Waveguide Device Design Using XFdtd®

Joseph J. Rokita

Remcom, Inc.

Remcom Inc.

315 S. Allen St., Suite 416 ◆ State College, PA 16801 ◆ USA

Tel: 1-814-861-1299 ◆ Fax: 1-814-861-1308 ◆ sales@remcom.com ◆ www.remcom.com

Outline

- Introduction to XFdtd (XF7)
- Why use simulation?
- How can XF7 help?
- Example: Modeling a waveguide cavity filter
- Results / sensitivity analysis
- Conclusion

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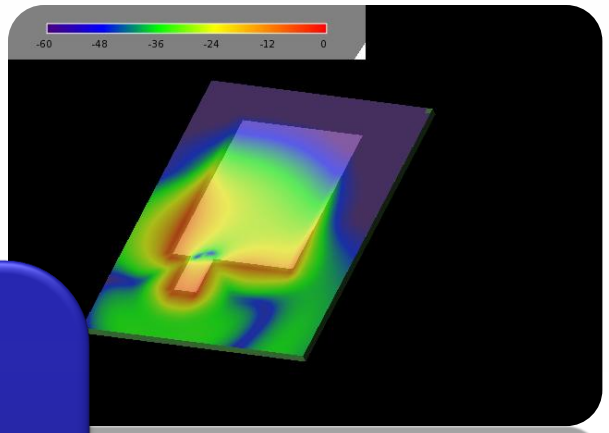
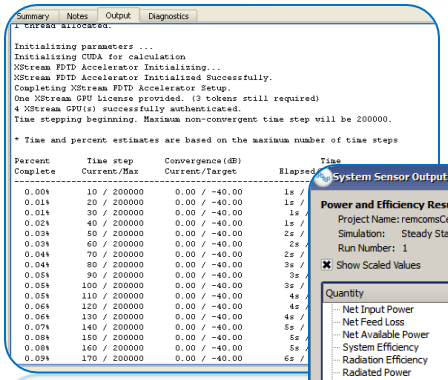
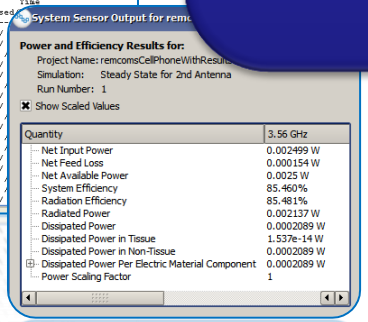
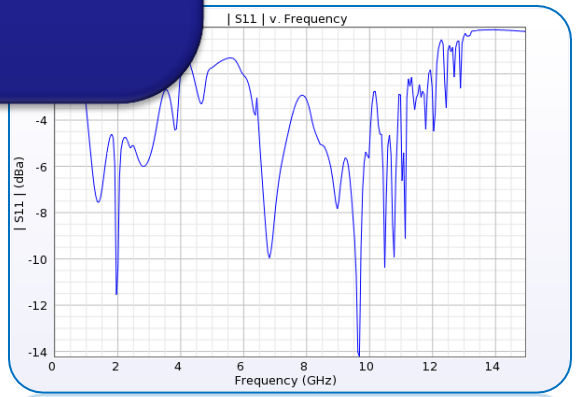
What is XFdtd?



- CAD modeling tool
- EM simulator
- Data visualization tool
- Technical computing environment







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Why Simulation?

- Reduce cost, time, and waste
  - Cost and lead times for obtaining prototypes
  - Cost and lead times for measurement
  - Rework
  - Material waste
- Simulation allows for rapid iteration
- Simulate real operating conditions
  - Aircraft in flight
  - Implanted medical device
- Advances in computer technology have reduced simulation times by orders of magnitude

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XF7 Workflow

- Starting a new project in XF is analogous to asking someone to build a prototype of your design and measure its performance
- You need to provide:
  - Parts list
  - Bill of materials
  - List of measurements to be taken
- The steps presented here represent a suggested workflow, but many of the steps can be performed in a different order.

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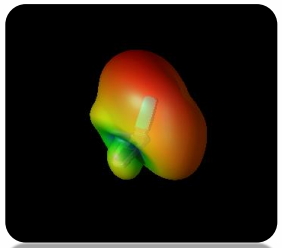
XF7 Workflow



Define Geometry

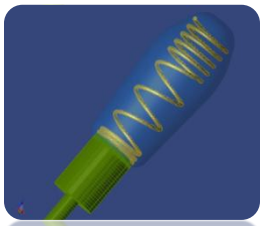
- What are the physical structures I want to test?

Materials

- Modeled using real-life EM properties as well as certain physical properties

Define Excitations and Circuit Components

- How are signals introduced into my system?

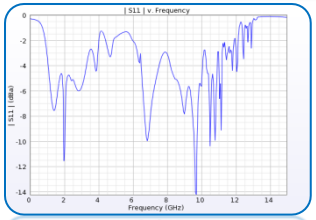


Sensors

- What type of measured data do I need and where?

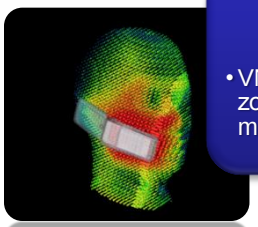
Gridding / Meshing

- Discretize physical objects in space so we can simulate using FDTD



Create / Run Simulation

- Simulating like attaching network analyzer (VNA)



View / Analyze / Export Results

- VNA for S-Params, chamber for far-zone, etc., all within one simulation… make changes and re-simulate

