



Filter Design using the Ansys AEDT and NuHertz FilterSolutions

Cole Williams – Application Engineer

Table of Contents

Overview and Landscape

Filter Analysis with Nexxim Circuit / HFSS

Recommended Filter Design Workflow

NuHertz Filter Solutions & SynMatrix

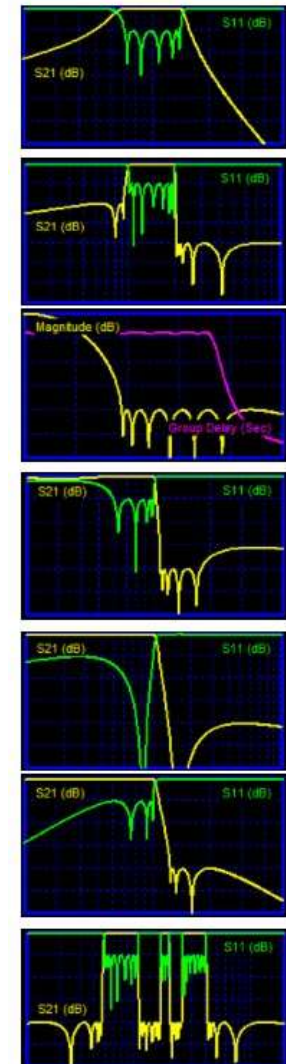
Electronic Filter Overview

- **What is an electronic filter?**

A circuit designed to selectively pass certain frequencies while blocking or attenuating others

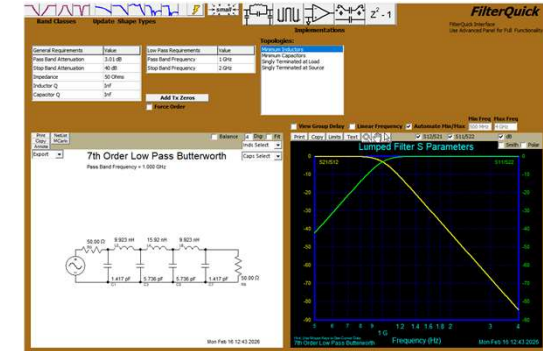
- Applications

- **Transmitters:** Modulation and amplification create harmonics that must be filtered out
 - **Receivers:** Selectivity and sensitivity depends upon filtering to remove spectrum outside the channel of interest
 - **Power Supplies:** Suppress output voltage ripple and harmonics
 - **Analog-to-Digital (ADC) sampling:** Must remove signal spectrum above $\frac{1}{2} \times$ sampling rate for ADCs
 - **Digital-to-Analog (DAC) reconstruction:** Must remove harmonics from the analog signal reconstruction due to the digital signal sample rate
- RF/Microwave filters can be analog or digital
 - RF/Audio filters can utilize Active components (Op-amps)
 - RF/Microwave filters can be implemented at the chip, package or even system level



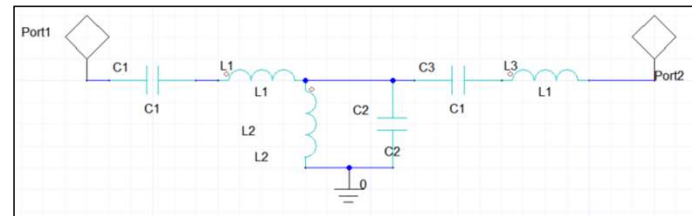
Filter Landscape in the Ansys Suite

- **Topology Generation** – NuHertz FilterSolutions and SynMatrix
 - Rapid prototype-level synthesis before circuit simulation
 - Define Filter Type (Low-pass, High-Pass, etc.)



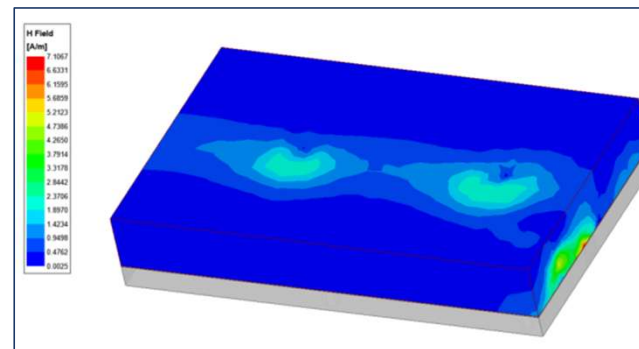
NuHertz

- **Circuit-Level Optimization** - Nexxim Circuit
 - Lumped RLC filter synthesis
 - Tolerance, Monte Carlo, and Optimization
 - Co-simulation with EM models

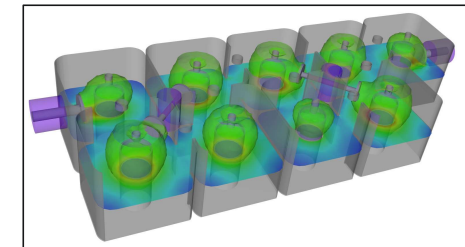


Nexxim Circuit

- **3D Electromagnetic Validation** - HFSS
 - Includes Parasitics from Pads, Vias, Planes
 - Coupling Between Components
 - Substrate & Stackup Effects



HFSS



SynMatrix

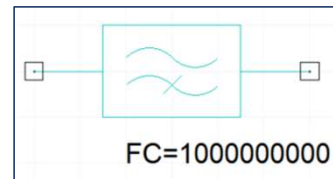
- **Thermal Reliability** – IcePak (Advanced)
 - Thermal impact on Q-factor
 - Temperature-dependent drift
 - Electro-thermal co-simulation



