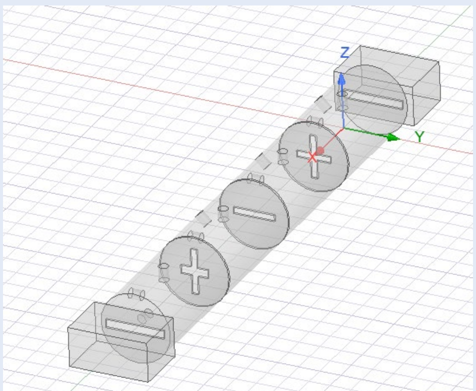
Designing Waveguide Filters Using Automatic 3D Modelling and AI Optimization

Background

Waveguide filters are structures used in higher frequency applications seen in industries such as aerospace, satcom, and military and defense applications. We will review an aerospace design requirement in this example.



From Synthesis, 3D modelling to Final Optimization

SynMatrix offers an all-in-one platform to help design, optimize and manufacture RF filters:

1. **Specification Analysis.** Feature-packed design and analysis for complex RF filter design.
2. **Optimization.** Features advanced CAT, auto 3D modelling, and intelligent optimization tailored for RF filters.
3. **Test and Measurement.** Advanced debug workflows integrated with Keysight, R&S and Copper Mountain VNAs.
4. **Manufacturing.** Real-time tuning and computer-aided manufacturing suite to help manage, production orders, and quality data audits.

Use Case Specifications:

- Frequency Band: 11350 MHz – 11650 MHz; BW: 300MHz
- Insertion Loss 1: <1.5dB through the whole passband
- Rejection:
- <50dB at 10750MHz – 11200MHz
- <50dB at 11800MHz – 12250MHz
- Return Loss: 18dB
- Group Delay: <12ns; Group Delay Flatness: < 3.5ns
- Temperature Range: -30℃ to +80℃

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Step 1: Specification Analysis

- The estimated unloaded Q is about 4500;The BW was extended about 35 MHz to compensate the thermal drift (Est. 14Mhz) by keeping the proper design margins
- Two real transmission zeros are used for improving the GD flatness
- Two imaginary transmission zeros are used for improve out band rejection

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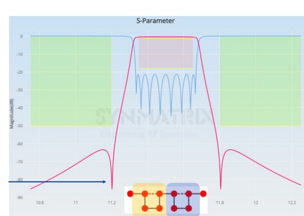

Fig1. Generate the golden matrix by identifying design margins, frequency info, and transmission.

	S	1	2	3	4	5	6	7	8	L
S	0	1.0689	0	0	0	0	0	0	0	0
1	1.0689	0	0.9102	0	0.2302	0	0	0	0	0
2	0	0.9102	0	0.5123	0	0	0	0	0	0
3	0	0	0.5123	0	0.6283	0	0	0	0	0
4	0	0.2302	0	0.6283	0	0.6211	0	0	0	0
5	0	0	0	0	0.6211	0	0.6063	0	-0.1213	0
6	0	0	0	0	0	0.6063	0	0.7481	0	0
7	0	0	0	0	0	0	0.7481	0	0.9309	0
8	0	0	0	0	0	-0.1213	0	0.9309	0	1.0689
L	0	0	0	0	0	0	0	0	1.0689	0

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APPLICATION CASE

SYNMATRIX

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Step 2: Automatic 3D generation

Single Resonator Analysis (Fig1, Fig2)

- Single resonator information: Dominated Mode (TE111), Cavity length: 1.247in, Cavity Radius: 0.33in
- Resonance Freq: **11.5GHz,** Unloaded Q: **10200** (using copper)

Coupling Schemes (Fig3)

- Set iris width=0.06in, iris thickness=0.02in
- Set frequency tuning screw depth=0.12in
- Default iris length=0.4724in (70% of Cylinder diameter)
- Frequency tuning screw depth is kept with 0.12in depth
- Sweep the coupling screws from 0.01in to 0.2in

I/O Analysis (Fig3)

- Select WR75 as I/O interface
- Set frequency tuning screw depth=0.12in
- Set iris width=0.06in, iris thickness=0.02in, iris length=0.55in

Final 3D Modelling (Fig4, Fig5)

- Construct a full 3D model
- Use drag-drop GUI to customize the topology design
- Fully parametrized in HFSS
- Use SynMatrix's **dispersive effect control** to improve extraction, coupling matrix, and initial simulation (Fig5)

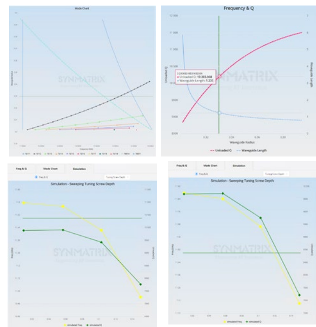


Fig1. Mode charts, Frequency & Q analysis. 2 rounds of parametric studies.

