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Compact Wideband Stepped Impedance Filters with Resonant Apertures

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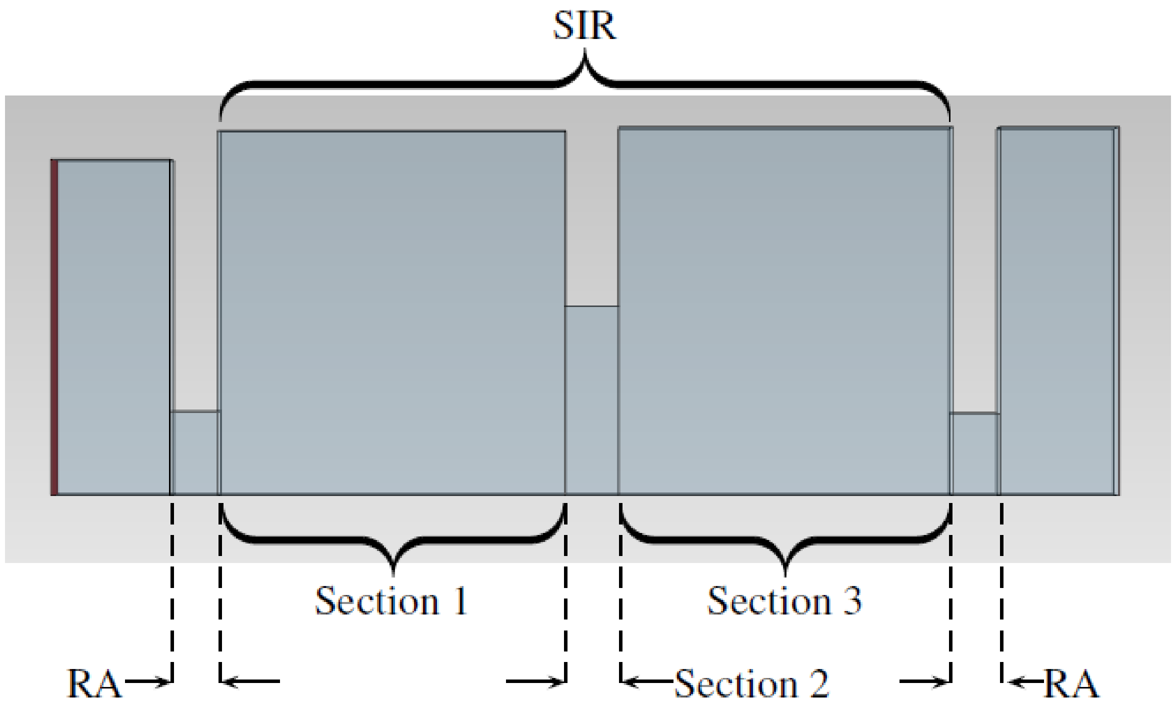
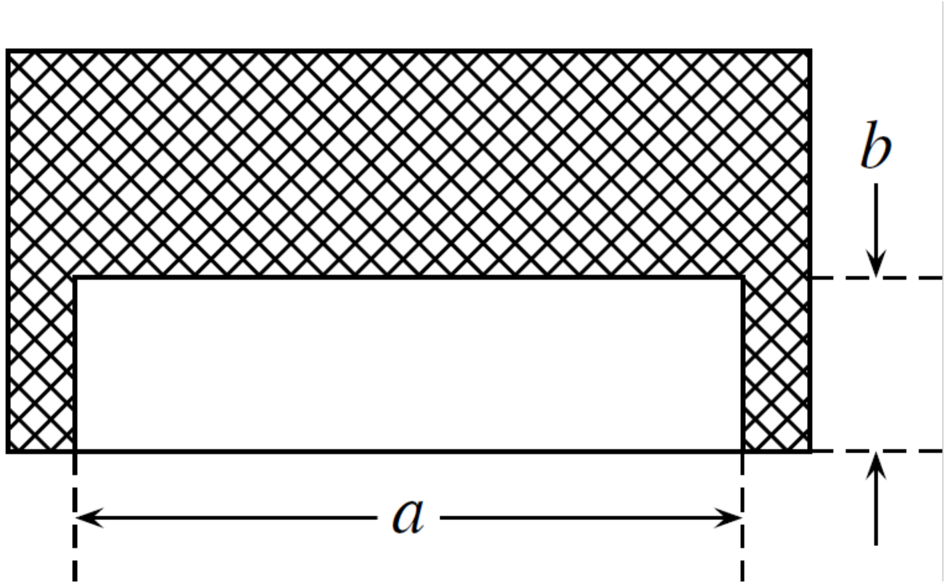
Challenges and objectives

- Current wireless communication equipment, for both ground and space applications, require ever smaller and more compact components.
- New filter structures with improved "size-performance" ratio.
- Wideband filters are problematic in terms of design and performance → Replicas and spurious responses.
- Proved solutions for narrowband applications:
  - Stepped Impedance Resonators (SIRs)
  - Resonant Apertures (RAs)

Challenge: use both solutions for wideband filters.

