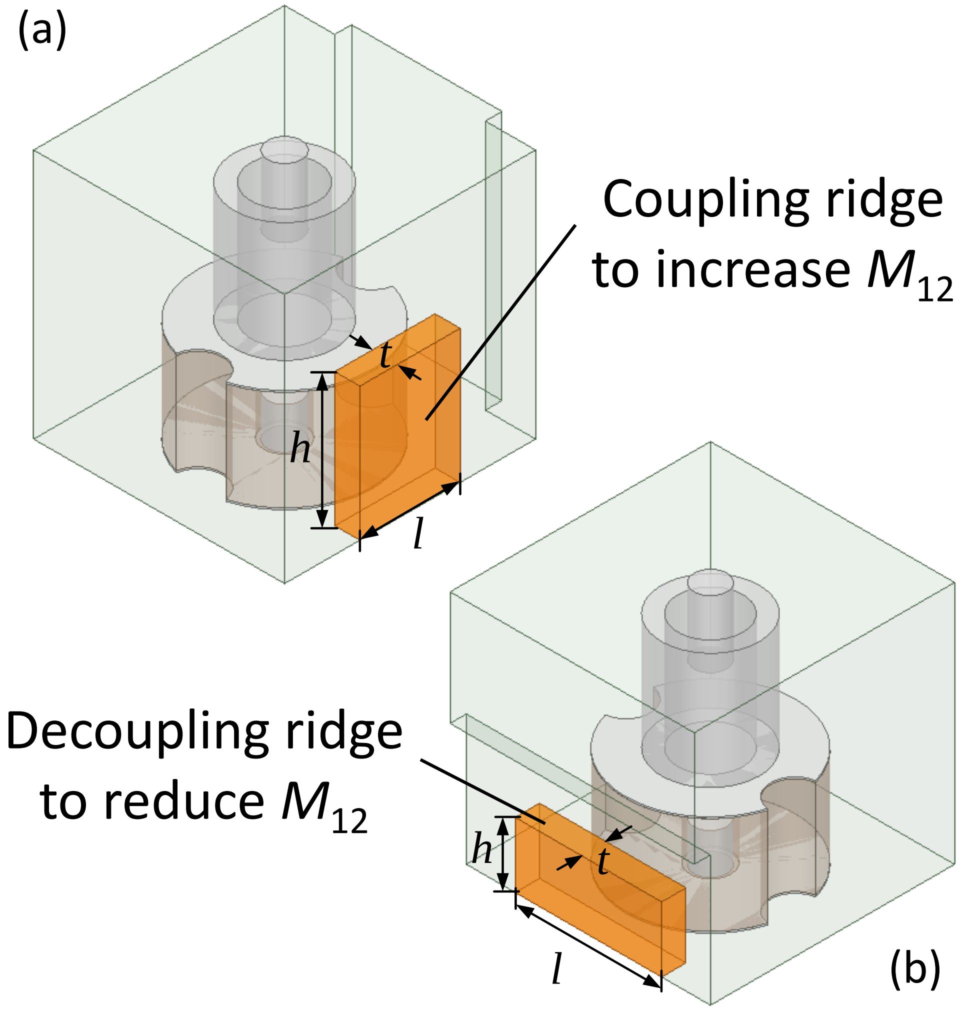
MDC Dual-mode Resonator

Control of Dual-mode Coupling

- Original dual-mode coupling is zero
- To realize a high-order filter, the effect of coupling window must be considered



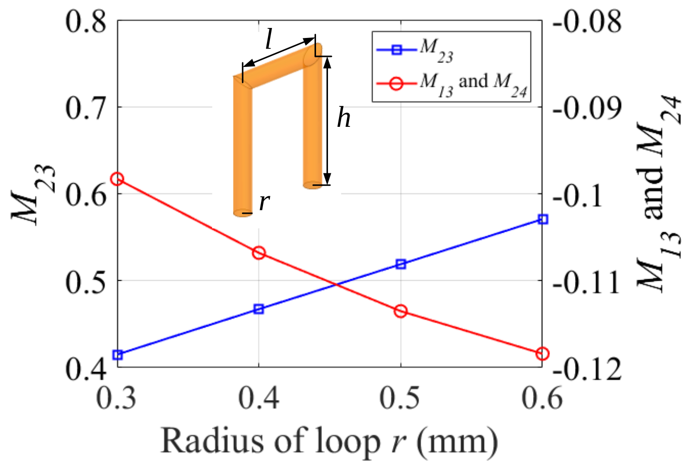
Arrangement with $M_{12} = 0$ Arrangement with $M_{12} \neq 0$