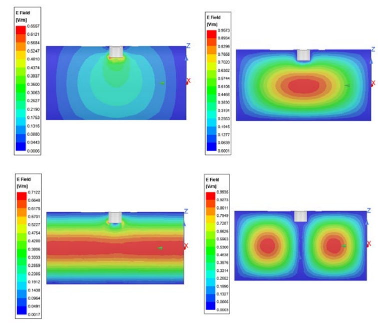


Fig2. Mode 1 (TE11), Mode2 (TE11 degenerate mode), Mode3 (TM01), Mode 4 (TE112).

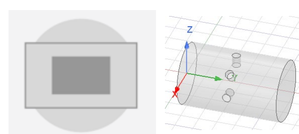


Fig3. Coupling scheme and I/O analysis.

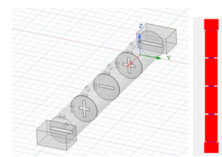


Fig4. Fully parameterized 3D modelling.

Step 3: Optimization

- TWO Intelligent Optimization workflows:
  - Perturbation + AI/Space Mapping
  - AI/Space Mapping (for complex cases)
- 1st round of intelligent AI optimization reveals stray coupling effect (Fig6)
- Generate a new, optimized coupling matrix that meets RF specifications using SynMatrix functions
- After 2nd round of auto AI optimization all the RF specifications are met (Fig7)

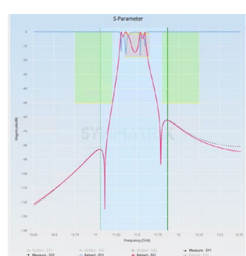


Fig5. Initial sim analysis. Dispersive function improves extraction.

Fig6. 1st round of AI results reveals stray coupling effect.

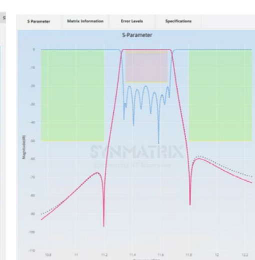
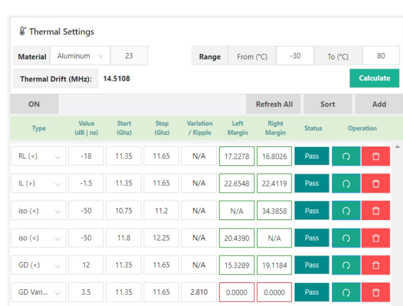


Fig7a. Final RF perf. after 2nd round of auto AI optimization.

Concluding Summary

- Specification Analysis: **20mins**
- 3D modeling analysis: **0.5hrs**
- AI optimization: 1st round: 2 hours; 2nd round: 2.3hours (3~4mins per simulation)
- The total design time (including auto-simulation): **5 hours**
- Estimated engineering labour time (minus the simulation time): **0.5 hours**



Thermal Settings

Material: Aluminum 23 | Range From (°C) -30 To (°C) 80

Thermal Drift (MHz): 14.5108

Type	Value (dB | ns)	Start (Ghz)	Stop (Ghz)	Variation / Ripple	Left Margin	Right Margin	Status
RL (<)	-18	11.35	11.65	N/A	17.2278	16.8026	Pass
IL (>)	-1.5	11.35	11.65	N/A	22.6548	22.4119	Pass
iso (<)	-50	10.75	11.2	N/A	N/A	34.3858	Pass
iso (<)	-50	11.8	12.25	N/A	20.4390	N/A	Pass
GD (<)	12	11.35	11.65	N/A	15.3289	19.1184	Pass
GD Vari...	3.5	11.35	11.65	2.810	0.0000	0.0000	Pass

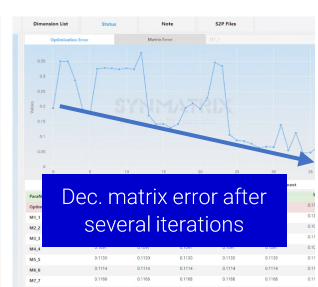


Fig7b. Final optimized results after 2nd round of AI optimization meets RF specifications.