Filters in Nexxim Circuit

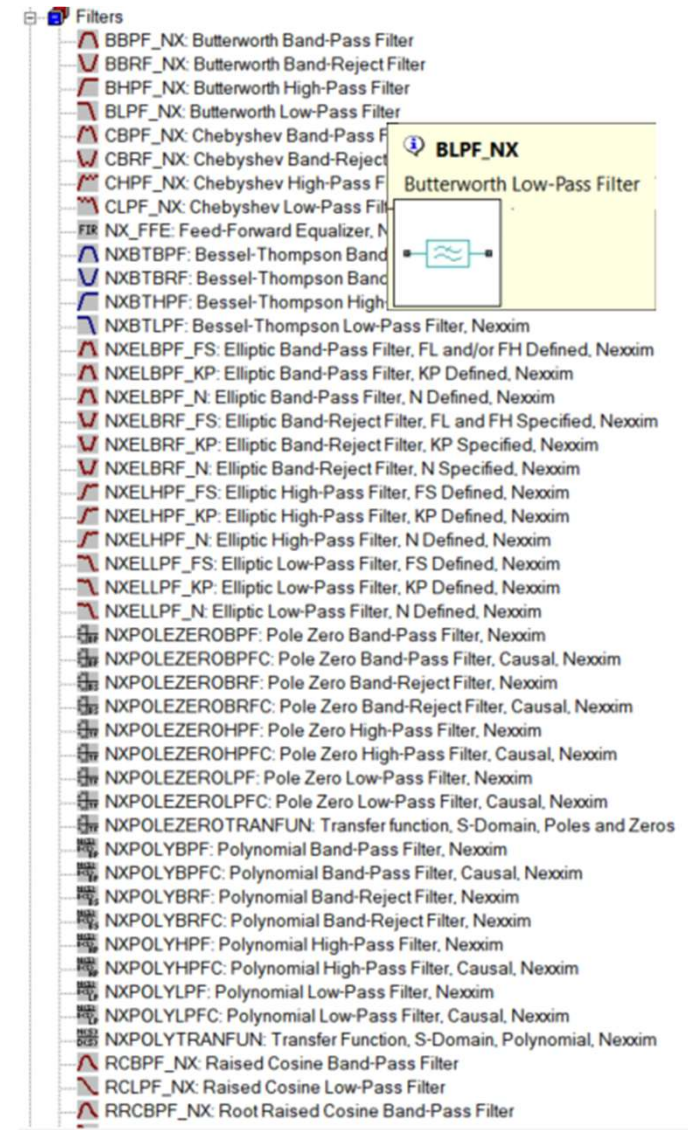
Circuit Tool Filter Blocks

- Early in system design, one may use the Filter Blocks
 - Low-pass, high-pass, band-pass, etc.
 - Shape (Chebyshev, Butterworth, etc.)
 - Even use a pole or polynomial based definition
- Understand system performance before designing the whole circuit



Name	Value	Unit	Evaluated V...	Description	Callback	Override
N	3		3	Order of filter	...	☐
FC	1000000000		1e+09	Cutoff frequency (Hz)	...	☐
ATT	3		3	Attenuation at cutoff frequency, dB	...	☐
QU	1e+36		1e+36	Unloaded Q for each resonator	...	☐
RRE	50		50	Reference resistance	...	☐
IL	0		0	Insertion loss in dB	...	☐

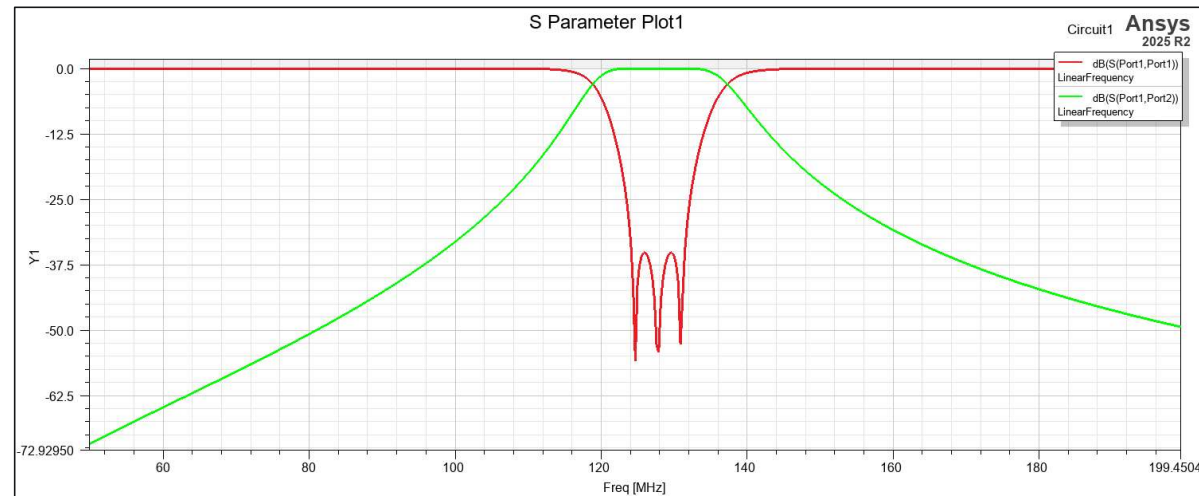
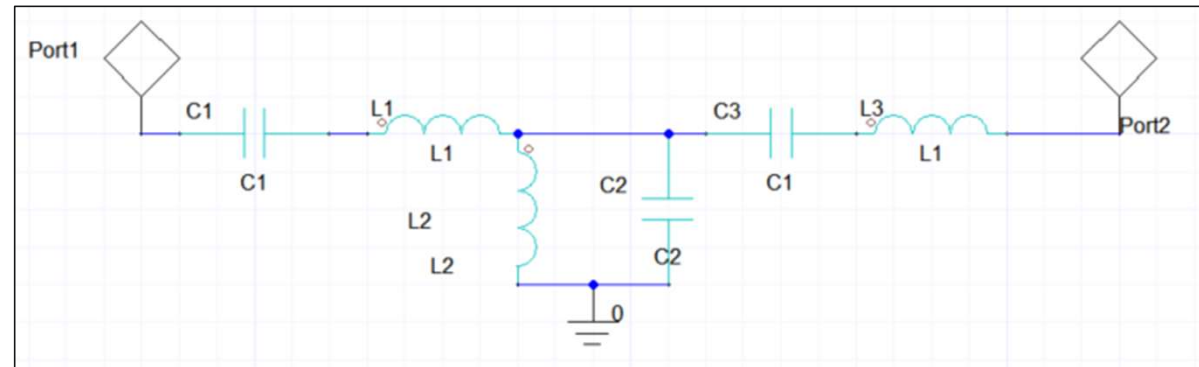
February 26



Circuit Tool with Lumped Elements

Name	Value	Unit	Evaluated V...
\$C1	3.3	pF	3.3pF
\$L1	470	nF	470nF
\$L2	4.7	nH	4.7nH
\$C2	330	pF	330pF
Project ...	Add...		

