



Waveguide Device Design Using XFDTD®

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Remcom, Inc.

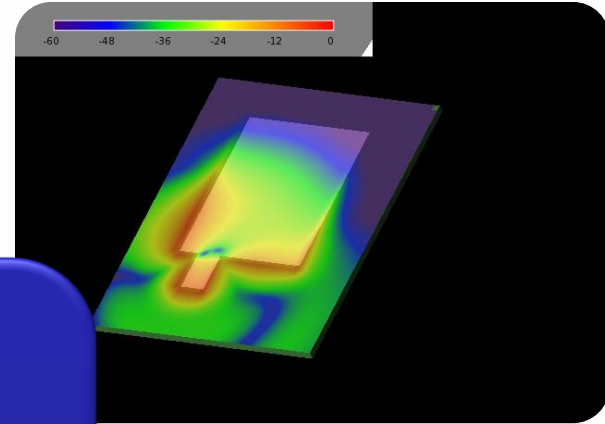
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Outline

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

What is XFDTD?



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

Summary Notes Output Diagnostics

```
1 *Process allocated.
Initialising parameters ...
Initialising CUDA for calculation
XFDTD FDTD Accelerator Initialising ...
XFDTD FDTD Accelerator Initialised Successfully.
Completing XFDTD FDTD Accelerator Setup.
One XFDTD GPU license provided. (3 tokens still required)
4 XFDTD GPU(s) successfully authenticated.
Time stepping beginning. Maximum non-convergent time step will be 200000.
* Time and percent estimates are based on the maximum number of time steps
```

Percent Complete	Time step	Convergence (dB)	Time Elapsed
0.00%	10 / 200000	0.00 / -40.00	1s /
0.01%	20 / 200000	0.00 / -40.00	1s /
0.01%	30 / 200000	0.00 / -40.00	1s /
0.02%	40 / 200000	0.00 / -40.00	1s /
0.03%	50 / 200000	0.00 / -40.00	2s /
0.03%	60 / 200000	0.00 / -40.00	2s /
0.04%	70 / 200000	0.00 / -40.00	2s /
0.04%	80 / 200000	0.00 / -40.00	3s /
0.05%	90 / 200000	0.00 / -40.00	3s /
0.05%	100 / 200000	0.00 / -40.00	3s /
0.05%	110 / 200000	0.00 / -40.00	4s /
0.06%	120 / 200000	0.00 / -40.00	4s /
0.06%	130 / 200000	0.00 / -40.00	4s /
0.07%	140 / 200000	0.00 / -40.00	5s /
0.08%	150 / 200000	0.00 / -40.00	5s /
0.08%	160 / 200000	0.00 / -40.00	5s /
0.09%	170 / 200000	0.00 / -40.00	6s /

Power and Efficiency Results for:

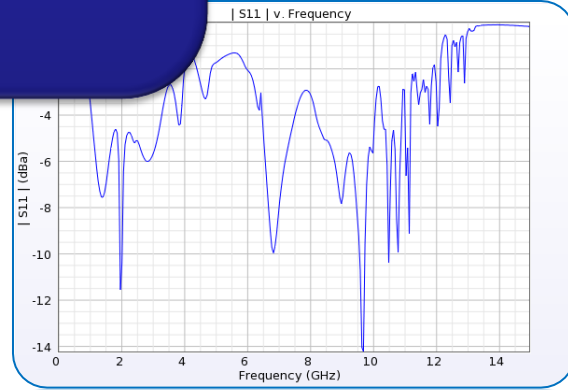
Project Name: remcomsCellPhoneWithResul

Simulation: Steady State for 2nd Antenna

Run Number: 1

Show Scaled Values

Quantity	3.56 GHz
Net Input Power	0.002499 W
Net Feed Loss	0.000154 W
Net Available Power	0.0025 W
System Efficiency	85.460%
Radiation Efficiency	85.461%
Radiated Power	0.002137 W
Disipated Power	0.0002089 W
Disipated Power in Tissue	1.537e-14 W
Disipated Power in Non-Tissue	0.0002089 W
Disipated Power Per Electric Material Component	0.0002089 W
Power Scaling Factor	1



