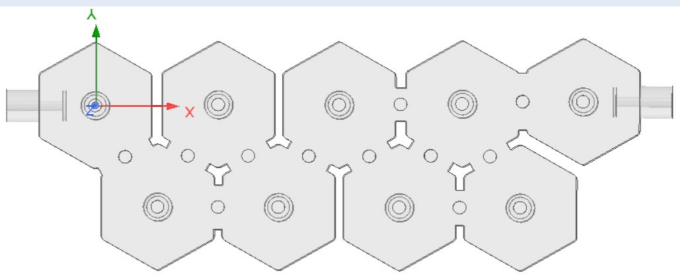
Designing Coaxial Cavity Filters Using Automatic 3D Modelling and AI Optimization

Background

Coaxial cavity filters are common structures used in sub-6 frequency ranges. They are used commonly in 5G telecom base station communication systems and can present challenging design criteria for filter designers.



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: 2620 MHz – 2690 MHz
- Insertion Loss 1: 1.5dB at 2620MHz – 2687MHz
- Insertion Loss 2: 2.0dB at 2687MHz – 2690MHz
- Rejection: 50dB at 2700MHz – 2715MHz
- Return Loss: 20dB
- Temperature Range: -20℃ to +60℃

Preliminary Analysis

- Freq Band: 2.6% BW—Geometry sensitivity. Simulation challenge.
- Insertion Loss: High Q cavity design due to the IL roll off at band edge.
- Rejection: very tight rejection criteria (10Mhz gap). More transmission zeros are required.
- RL: need to consider matrix sensitivity which may cause the RL variation.

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Step 1: Specification Analysis

- The estimated unloaded Q is about 3500
- The BW was extended about 8 MHz to compensate the thermal drift by keeping the proper design margins
- A CT(cascade triplet) and CQ(cascade quadruplet) are applied to provide the extra rejection at the higher side
- Estimated thermal drift is about 1 MHz

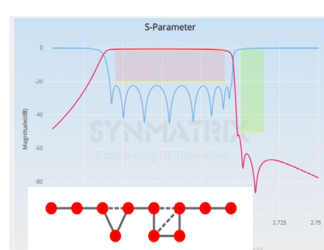

Fig1. Generate the golden matrix by identifying design margins, frequency info, and transmission zeros.

Input GD 7.745 ns Output GD 7.745 ns NORM

S	1	2	3	4	5	6	7	8	9	L
0	1.0836	0	0	0	0	0	0	0	0	0
1.0836	0.0066	0.9474	0	0	0	0	0	0	0	0
0	0.9474	0.0090	0.4451	0.4968	0	0	0	0	0	0
0	0	0.4451	-0.8868	0.3798	0	0	0	0	0	0
0	0	0.4968	0.3798	0.0583	0.6037	0	0	0	0	0
0	0	0	0	0.6037	0.0531	0.5787	0	0.1888	0	0
0	0	0	0	0	0.5787	-0.2488	0.2178	0.5339	0	0
0	0	0	0	0	0	0.2178	-0.9894	0.3524	0	0
0	0	0	0	0	0.1888	0.5339	0.3524	0.0090	0.9474	0
0	0	0	0	0	0	0	0	0.9474	0.0066	1.0836
0	0	0	0	0	0	0	0	0	1.0836	0

Fig2. Generating the coupling matrix and group delay for I/O.

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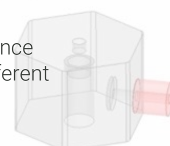
Step 2: Automatic 3D generation

Single Resonator Analysis
- Several resonator types are available
- Thermal drift analysis
- Parametric studies analysis

Coupling Schemes
- Customize your coupling schemes definition
- Parametric studies analysis
- Regression analysis to help obtain coupling dimension value



I/O Analysis
- Parametrized modelling
- Group delay method to analyze I/O performance
- Customize the port interface by selecting different waveguide sizes

Final 3D Modelling
- Construct a full 3D model
- Use a drag-drop GUI interface to customize the topology design
- Fully parametrized in HFSS

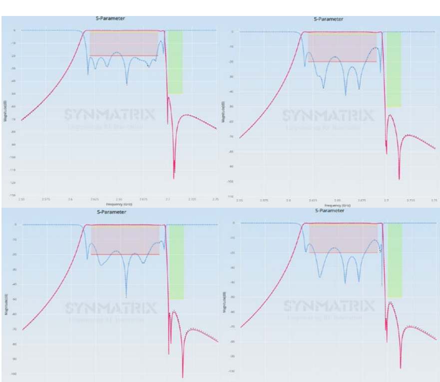
Step 3 (i): Optimization

- For complicated designs and poor initial performance, use the AI method as a starting point.
- Use AI optimization workflow integrated with Ansys HFSS to automatically converge to a final solution

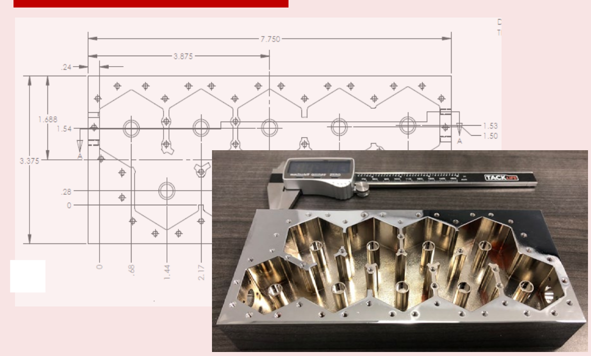
Fig3. The initial performance is very poor. Users should start immediately with the AI method.

Step 3 (ii): Optimization (Results)

- RL start to oscillate after 28 rounds simulation; frequency error is the major reason
- Need to increase the mesh quantities to improve the simulation accuracy
- The coupling error level is lower than 1% and frequency error is lower than 3%
- The optimized dimension modification is smaller than 0.001mm, which is not practical in the real life



Concluding Remarks



- **Total design time: ~7.5 hours**
- Specification Analysis: 20mins
- 3D modeling analysis: 1hrs(including parametric studies)
- Single resonator and I/O structure simulation is critical
- AI optimization: 36x simulation take [6 hrs]
- Est. meaningful engineering time: **1.5 hours**
- All RF performance can be met after optimization

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