- 3rd Order Bandpass Filter
 - 118MHz to 138MHz
 - Band used in aviation applications
- Three types of “studies”
 - Parametric Sweep
 - Tuning
 - Optimization
- The studies above should be performed regardless of:
 - Filter Implementation (Lumped vs Distributed vs Active)
 - Filter Topology
 - Filter Class
 - Design Type (HFSS vs 3D Layout vs Circuit)

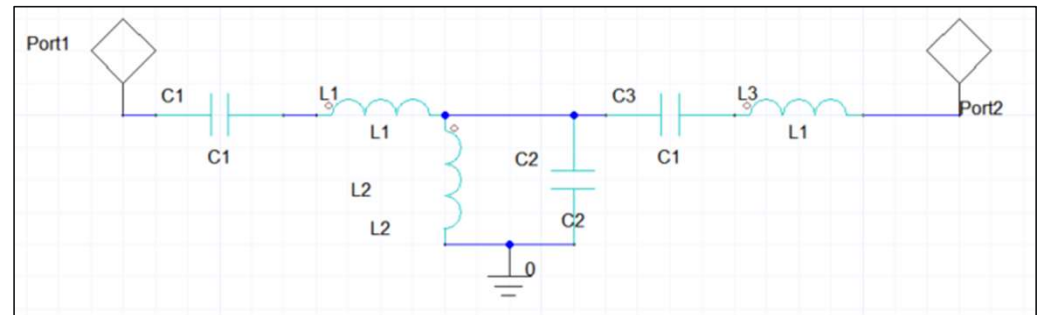
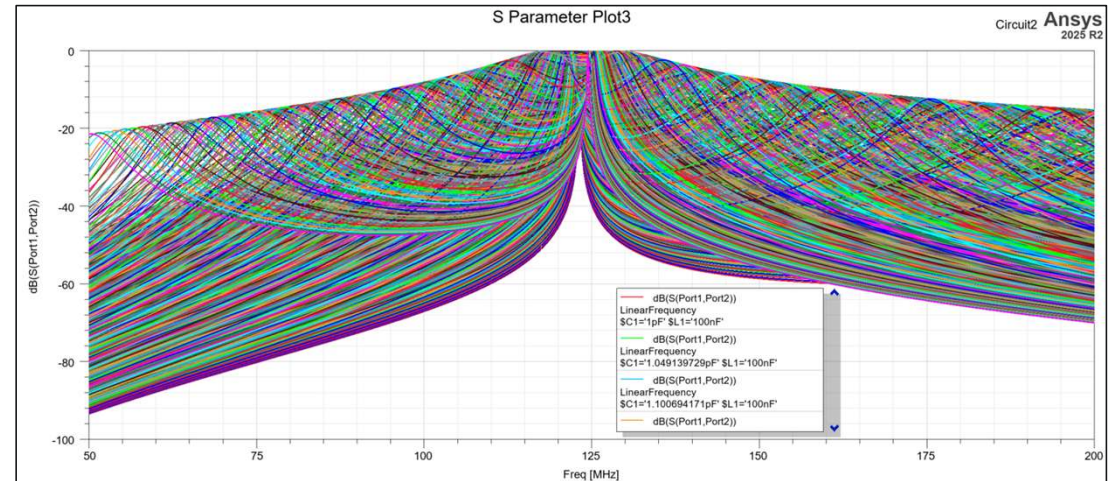




| Types of Studies within Nexxim Circuit

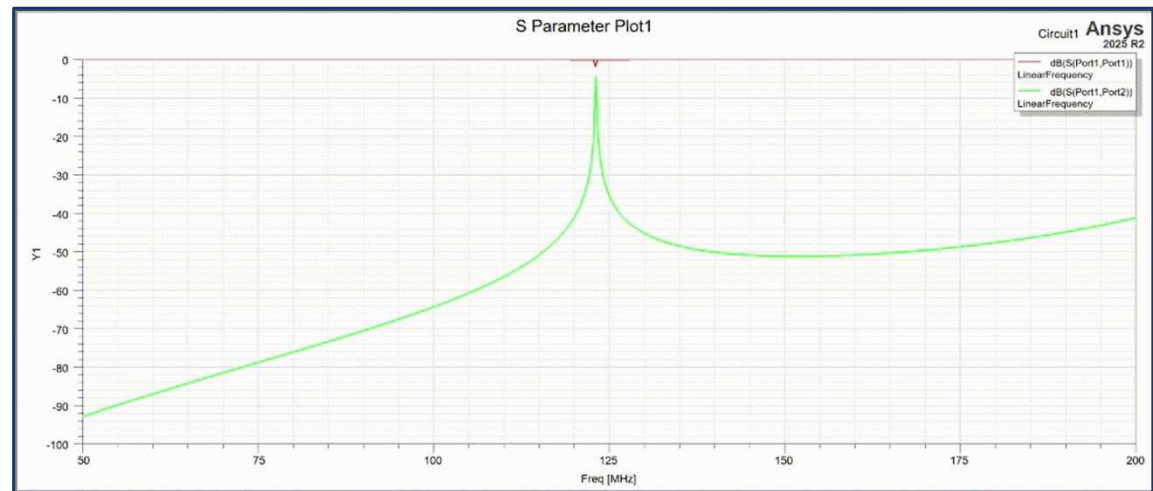
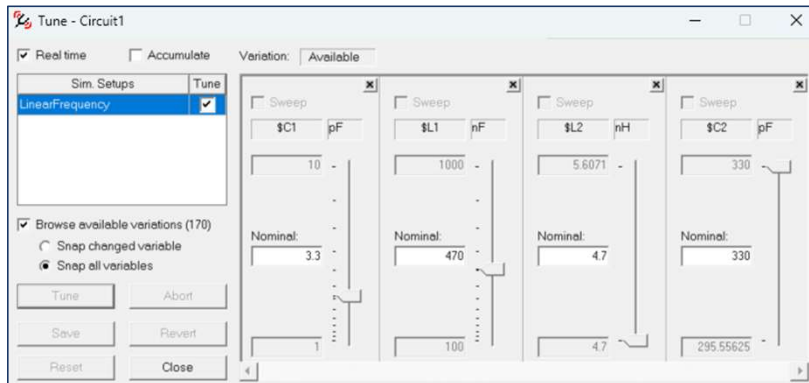
Parametric Sweep