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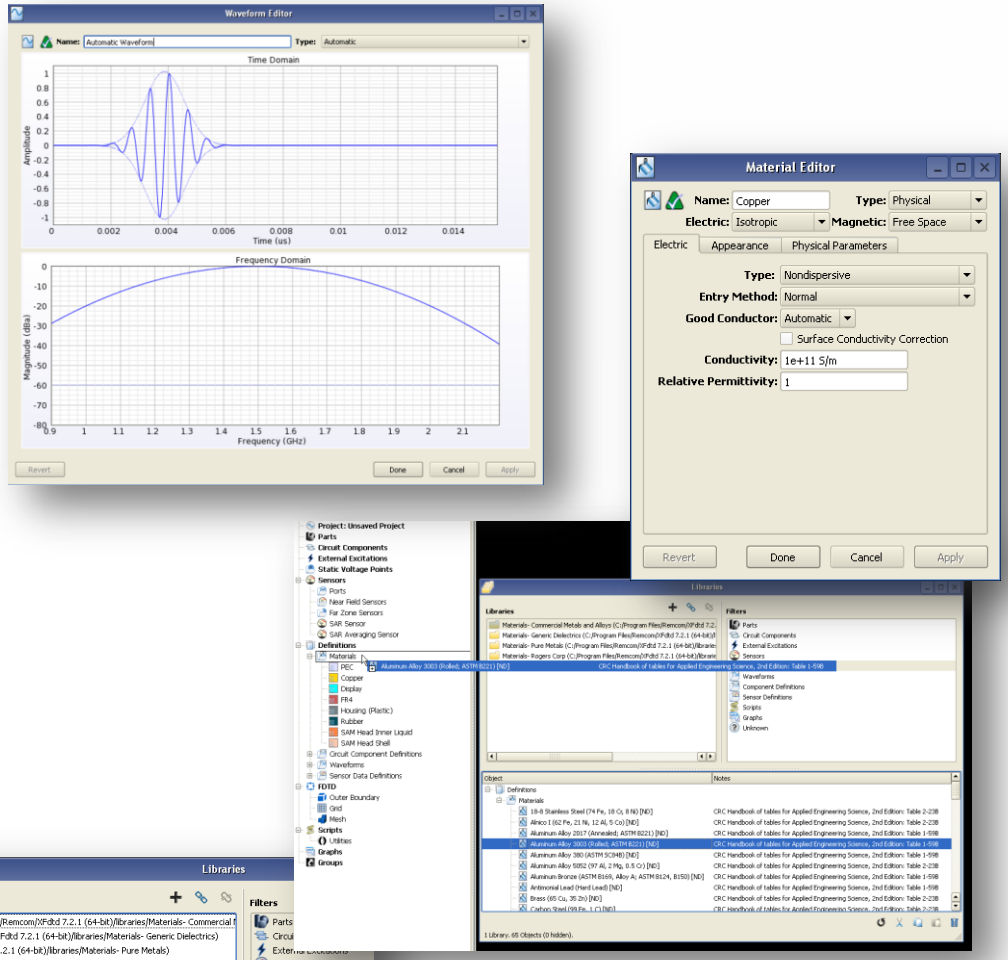
How Can XFdtd Help?

- Full-wave, first-principles code
  - No assumptions
  - Simulate complex objects with high accuracy
- FDTD
  - Time-domain method allows exciting many frequencies with a single simulation
  - Can use a great variety of materials



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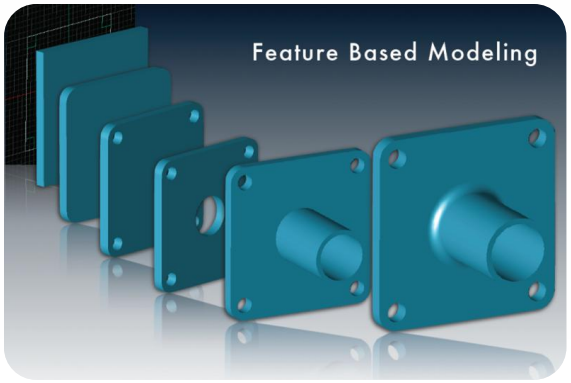
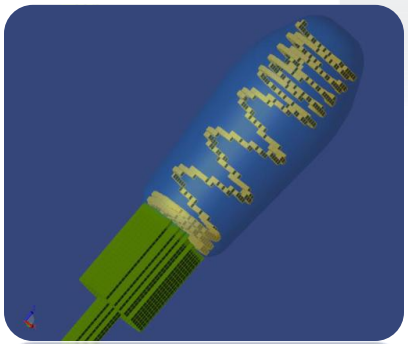
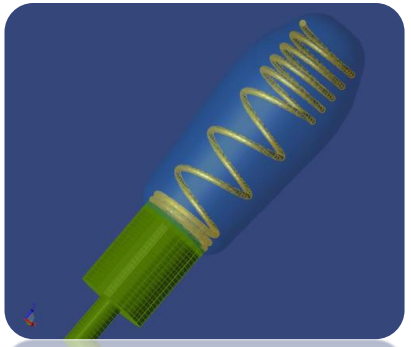
How Can XFdtd Help?

- Robust CAD import and geometry creation / manipulation
- XACT Accurate Cell Technology®
  - A subcellular modeling technique to precisely capture curved surfaces, thin sheets and small gaps.
    - Good conductors
    - Dielectrics
  - Permits larger cell size, meaning less memory footprint, faster simulation