Challenges and objectives





Stepped Impedance Resonators:
Useful against the presence of spurious responses near the pass-band

Resonant Apertures:
Increase the order of the filter
↓
Small overall size
↑↑ Selectivity

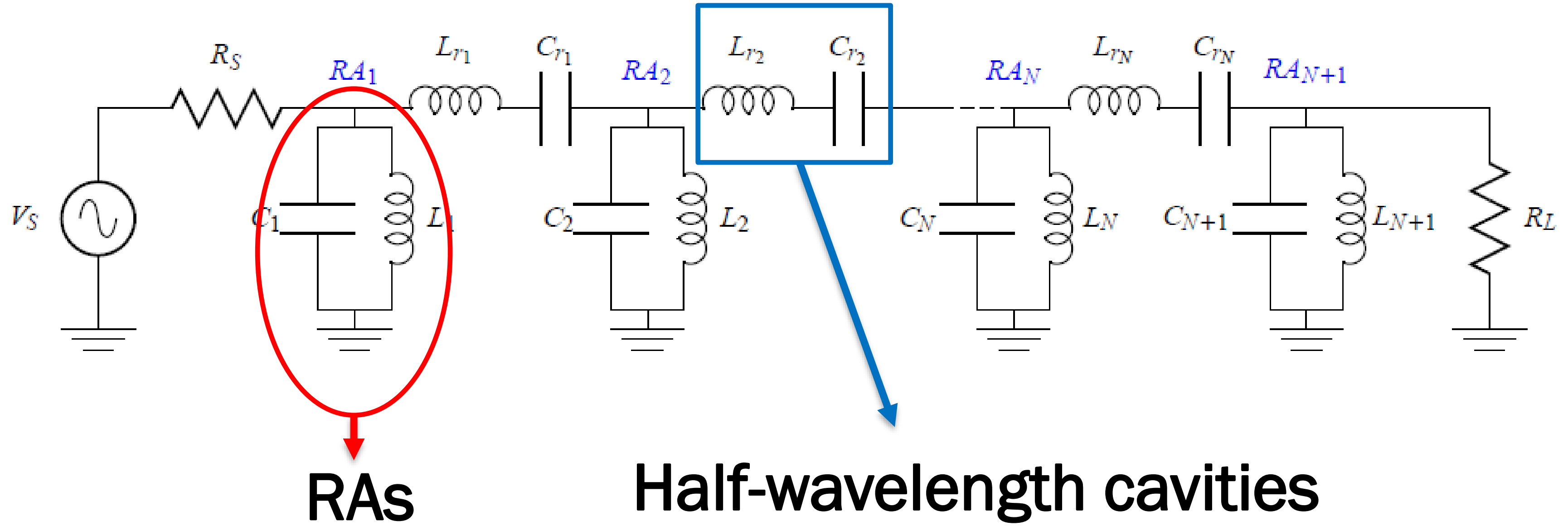
Challenges and objectives

Principal objectives of this research:

- New structure of compact wideband waveguide filter.
- Significant out-of-band response improvement.
- Combine use of SIRs and RAs.
- Easy to manufacture, small and simple structure.
- High order filters.