- Define Variables to be swept over a Range
 - Enables user to simulate several design variations using a single model
- Vary parameters:
 - Magnitude
 - Material properties
 - Size (geometrical dimensions)
 - More!
- For Lumped Filters, this means varying L and C values for each component



Tuning

- Useful to perform real-time analysis of a design by modifying specific variables
- Some setup required
 - Tuning must be performed after a Parametric Sweep
 - The tuning variables must be defined as such in the Project Variables window



Optimization

- An optimization analysis allows the user to determine an optimum solution for a problem.
- In optimization analyses, there are
 - Many available optimizers
 - Constraint-based criteria
 - Limit maximum iterations
 - Create custom Cost Functions
 - Non-linear cost functions
- For this circuit:
 - Defining Optimizer
 - Defining Cost Function
 - i.e., weights

Setup Optimization

Goals | Variables | General | Options

Optimizer: **Nonlinear Programming by Quadratic Lagrangian(Gradient)** Setup...

Estimated Variations: 100

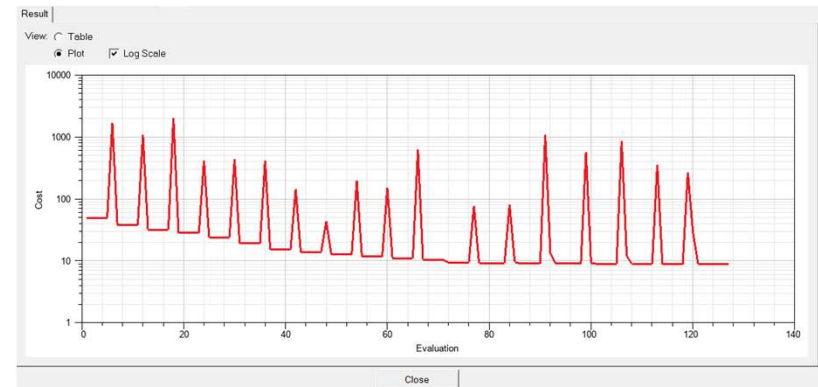
Cost Function:

	Calc. Solution	Calculation	Calc. Range	Condition	Goal	Weight
LinearFrequency	dB(S(Port1,Port2))		Freq(118MHz:138MHz)	>=	[-3]	[1]
LinearFrequency	dB(S(Port1,Port2))		Freq(50MHz:118MHz)	<=	[-20]	[1]
LinearFrequency	dB(S(Port1,Port2))		Freq(138MHz:200MHz)	<=	[-20]	[1]

Setup Calculations... Delete

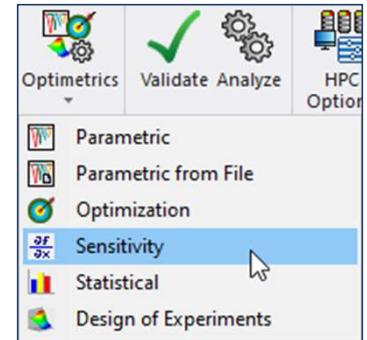
Acceptable Cost: 0 Noise: 0.0001 ☐ Stop on satisfy Acceptable Cost ☐ Show Advanced Options

Edit Variables HPC and Analysis Options... OK Cancel



Ansys Optimetrics

- Each of the three analyses shown previously fall under Ansys Optimetrics
- Optimetrics enables the user to determine the best design variation among a model's possible variations
 - Parametric Sweep
 - Tuning
 - Optimization
 - Statistical
 - Sensitivity
 - More!
- Which method of analysis depends on application and design goals



Parametric	In a parametric analysis, you define one or more <i>variable sweep definitions</i> , each specifying a series of variable values within a range. For example, you can parameterize component values. (See Variables in Maxwell for more information.) Optimetrics solves the design at each variation. You can then compare the results to determine how each design variation affects the performance of the design. Parametric analyses are often used as precursors to optimization solutions because they help to determine a reasonable range of variable values for the optimization analysis.
Optimization	For an optimization analysis, you identify the cost function and the optimization goal. Optimetrics changes the design parameter values to meet that goal. The cost function can be based on any solution quantity that Maxwell can compute.
Sensitivity	In a sensitivity analysis, you use Optimetrics to explore the vicinity of the design point to determine the sensitivity of the design to small changes in variables.
Tuning	Tuning allows you to change variable values interactively while monitoring the performance of the design. If you want to ensure that tuning does not resolve variations already solved by parametric setup, you must check Save Fields Mesh in the Options tab of the optimetrics setup.
Statistical	In a statistical analysis, you use Optimetrics to determine the distribution of a design's performance, which is caused by a statistical distribution of variable values.
Design of Experiments	Design of Experiments involves the creation of a response surface that depicts and predicts how variable values will affect the design.
DesignXplorer	An optimization tool for studying a range of design variations, used with Design of Experiments.
optiSLang	optiSLang simulations can be integrated with Ansys Electronics Desktop, such that you can create a setup very much like an Optimetrics setup to run through an optiSLang installation.