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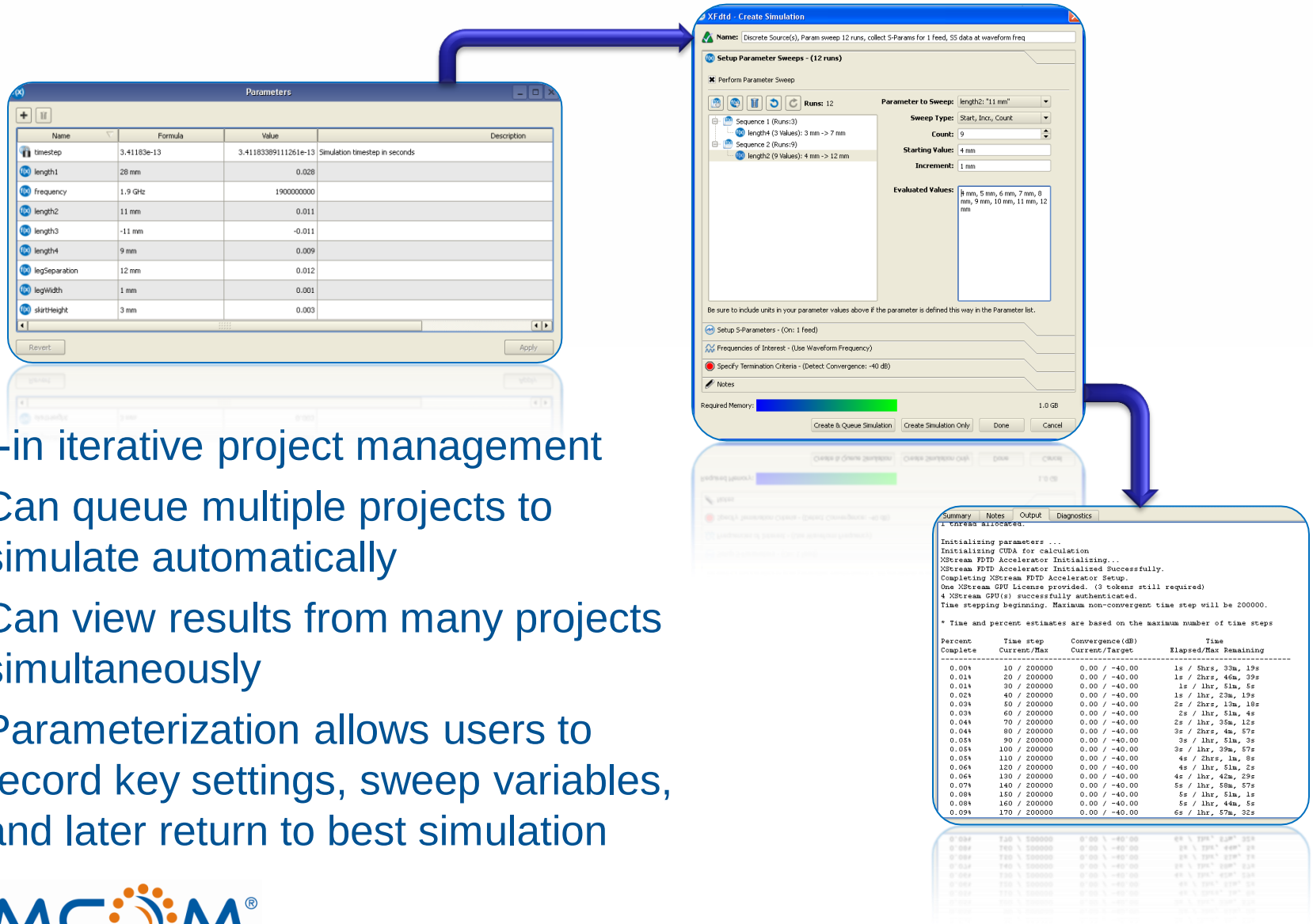
How Can XFdtd Help?



- Built-in iterative project management
  - Can queue multiple projects to simulate automatically
  - Can view results from many projects simultaneously
  - Parameterization allows users to record key settings, sweep variables, and later return to best simulation

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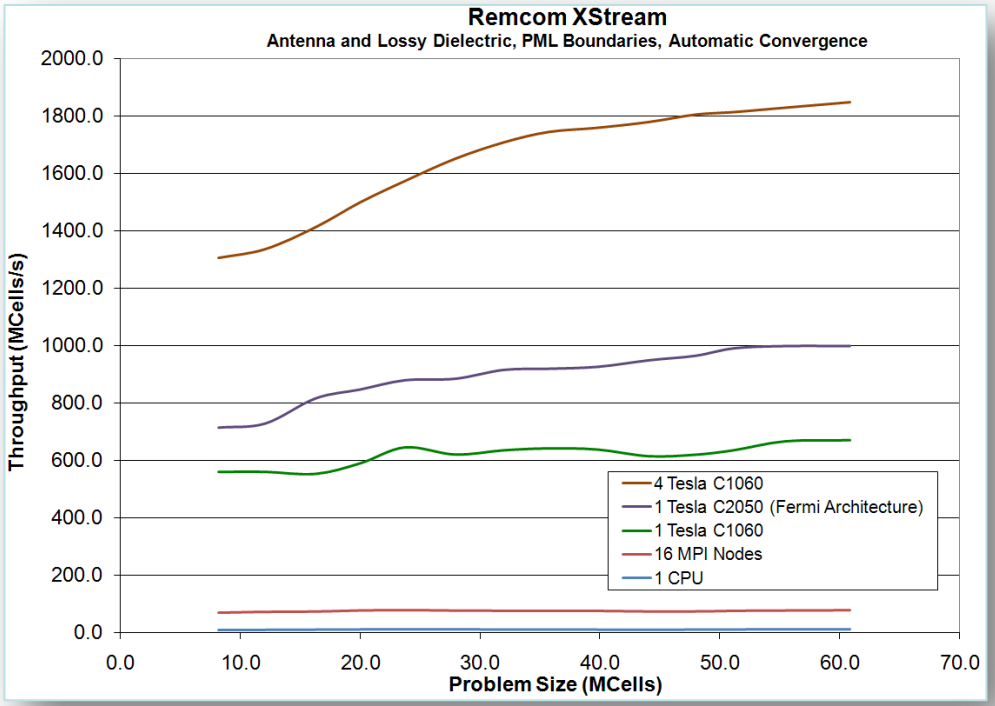
How Can XFdtd Help?