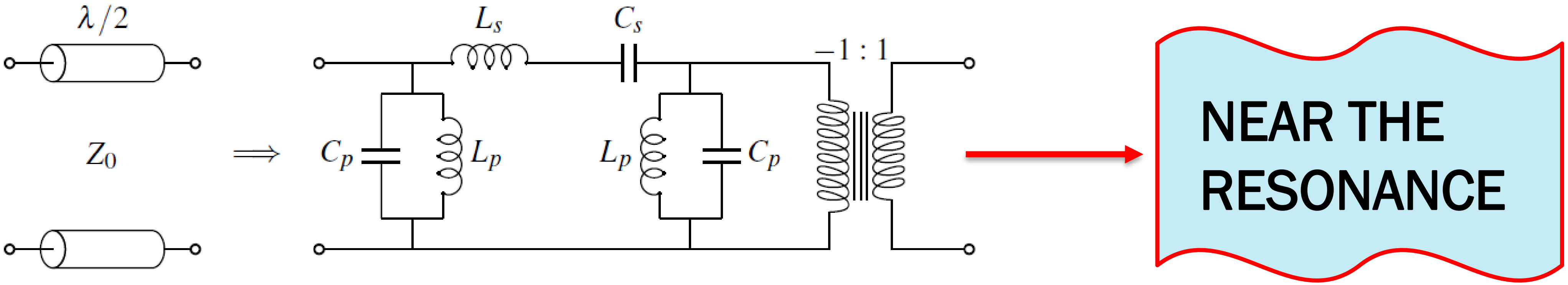
Design procedure

1. Lowpass lumped and passband lumped elements prototypes:
   – Chebyshev filter. g_i values from RL (Return Losses) and N (Order).
   – The filter shall be of order N = Na + Nc, where Na = (N + 1)/2 will be the number of RAs, and Nc = (N − 1)/2 will be the number of resonant cavities.



Design procedure

2. Series resonator by half-wavelength cavities:



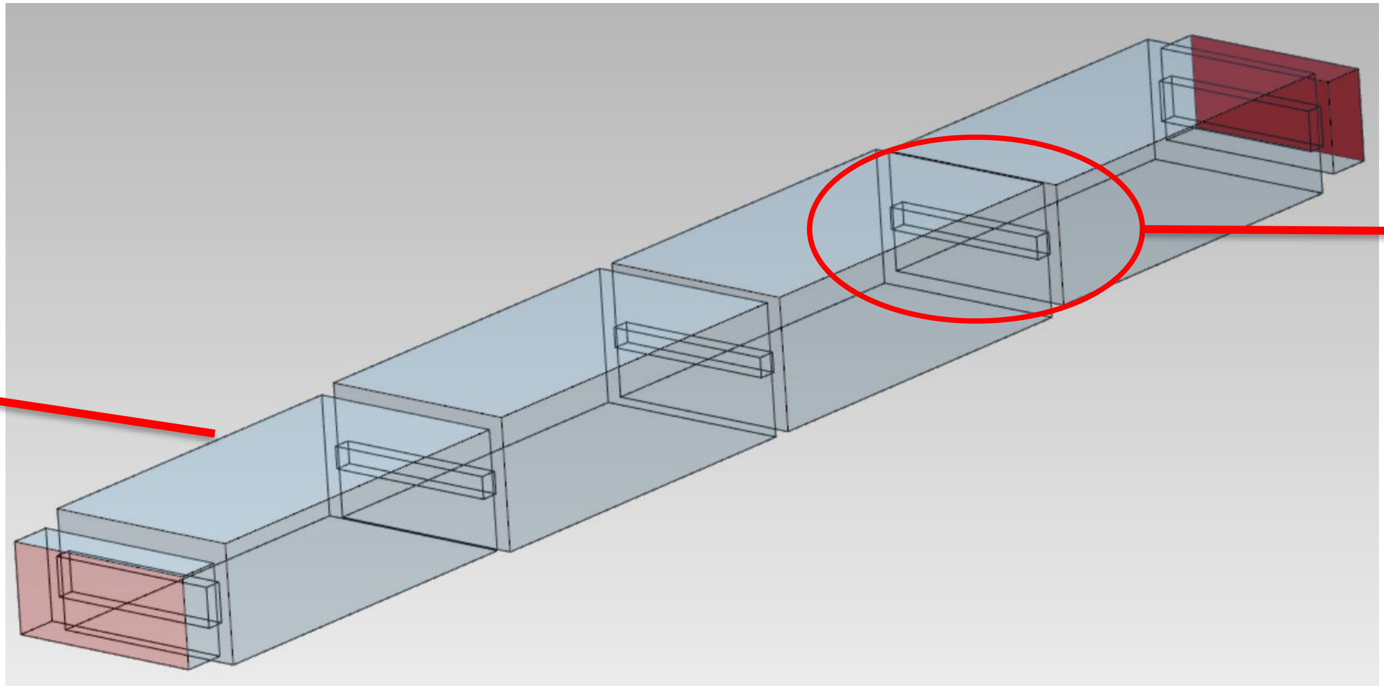
- Calculate the waveguide wavelength λ_{gi}, the slope parameter X_i and the characteristic impedance Z_{0i} of every *i*-th series resonator. These parameters allow us to obtain the dimensions $\boldsymbol{a_i}$ (waveguide width) and $\boldsymbol{b_i}$ (waveguide height) for each rectangular cavity (resonator).