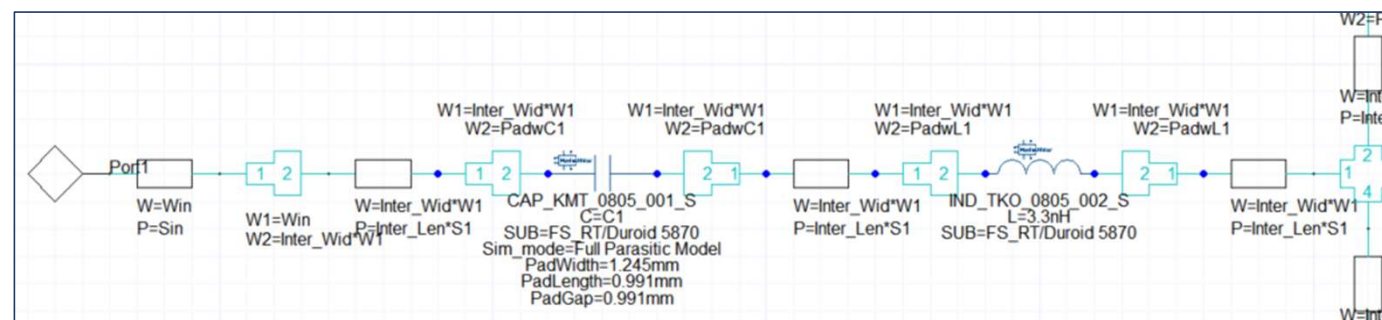
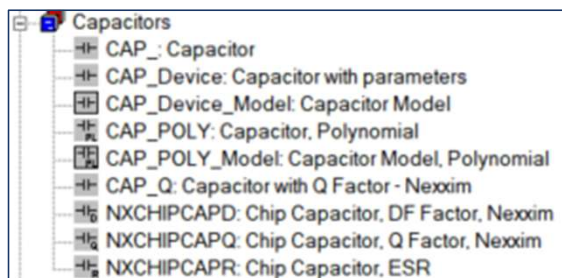
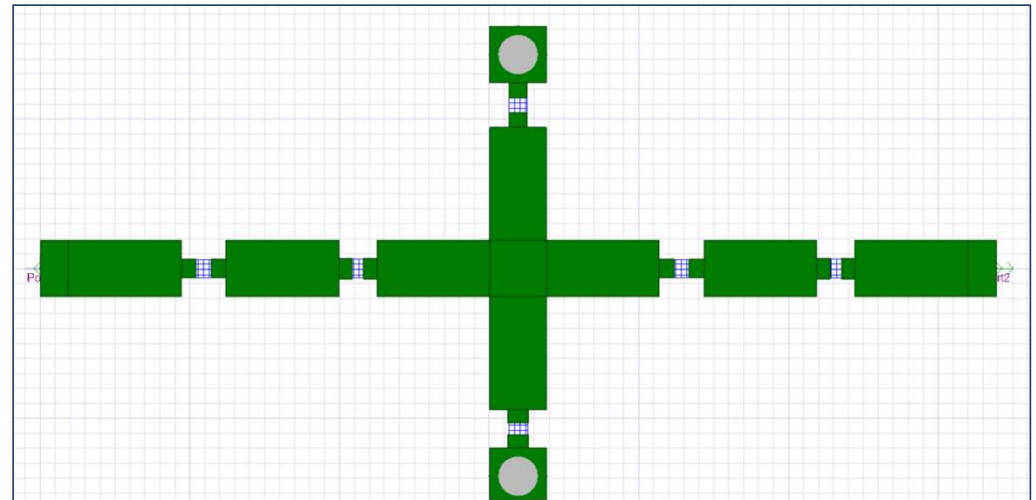


Expanding the Fidelity of the Model

-

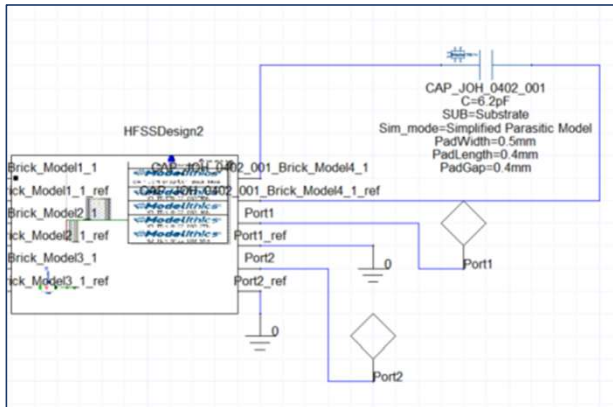
Filter Design with Lumped, Distributed, and Parasitic Models

- For even more detail, one could add real C's and L's to the model
- The circuit tool can create a PCB layout with the defined elements
 - Here, 0805 Kemet capacitors and Murata inductors
- Not required to have a full model. SMDs can be defined in many ways
- User can optimize interconnect length / width and mounting pad width as well as in-series element values