- XStream® GPU Acceleration
  - Leverage the power of NVIDIA's CUDA architecture
  - Massively parallelized implementation
  - Speed improvements that are hundreds of times faster than a 64 bit CPU
  - License to employ a single GPU bundled for free with XF7
    - Licenses for additional GPUs available



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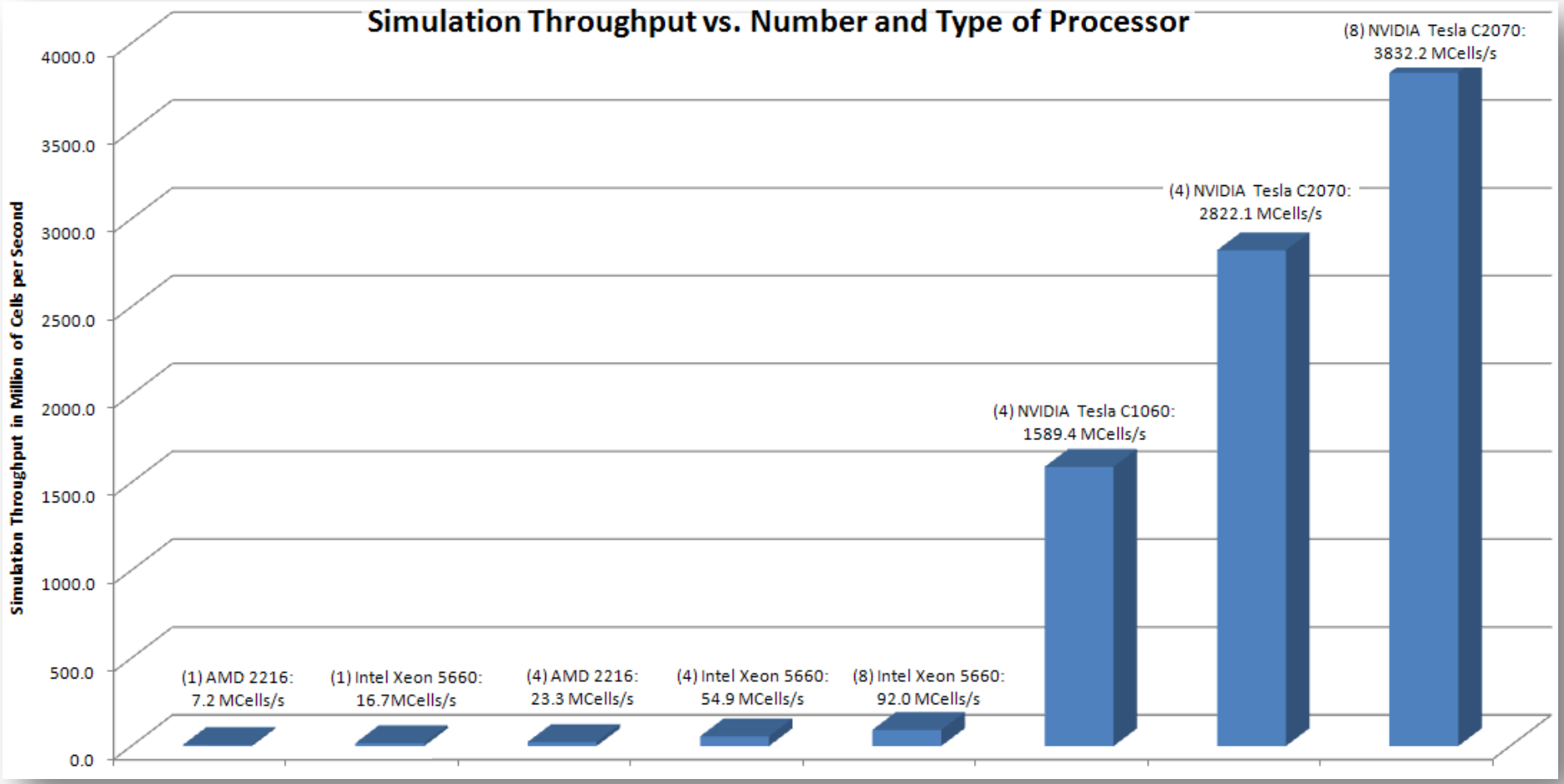

- 1 AMD 2216: 7.2 Mcells/s
- 1 Intel Xeon 5660: 16.7 Mcells/s
- 8 Intel Xeon 5660: 92.0 Mcells/s
- 8 Tesla C2070: 3832.2 Mcells/s

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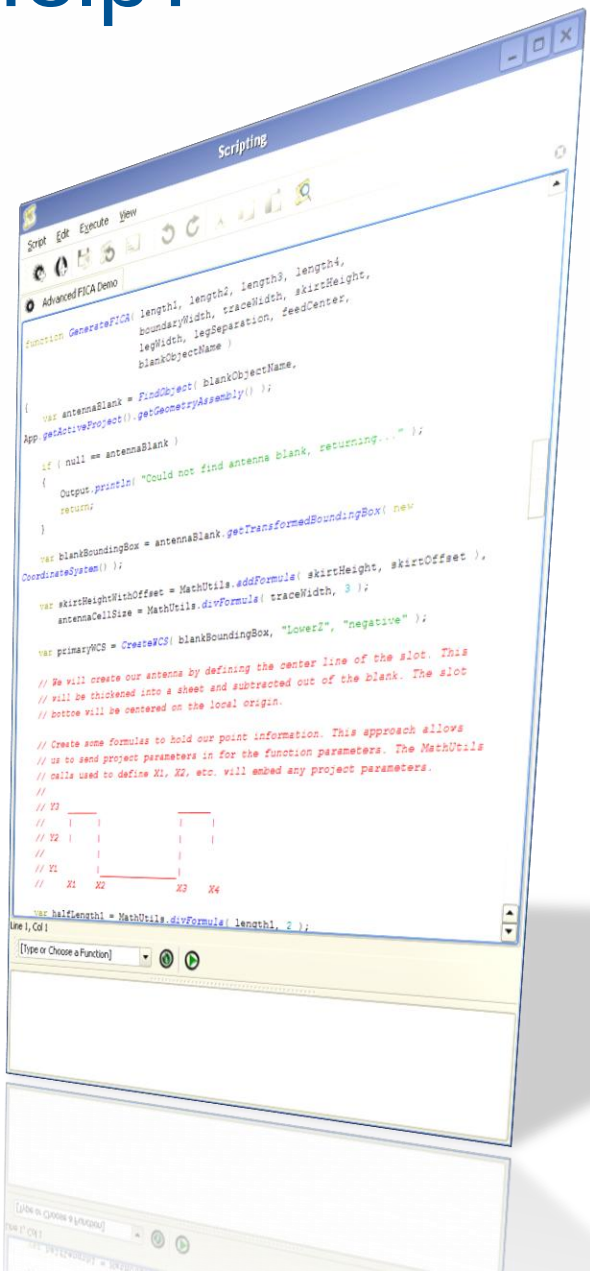
How Can XFdtd Help?