Design procedure

3. Parallel resonators by RAs:

- Matching the response of every shunt resonator with the corresponding iris with suitable dimensions.

Half-wavelength cavity

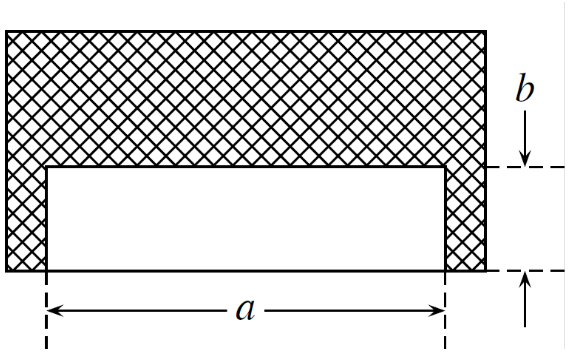


RA small *b* dimension

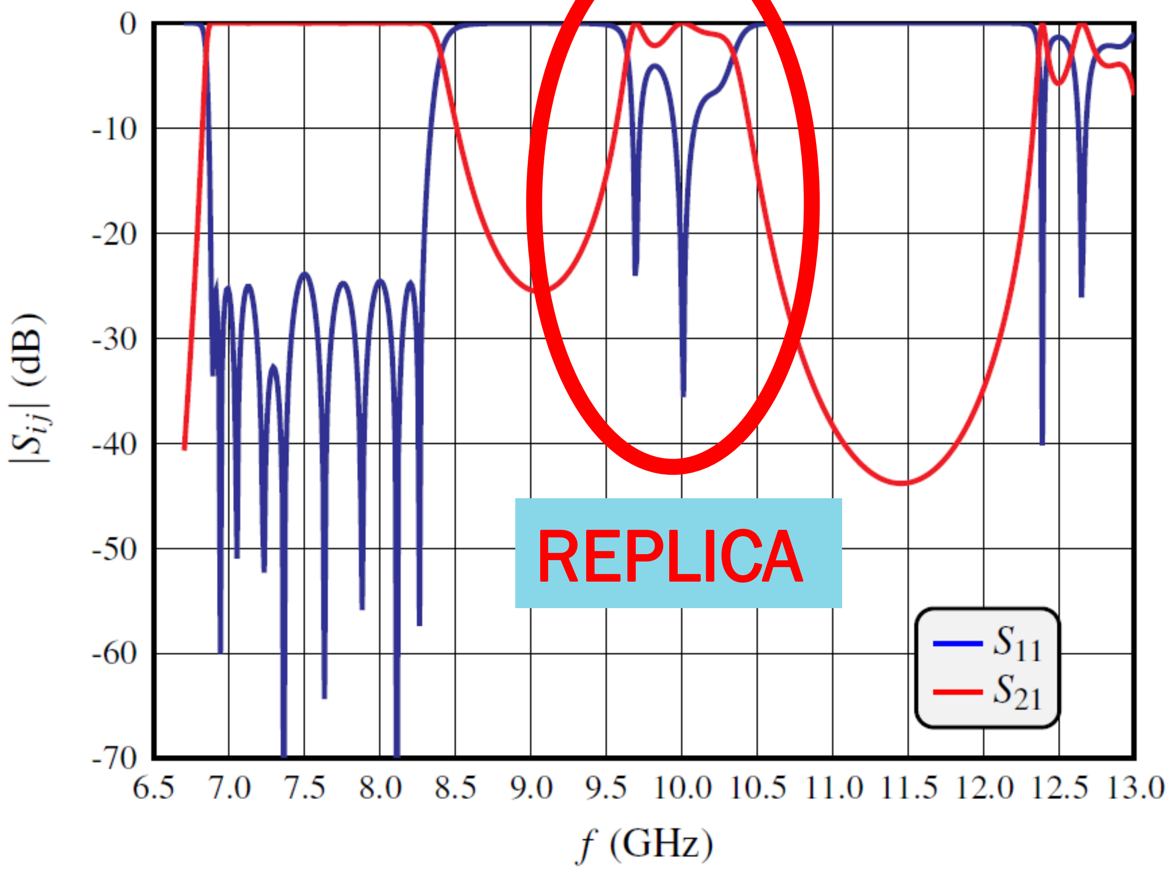
Design procedure

4. Shifting the RAs and passband waveguide filter response:

- Power handling capacity enhancement

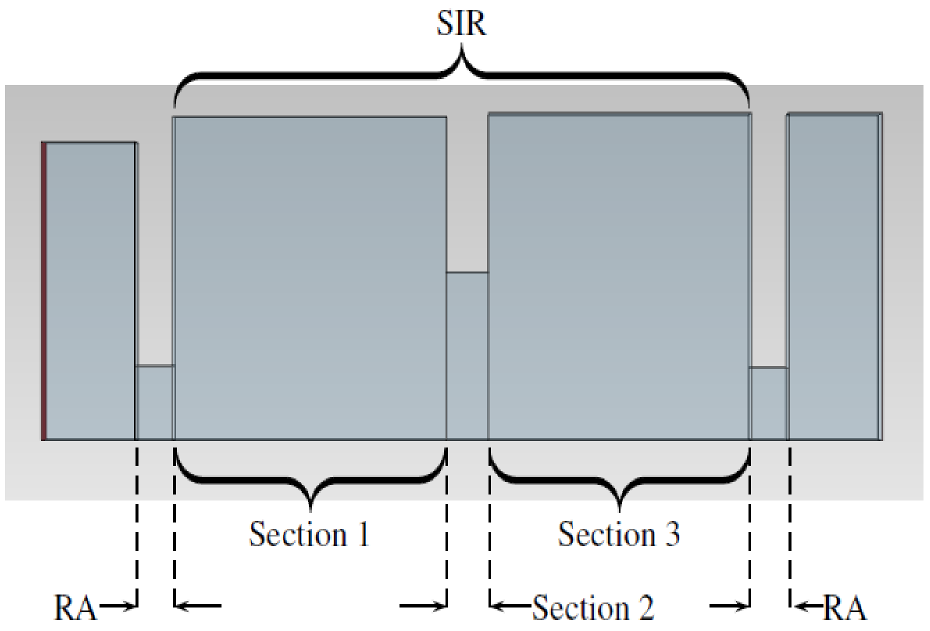


RAs to the bottom
b (height) ↑↑

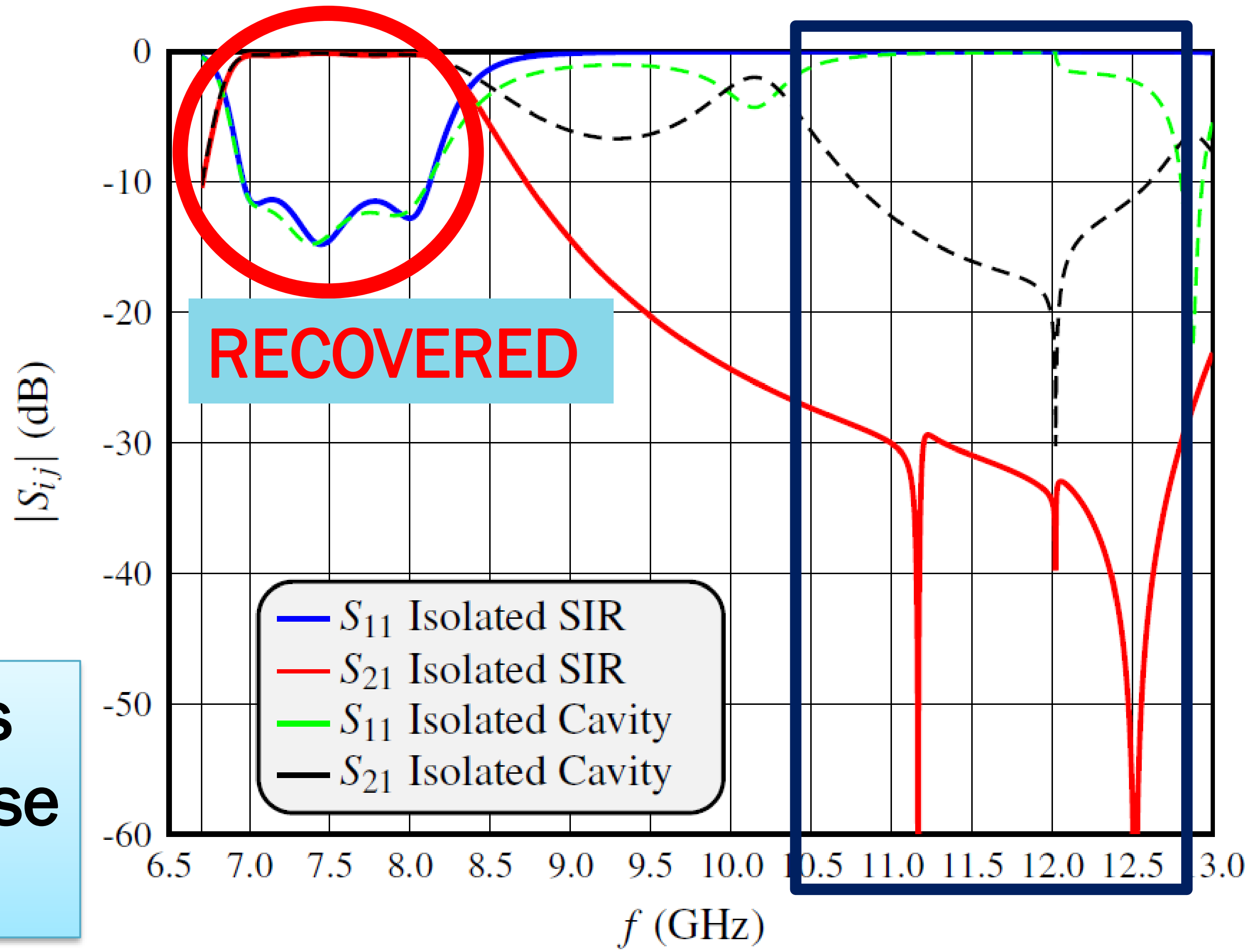