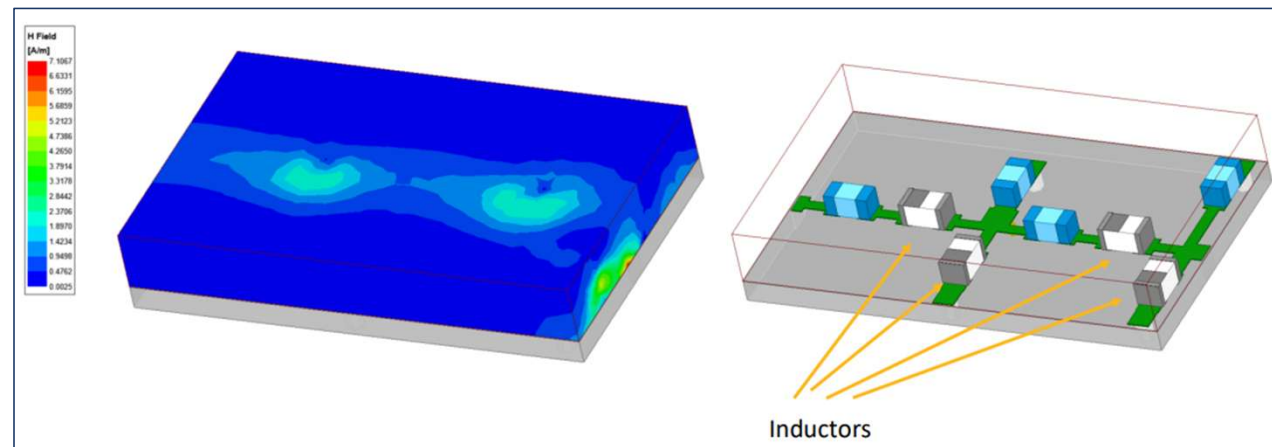
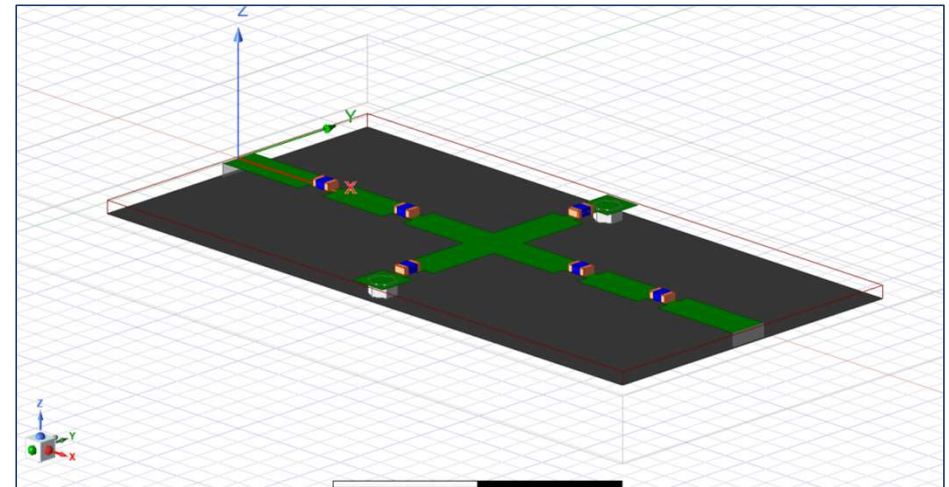


HFSS: MCAD

- Can make full HFSS model
 - Not netlist (circuit) or layup (3D Layout) definitions, but full 3D geometry
 - Geometry of traces/pads exported from 3D Layout
 - Caps and Inductors defined as 3D components
- Can use circuit tool when there is no HFSS 3D component available:



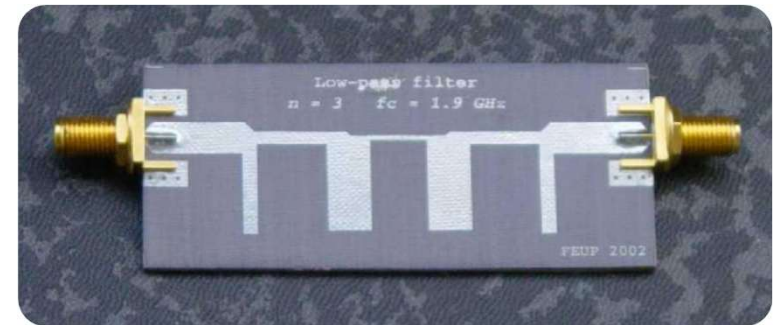
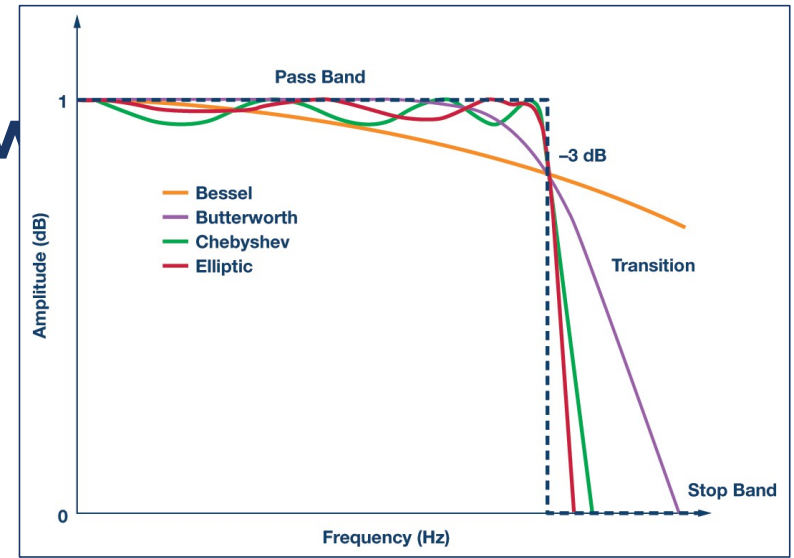
February 26



From Similar Training Problem

Ansys Filter Design Workflow

1. Define Filter Specifications/Requirements
 - Filter Class (Lowpass, Bandpass, etc.)
 - Cutoff frequencies
 - Attenuation and Ripple
2. Select Topology and Family
 - Filter Shape (Bessel, Chebyshev, Butterworth, etc.)
 - Order
3. Calculate Component Values/Candidate Design
4. Circuit-Level Simulation and Optimization
 - Tuning (Trace and Component)
5. Field-Level Simulation and Verification
6. Build Prototype and Test