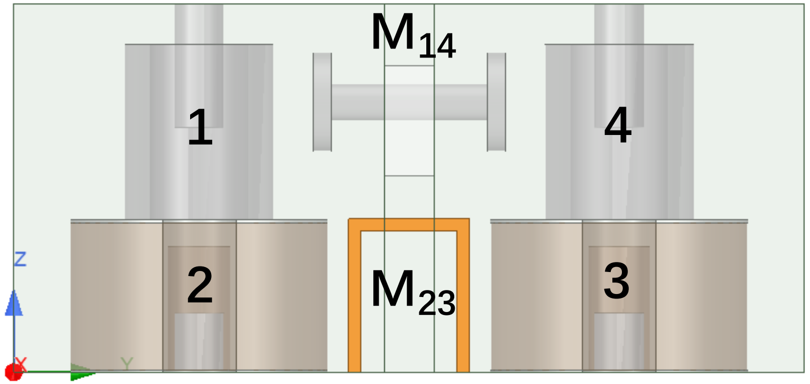
Possible Coupling Sections

A Inline quadruplet section

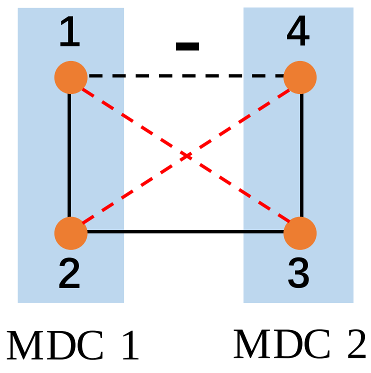
- HE_{11b} mode is further suppressed
- One TZ on each side of passband is realized
- A grounded double loop can increase inline coupling while reduce diagonal couplings



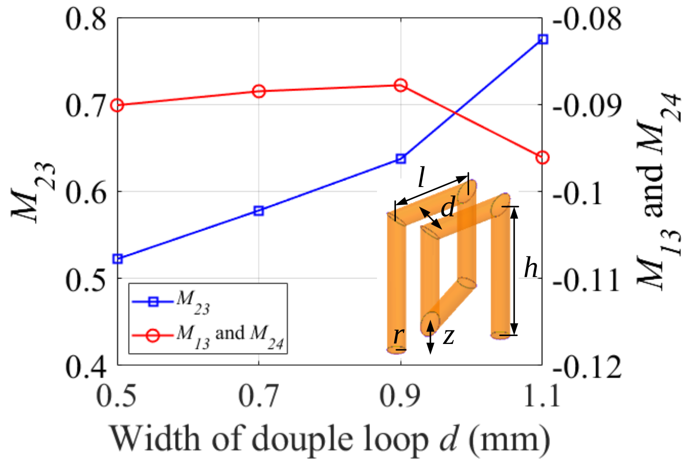
Single loop (h = 6 mm and l = 4.2 mm)



EM model of quadruplet section



Coupling diagram

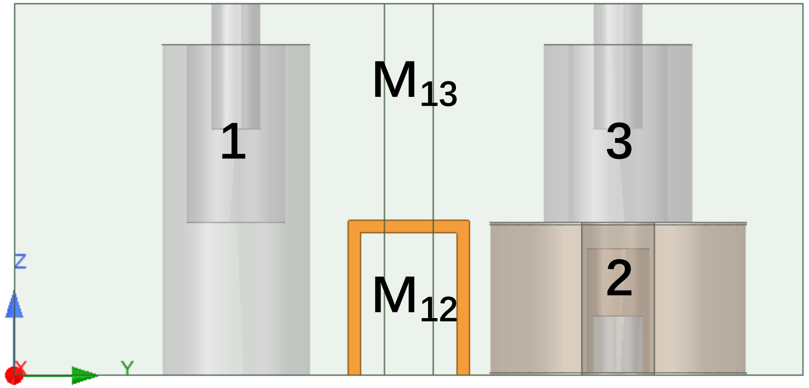


Double loop (r = 0.3 mm and z = 1.5 mm)