Design procedure

5. Use SIRs to significantly improve the out-of-band response:



Each section and the adjacent irises are optimized to recover the response of the original isolated cavity.



Design procedure

6. Complete filter assembly and final optimization:

- Once each SIR is optimized, the complete filter can be assembled.
- At this point, an additional fine optimization is required to obtain the final response.
- In-band response will be basically identical to the one obtained without SIRs, satisfying the specifications within the pass-band.
- However, the out-of-band response will be noticeably enhanced.
- All this features will be shown in the next design example.

Design example

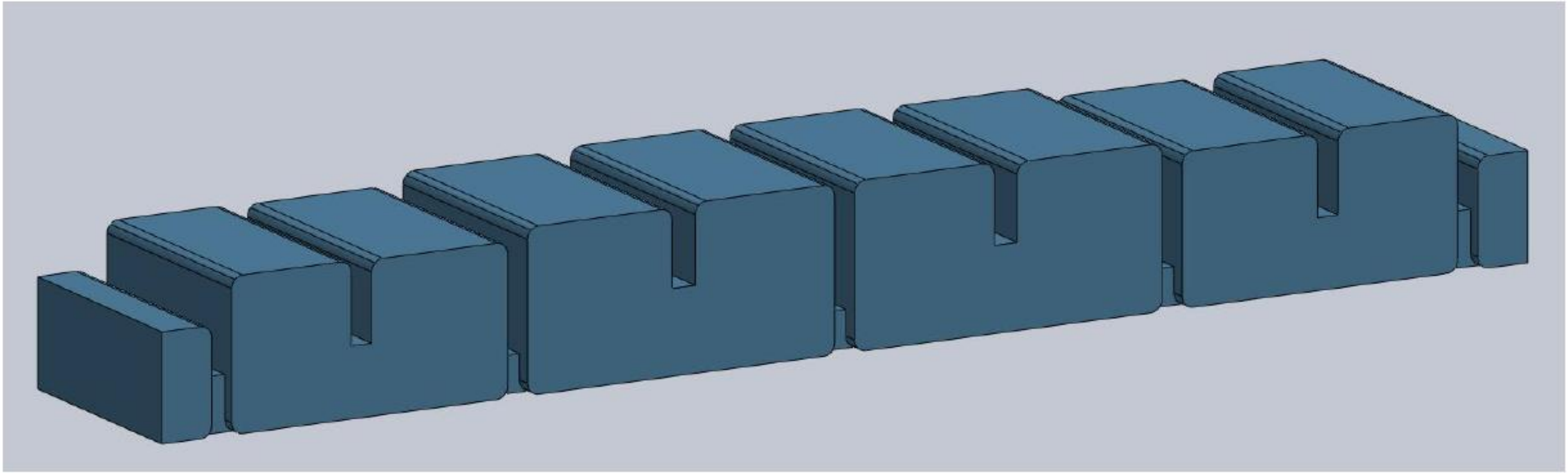
- Wideband WR-90 filter based on RAs and SIRs.

- Final model with rounded corners with radius r = 1.1 mm.
- Final optimization was performed using the Aggressive Space Mapping (ASM) technique, where FEST3D has been used as the Low Accuracy (LA) space, and HFSS as the High Accuracy (HA) space.