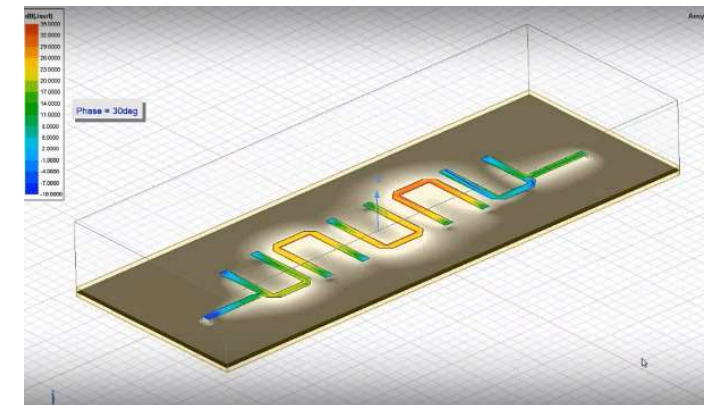
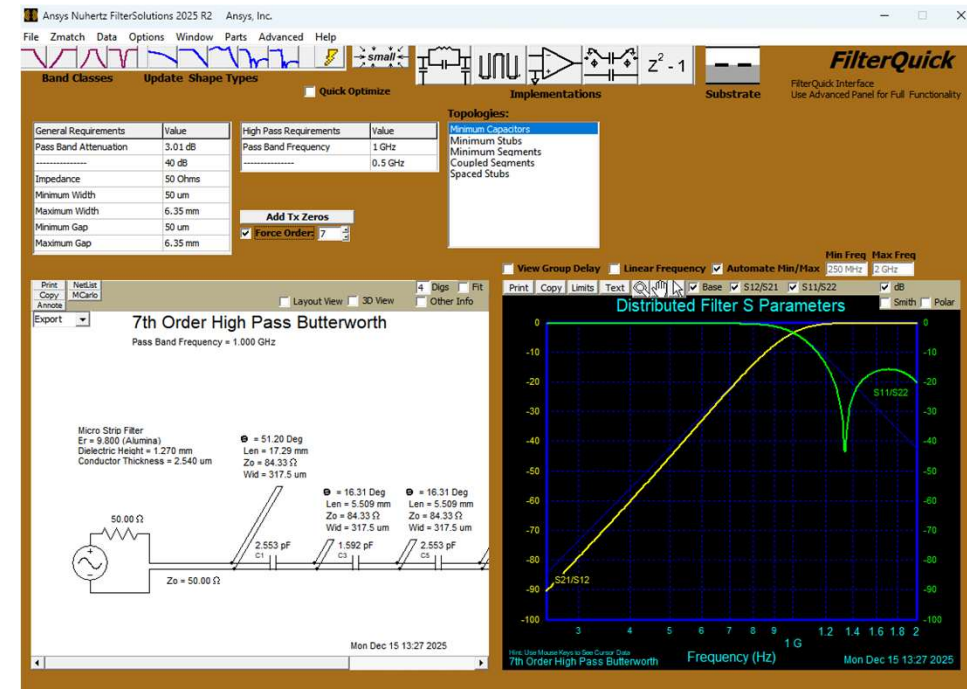
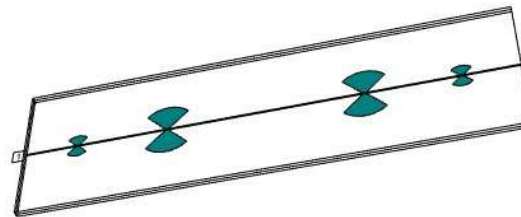