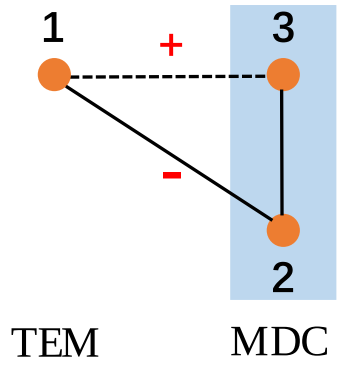
Possible Coupling Sections

A Inline triplet section

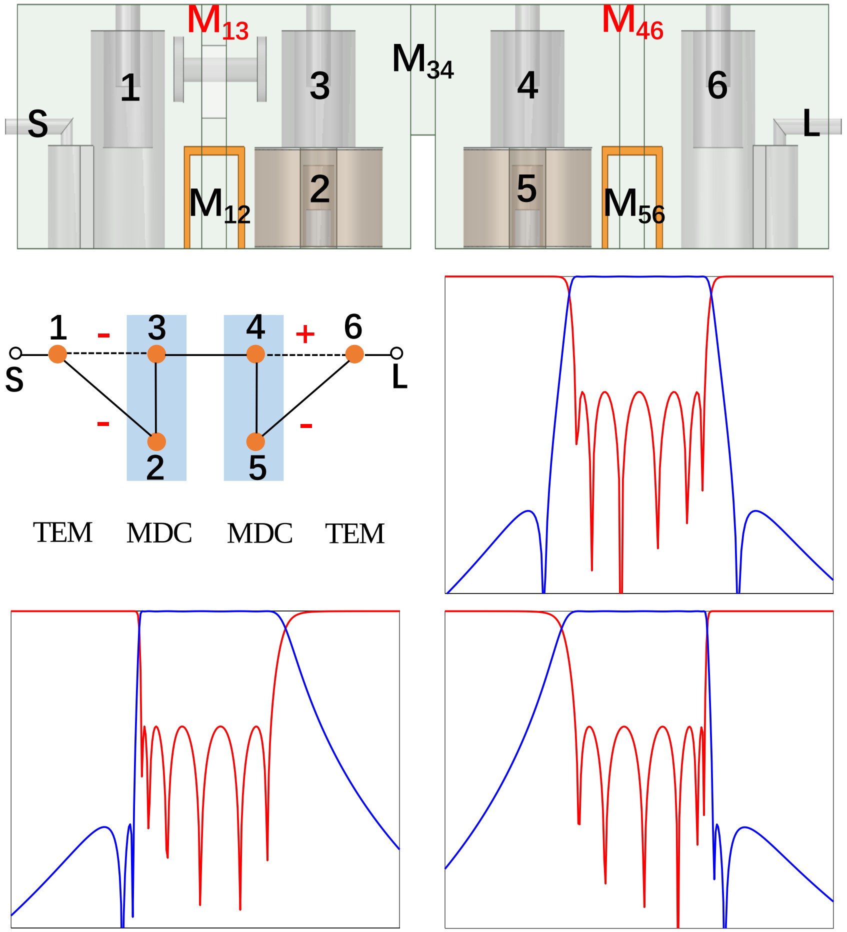
- One single-mode cavity + one MDC cavity
- One TZ can be on either side of passband
- Larger inline coupling M_{12} can be realized by coupling single TEM mode and HE_{11a} mode