SPECIFICATIONS

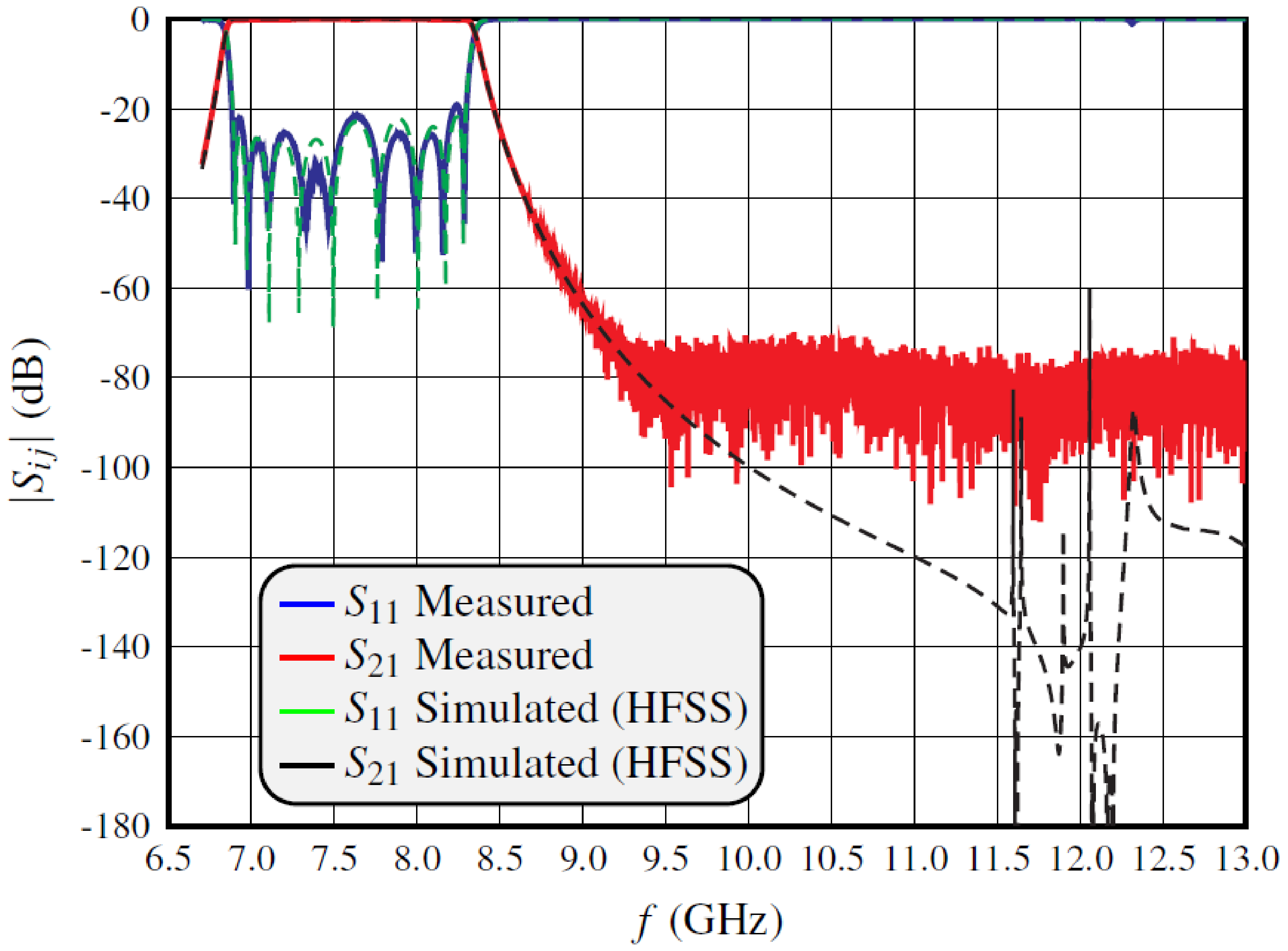
Parameter	Goal
Order	9
Bandwidth	$BW = 1.4$ GHz
Return loss	$RL > 22$ dB
Center frequency	$f_0 = 7.55$ GHz
Fractional bandwidth	$\mathcal{W}_\lambda = 106.6$ %
WR-90 Waveguide	$a = 22.86$ mm $b = 10.16$ mm