- Scripting
  - Robust scripting engine can allow greater efficiency of design, optimization, further analysis, etc…
  - Allows creation and modification of simulations, parameters, and results, so automated iterative design and output post-processing can be done within the software
  - XTend Script Library provides custom functionality “out of the box”



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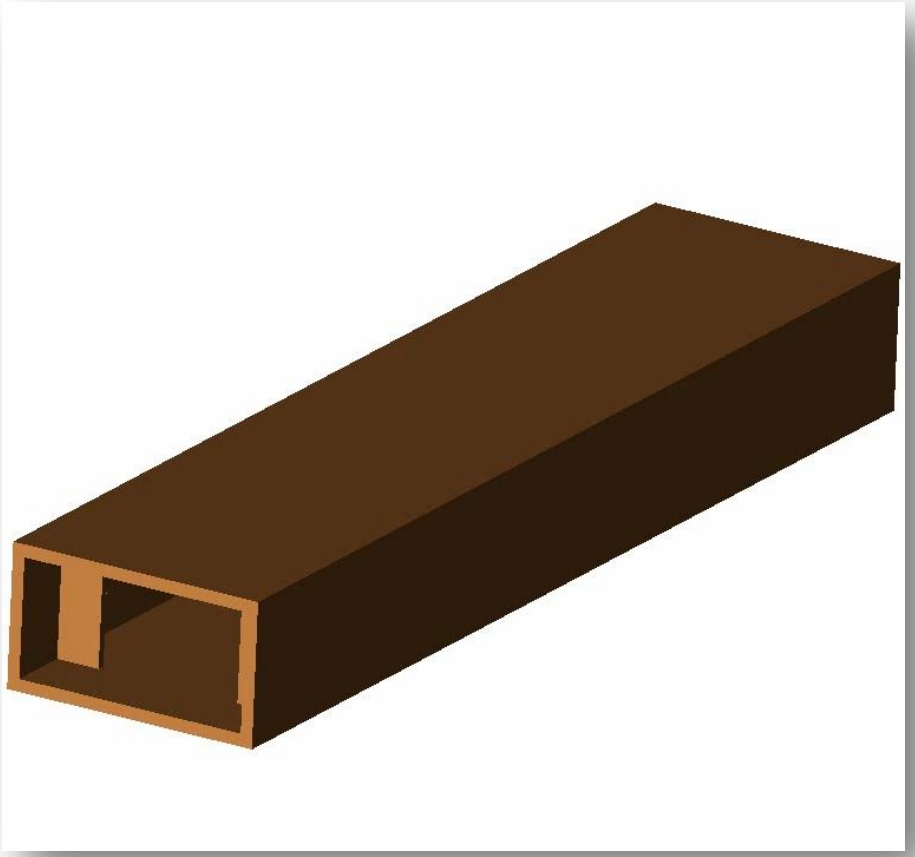
Waveguide Cavity Filter

- Want bandpass filter for Ka band
- |S11| < -20 dB for *f* 27.5 GHz to 28.3 GHz
- |S11| > -0.05 dB for *f*<27 GHz and *f*>28.8 GHz
- Will design filter device with iris coupling windows and cavities
  - Design parameters include window size of irises and length of cavities
  - Can use equations to get initial design, then optimize to get better result
  - Verify using simulation at each step
- Perform sensitivity analysis to determine performance of device given specified manufacturing tolerances



Click to watch video…

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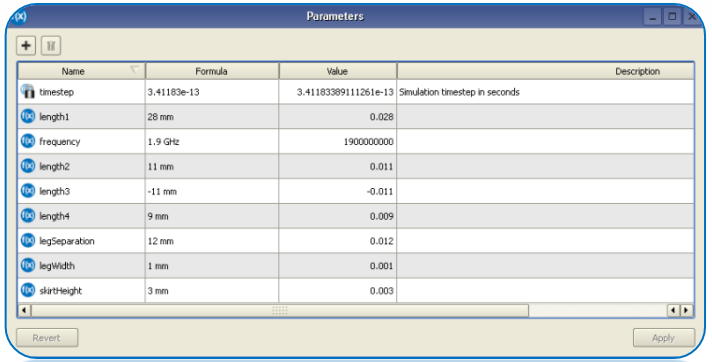
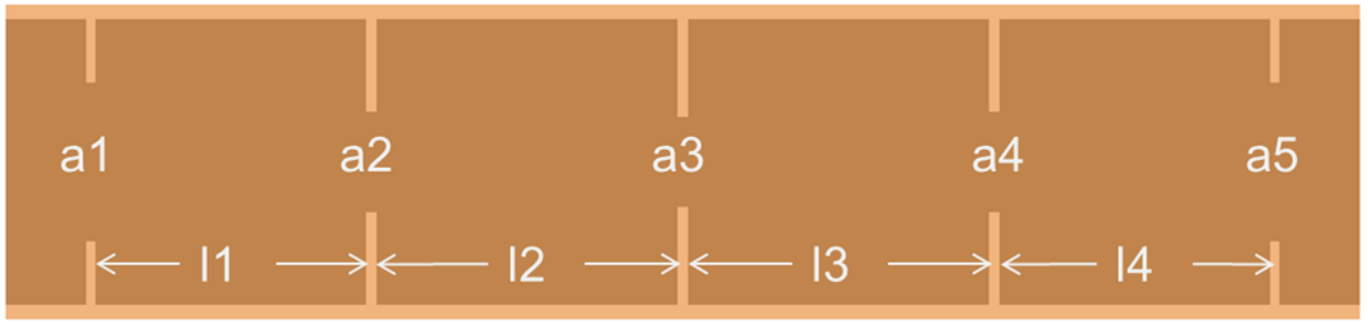
Waveguide Cavity Filter