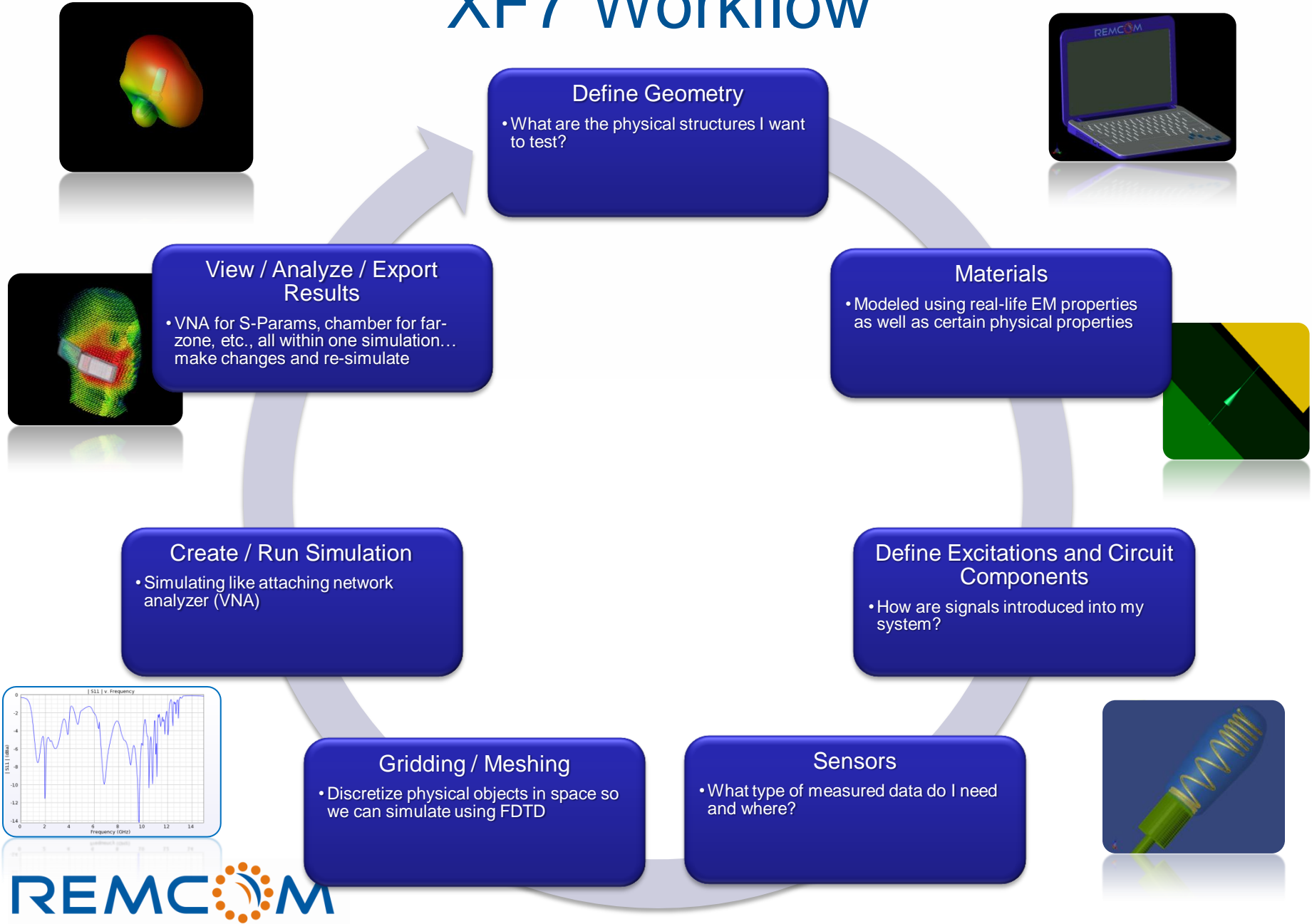
Why Simulation?