Design example



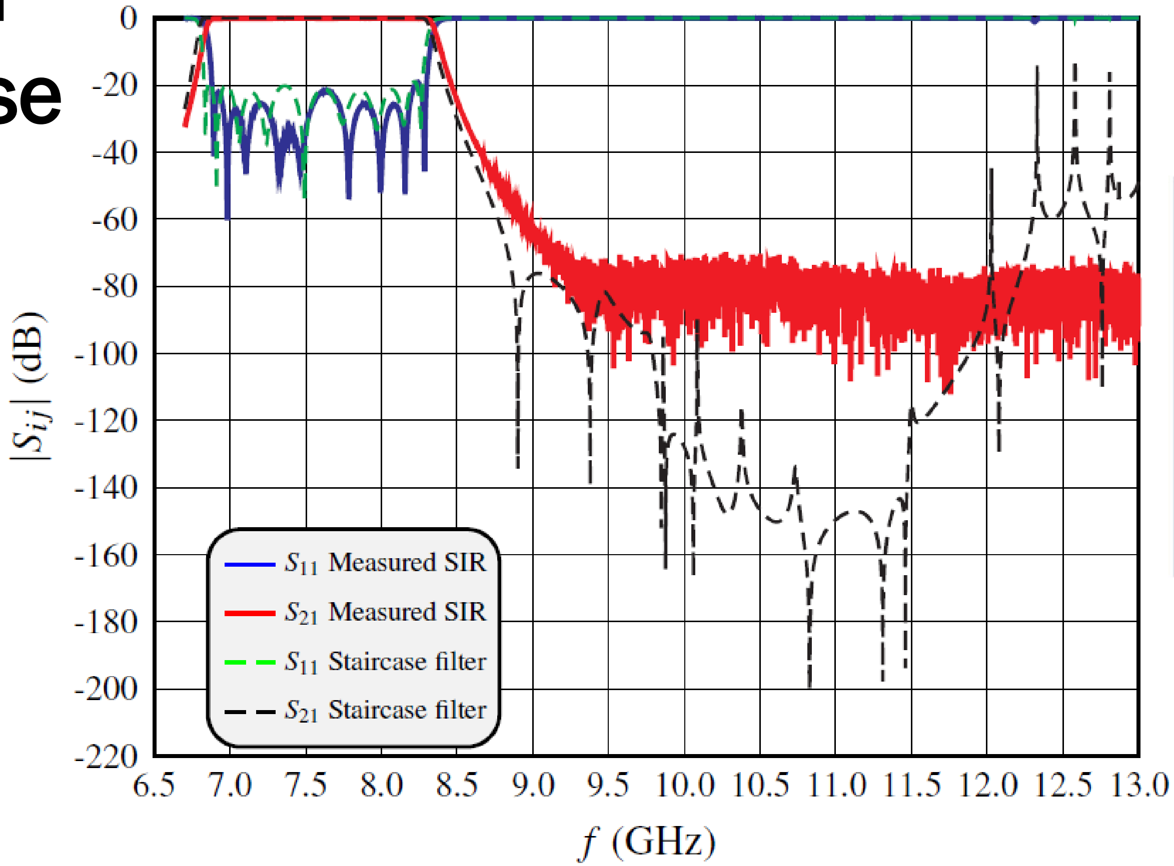
Design example

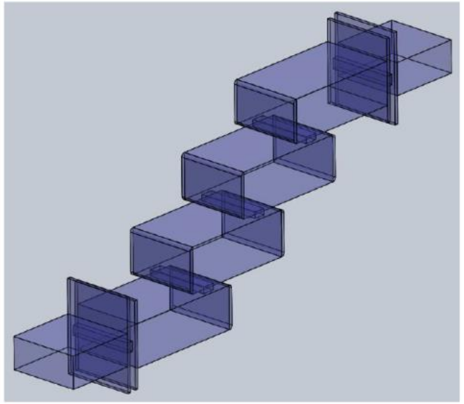
- In band specifications agreed.
- Out-of-band response improvement.
- Extremely wide spurious-free range that goes up to the upper limit of the X-band.
- Simple and compact structure.



Design example

- Comparison between SIR filter and staircase filter with the same specifications.





- NOTICEABLE OUT-OF-BAND IMPROVEMENT
- NOTE THE SIMPLICITY OF THE STRUCTURE

Design example

Conclusions

- The combination of SIRs and RAs was successful.
- Huge spurious-free range.
- Noticeable out-of-band response improvement.
- Filter structure easy to manufacture.
- Very small and compact filter footprint.
- Ideal solution for modern wireless payloads, for both ground and space applications, where improved performance and size reduction are driving requirements.