EM model of triplet section



Coupling diagram

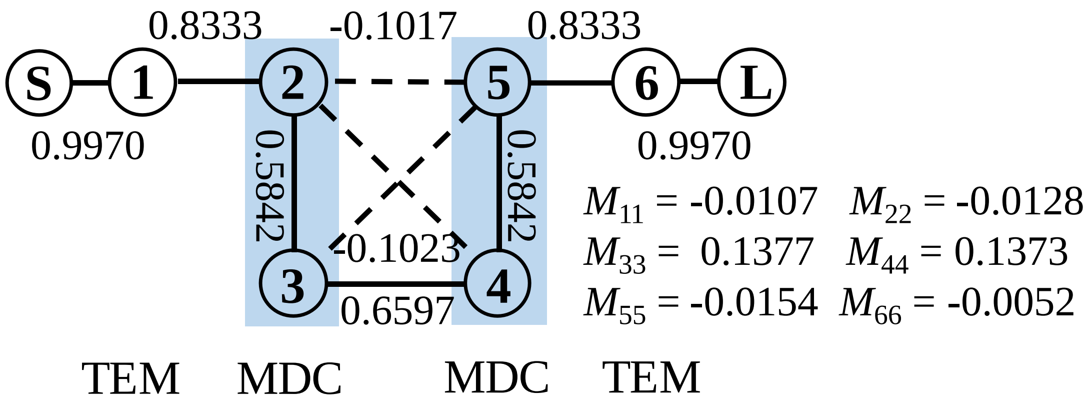


Two cascaded triplets with possible 6-2 responses

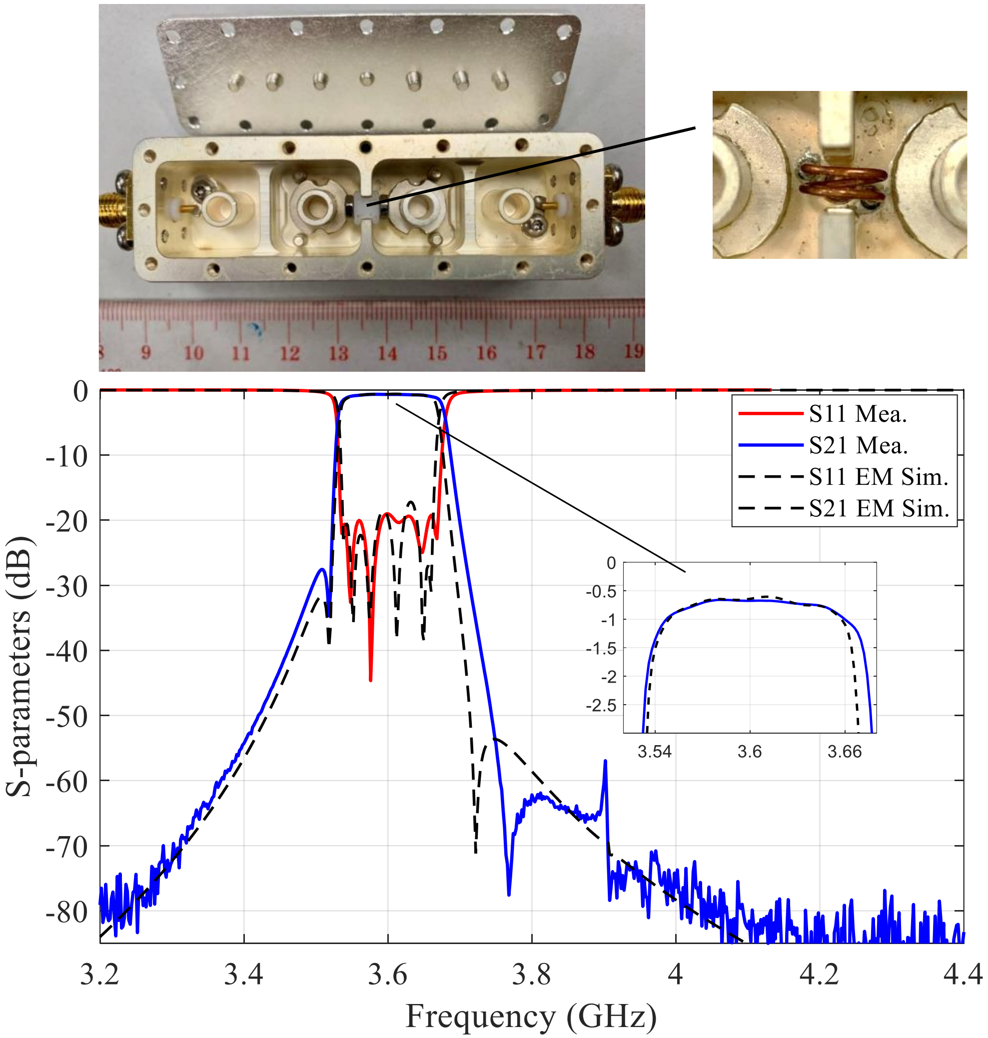
Design Examples

A 6-2 bandpass filter with one CQ

- f_0 = 3.6 GHz, BW = 125 MHz (3.47%)
- Asymmetric TZs at -1.3 & 2.2 rad/s
- An asymmetric structure leads to a weak propagation of the HE_{11b} mode