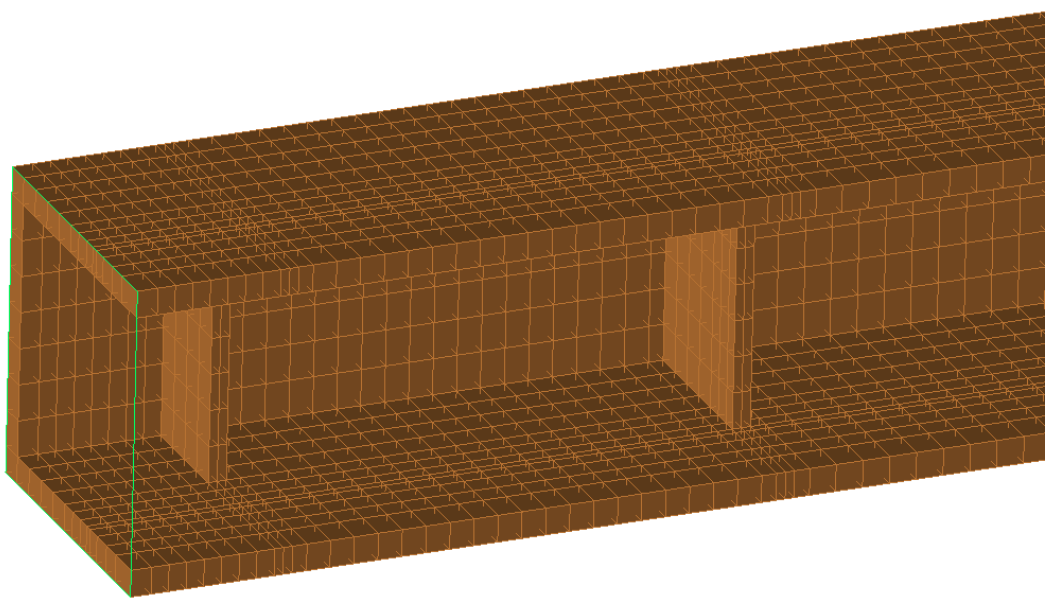
- Feature-based modeling allows changes mid-design
- Device dimensions fully parameterized
  - Enables optimization and sensitivity studies
  - a1-a5: iris widths
  - l1-l4: cavity lengths





Waveguide Cavity Filter

- Variable grid and fixed-points allow the mesh to precisely match a real-world device
- A more complicated device could be modeled using XACT mesh



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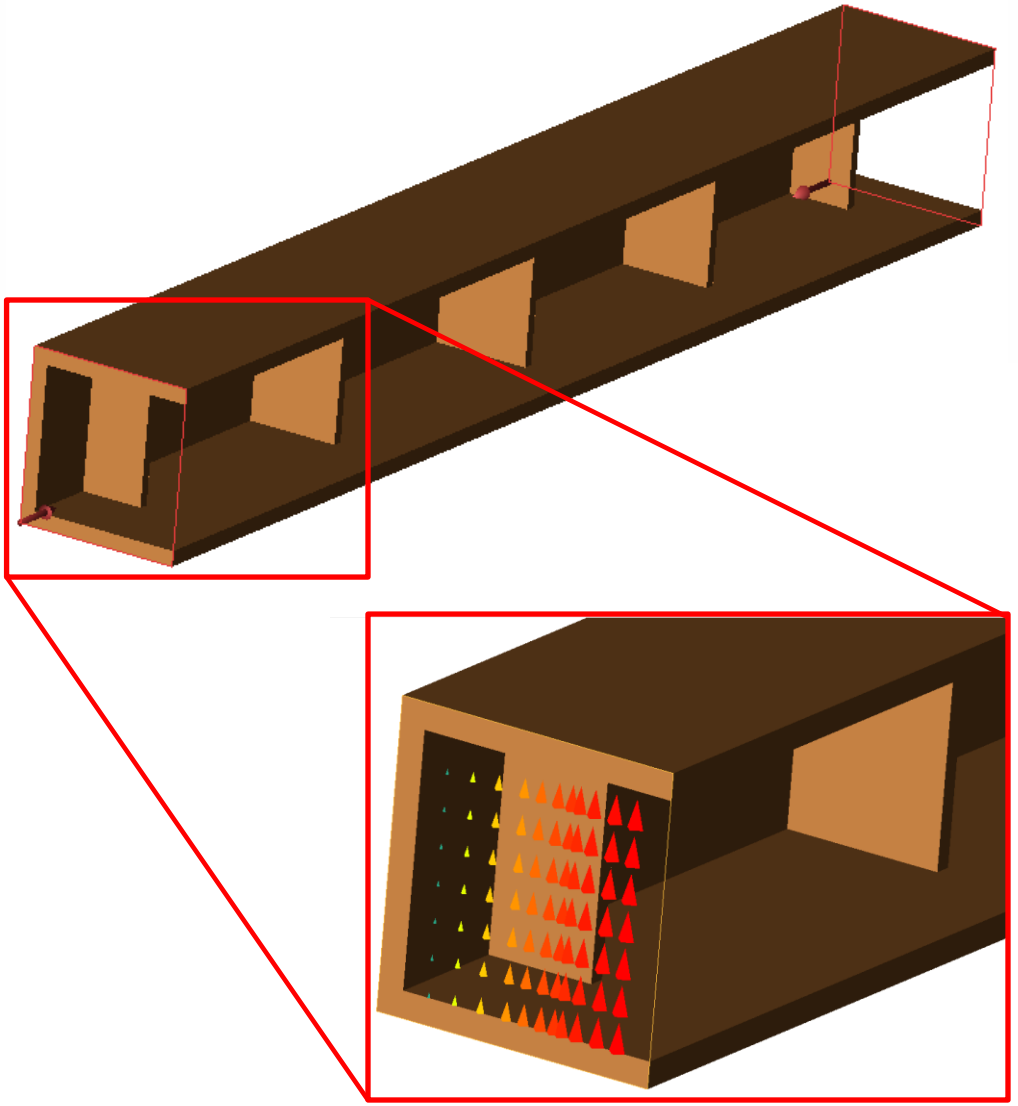
Waveguide Cavity Filter