NuHertz FilterSolutions and SynMatrix

Add-on Tools

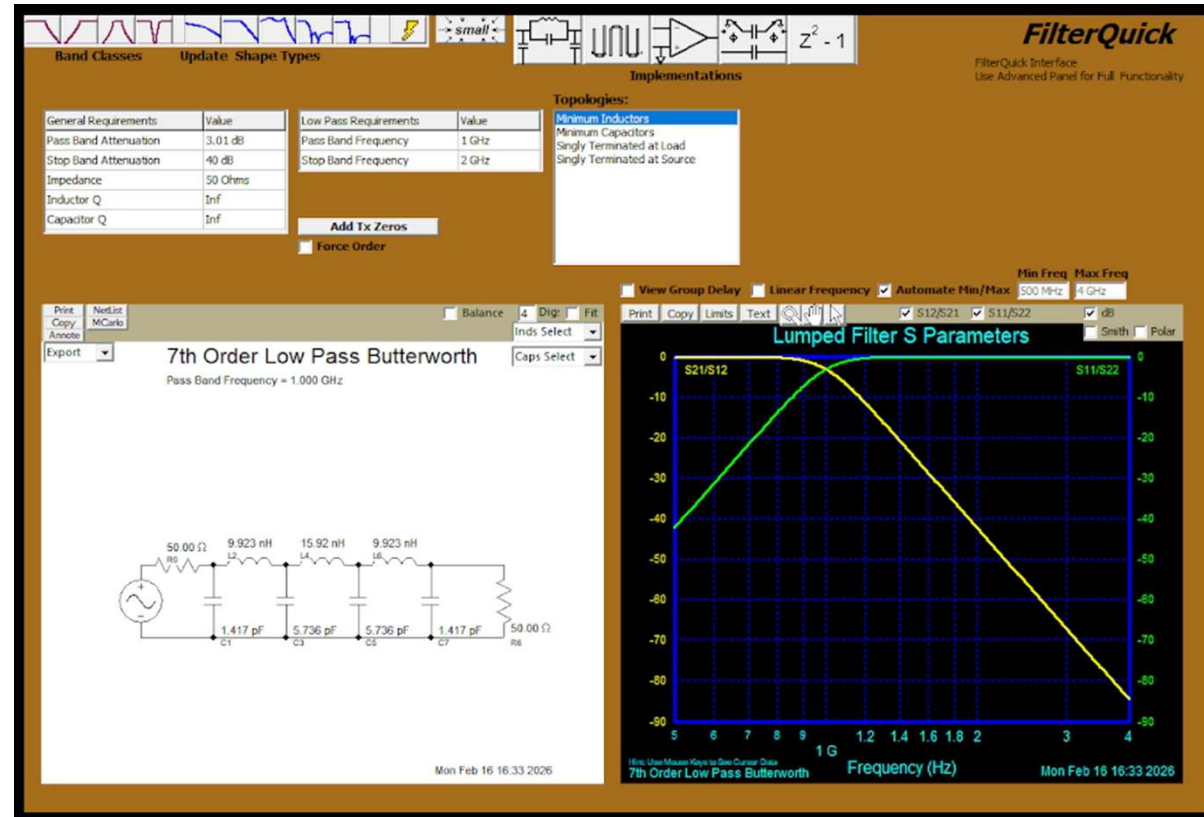
Ansys NuHertz Filter Design

- A filter synthesis & analysis software for passive, active, and switched capacitor circuit synthesis
- Supports:
 - Modification analysis with parasitic effects
 - Digital filter IIR and FIR design
- User defines:
 - Band Class, Shape type, implementation, cutoff frequencies, and parasitics
- Outputs:
 - Candidate filter design with component values



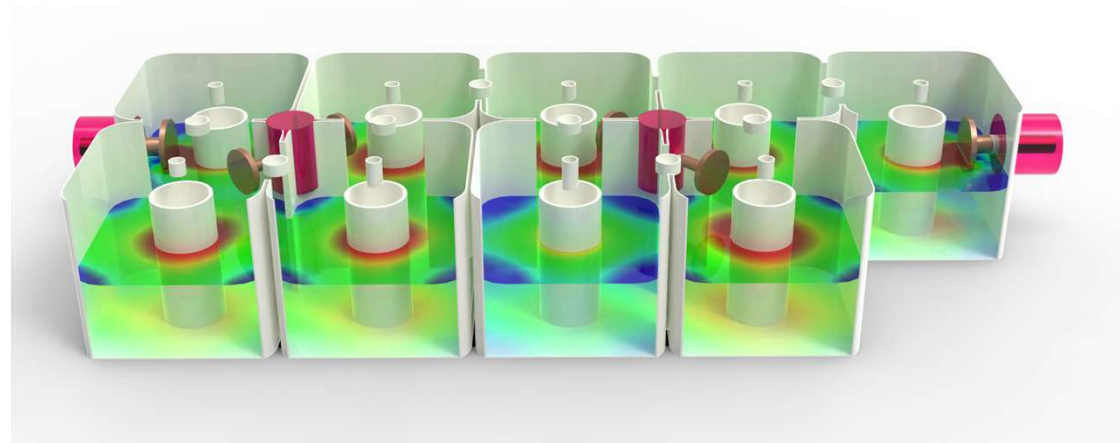
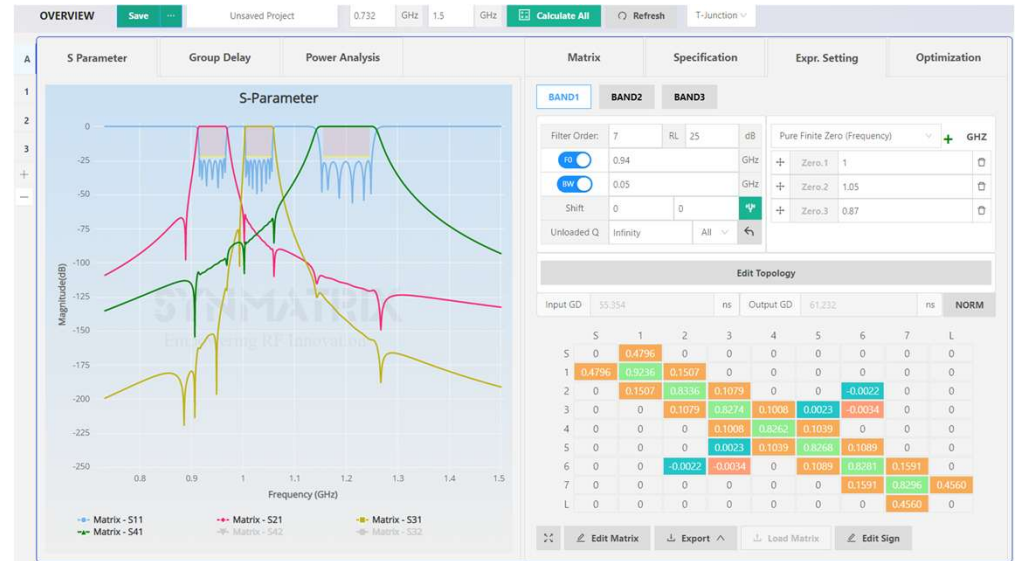
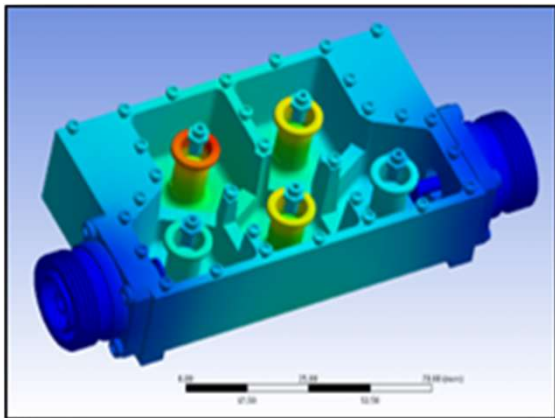
Ansys NuHertz Filter Design

- Requirements:
 - 88 to 108 MHz Bandpass Filter
 - FM Radio
 - Type: Butterworth
 - Attenuation: 80dB/decade



SynMatrix

- A Filter Synthesis & Optimization Platform for Waveguide, Cavity, and SIW Filters
- Supports:
 - Automated 3D geometry generation
 - AI-driven optimization & space mapping
 - Monte Carlo & sensitivity analysis for yield prediction



February 26

Questions??
Comments??

Thank you!

If you have any technical questions, please reach out to support@drd.com