- 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

XF7 Workflow

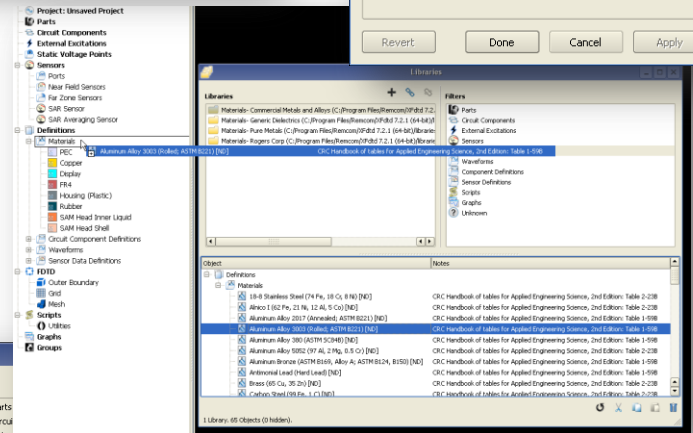
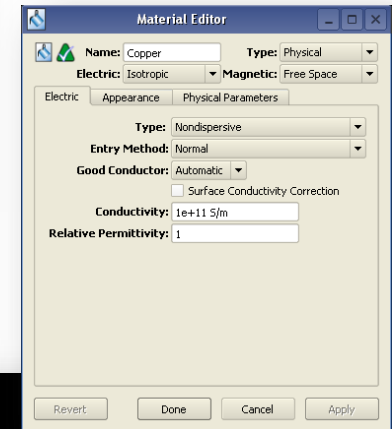
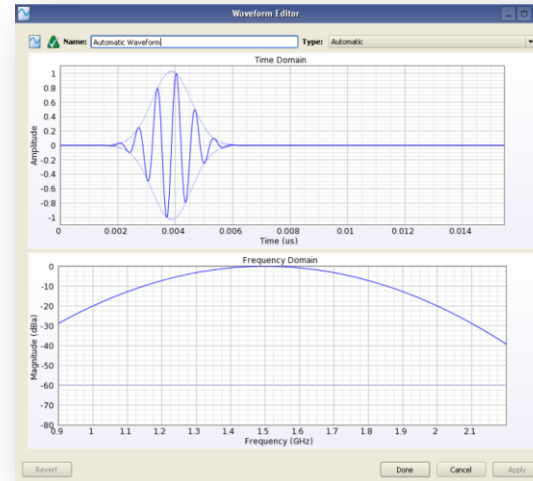
- Starting a new project in XF is analogous to asking someone to build a prototype of your design and measure its performance
- You need to provide:
 - Parts list
 - Bill of materials
 - List of measurements to be taken
- The steps presented here represent a suggested workflow, but many of the steps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

XF7 Workflow



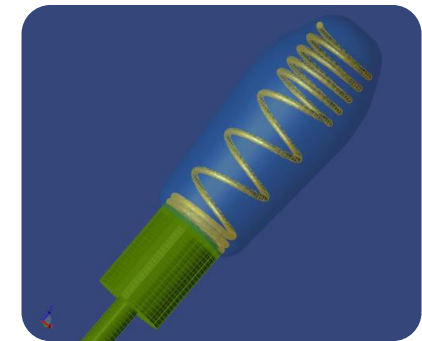
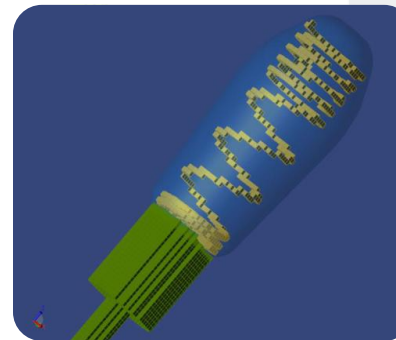
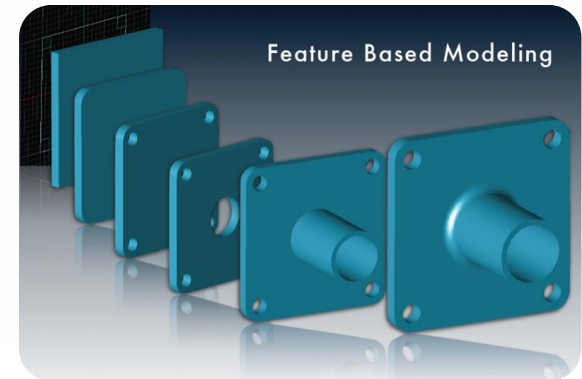
How Can XFDTD Help?