- Waveguide ports were created for input and output
- Active port calculates modes and “injects” energy into the simulated device



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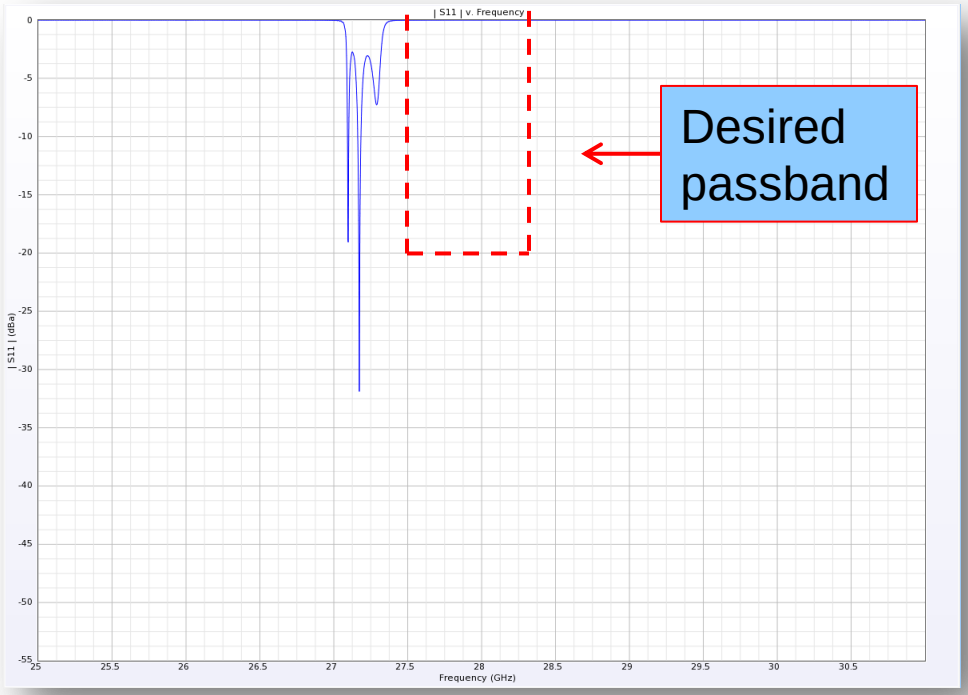
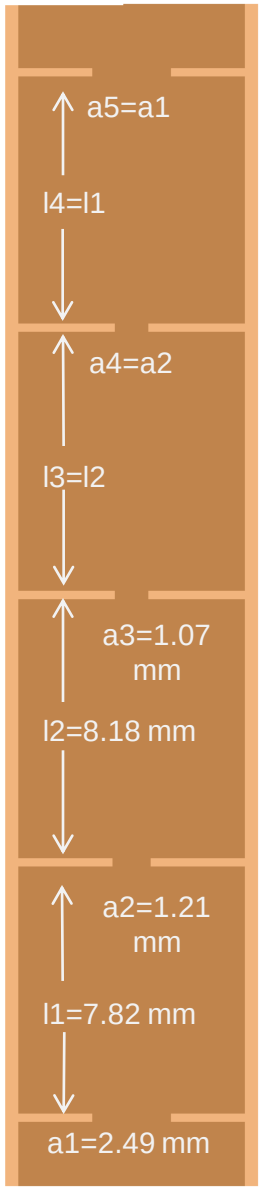
Waveguide Cavity Filter