Topology with synthesized coupling coefficients

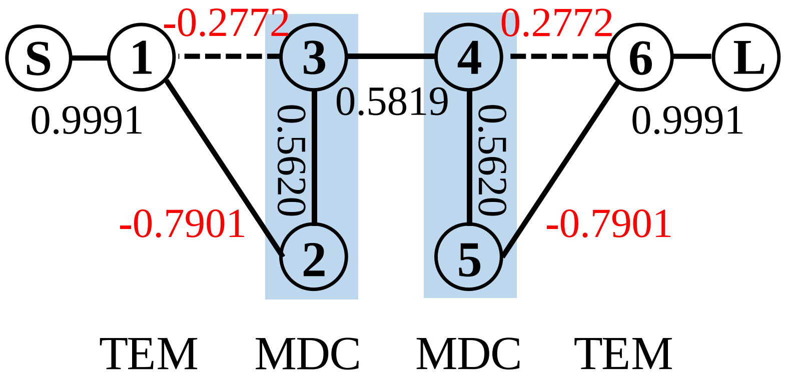


Photograph and responses of the 6-2 prototype

Design Examples

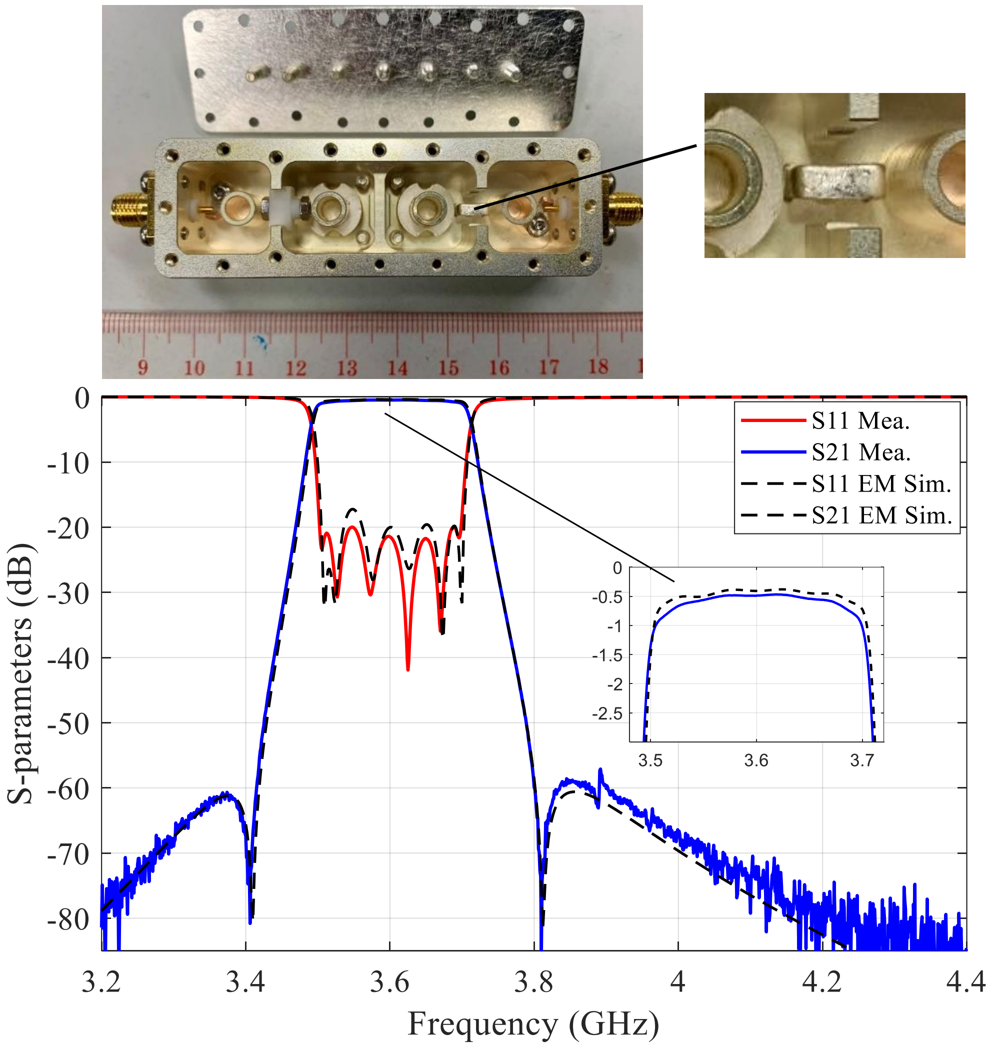
A 6-2 bandpass filter with two CTs

- f_0 = 3.6 GHz, BW = 200 MHz (5.56%)
- Symmetric TZs at -2.0 & 2.0 rad/s
- The proposed triplet section facilities an independent control of each TZ
- Resonances of HE_{11b} are not obvious



M_{11} = 0
M_{22} = -0.3985
M_{33} = 0.0335
M_{44} = -0.0335
M_{55} = 0.3985
M_{66} = 0

Topology with synthesized coupling coefficients



Photograph and responses of the 6-2 prototype

Summary

A novel dual-mode resonator utilizing two dissimilar fundamental modes is proposed:

- Same volume as metallic coaxial resonator
- Similar unloaded *Q* with original TEM mode
- Various inter-cavity couplings to realize TZs

A promising option for bandpass filters with:

- Compact size
- Inline layout
- Wide spurious rejection band