- Equations led to the initial design

|S11| vs. Frequency

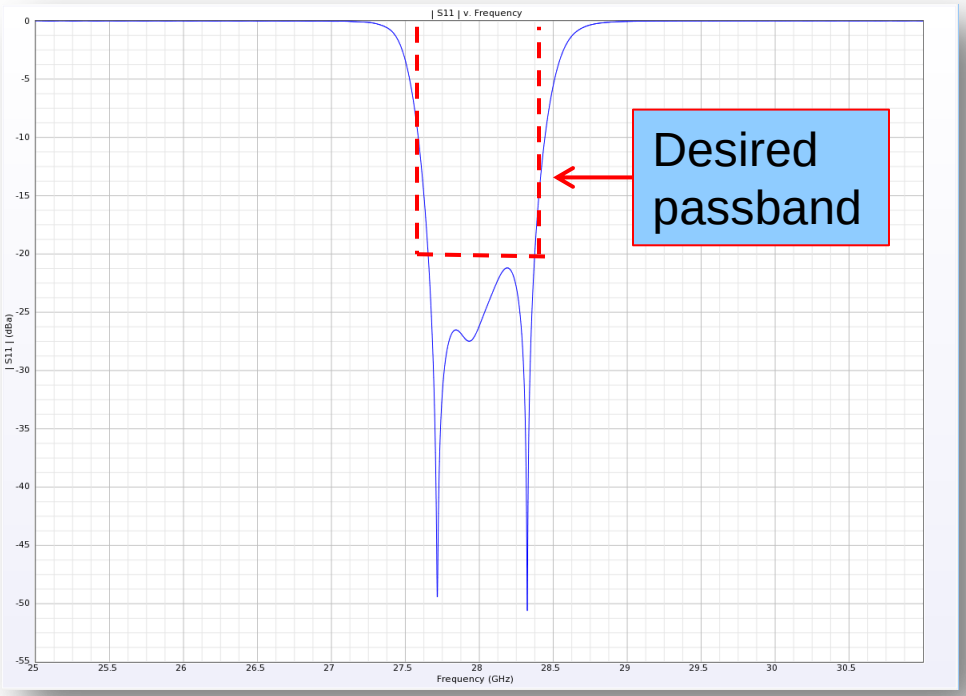


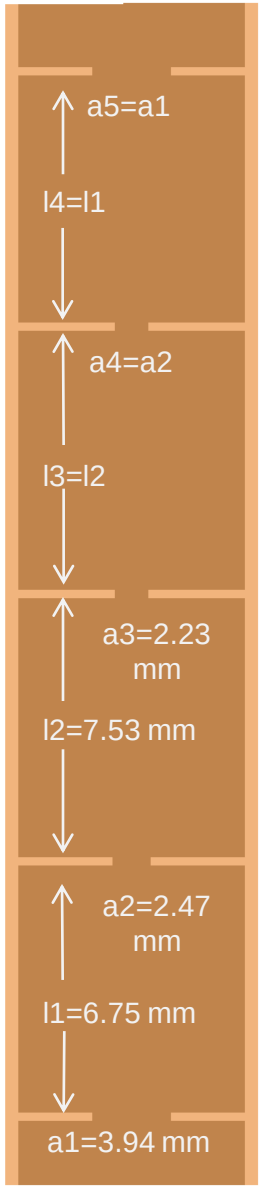


- Good start, but optimization needed

Waveguide Cavity Filter

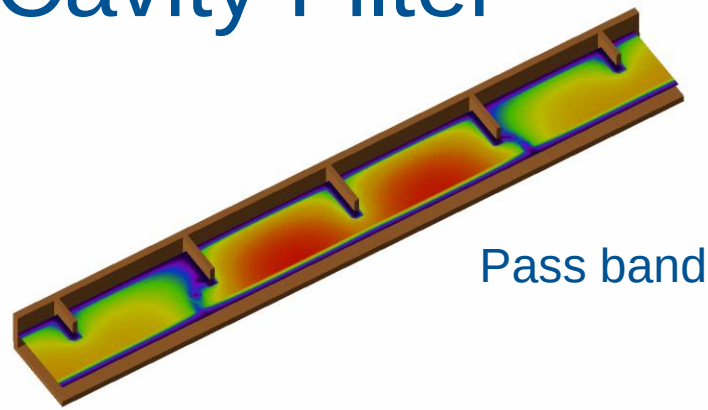
- Mode matching resulted in better pass-band performance





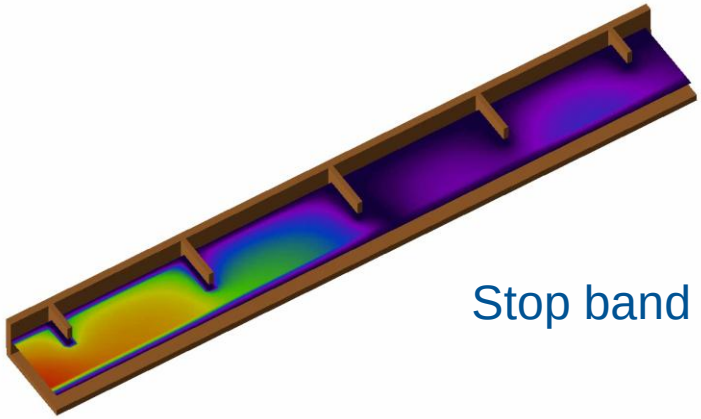
Waveguide Cavity Filter

- Time-domain code allows for solutions at multiple frequencies with single simulation
- Steady-state E-field in pass-band is transmitted to output port, while stop-band energy is contained



Pass band

Click to watch video…



Stop band

Click to watch video…

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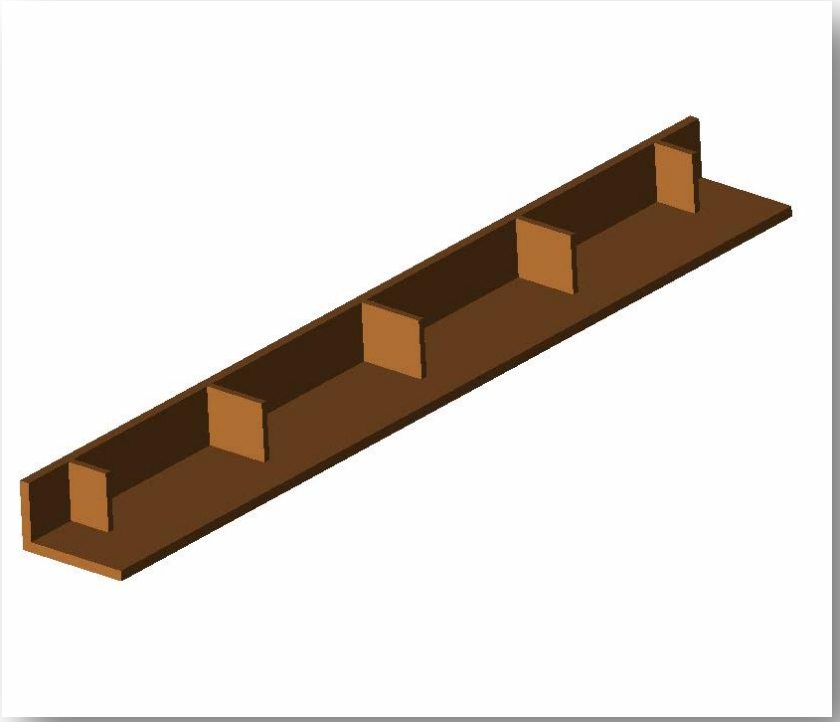
Waveguide Cavity Filter

- Want to know how chosen manufacturing tolerances will affect results
- Since model is fully parameterized, sensitivity analysis is simple
- Scripting can be used to automate the geometry variations, launch simulations, and perform analysis



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Waveguide Cavity Filter

- Manufacturing method chosen allows for tolerances within 20 μm
- Scripting automated the geometry creation, launched simulations, and analyzed results
- Ran with 2 NVIDIA C2075 GPUs
- 512 simulations required about 8 hrs., 34 min. (about one min. per simulation)
- Plot shows top twenty worst-performing variations from sensitivity analysis (best in blue)
- Can then determine whether the chosen manufacturing technique is acceptable, or if another must be chosen

Conclusion

- XFdtd is a powerful, multi-purpose, full-wave FDTD simulation tool
- Provides tools to ease and speed workflow of design and analysis
- Can model complex structures, such as filters
- Host of features permits advanced analysis such as sensitivity studies

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