- 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

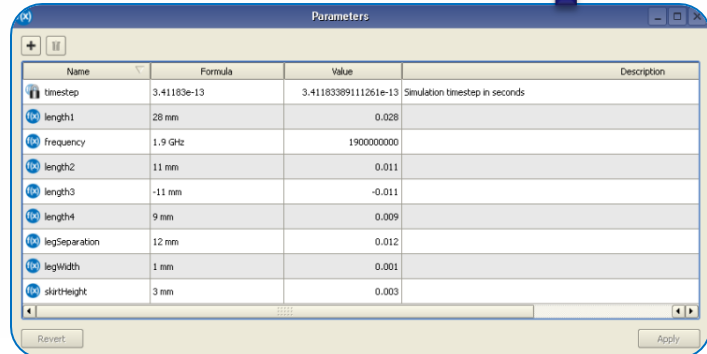


How Can XFtd Help?

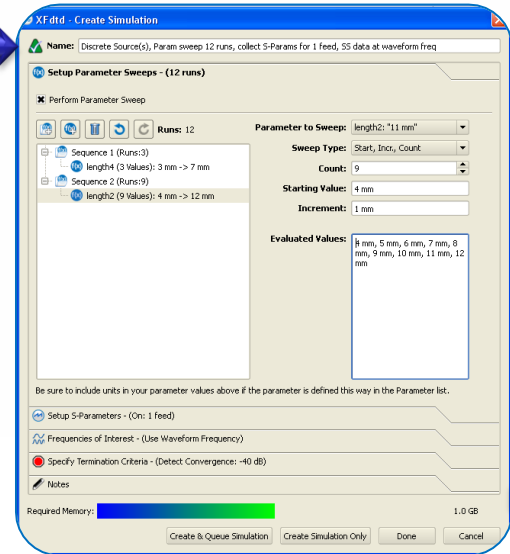
- Robust CAD import and geometry creation / manipulation
- XACT Accurate Cell Technology[®]
 - A subcellular modeling technique to precisely capture curved surfaces, thin sheets and small gaps.
 - Good conductors
 - Dielectrics
 - Permits larger cell size, meaning less memory footprint, faster simulation



How Can XFtd Help?



Name	Formula	Value	Description
timestep	3.41183e-13	3.41183389111261e-13	Simulation timestep in seconds
length1	28 mm	0.028	
frequency	1.9 GHz	1900000000	
length2	11 mm	0.011	
length3	-11 mm	-0.011	
length4	9 mm	0.009	
legSeparation	12 mm	0.012	
legWidth	1 mm	0.001	
slatHeight	3 mm	0.003	



XFtd - Create Simulation

Name: Discrete Source(s), Param sweep 12 runs, collect 5-Params for 1 Feed, 55 data at waveform freq

Setup Parameter Sweeps - (12 runs)

Perform Parameter Sweep

Runs: 12

Parameter to Sweep: length2: "11 mm"

Sweep Type: Start, Incr., Count

Count: 9

Starting Value: 4 mm

Increment: 1 mm

Evaluated Values: 8 mm, 5 mm, 6 mm, 7 mm, 8 mm, 9 mm, 10 mm, 11 mm, 12 mm

Be sure to include units in your parameter values above if the parameter is defined this way in the Parameter list.

Setup 5-Parameters - (On: 1 Feed)

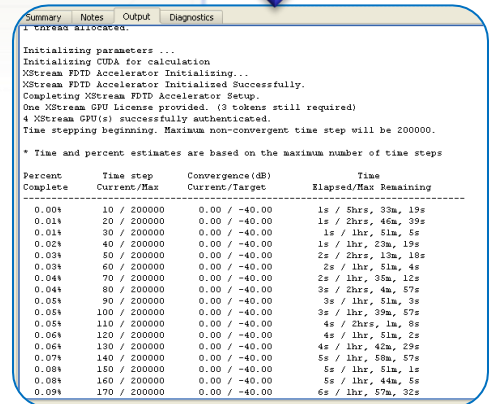
Frequencies of Interest - (Use Waveform Frequency)

Specify Termination Criteria - (Detect Convergence: -40 dB)

Notes

Required Memory: 1.0 GB

Create & Queue Simulation Create Simulation Only Done Cancel



Summary Notes Output Diagnostics

* XStream Accelerator *

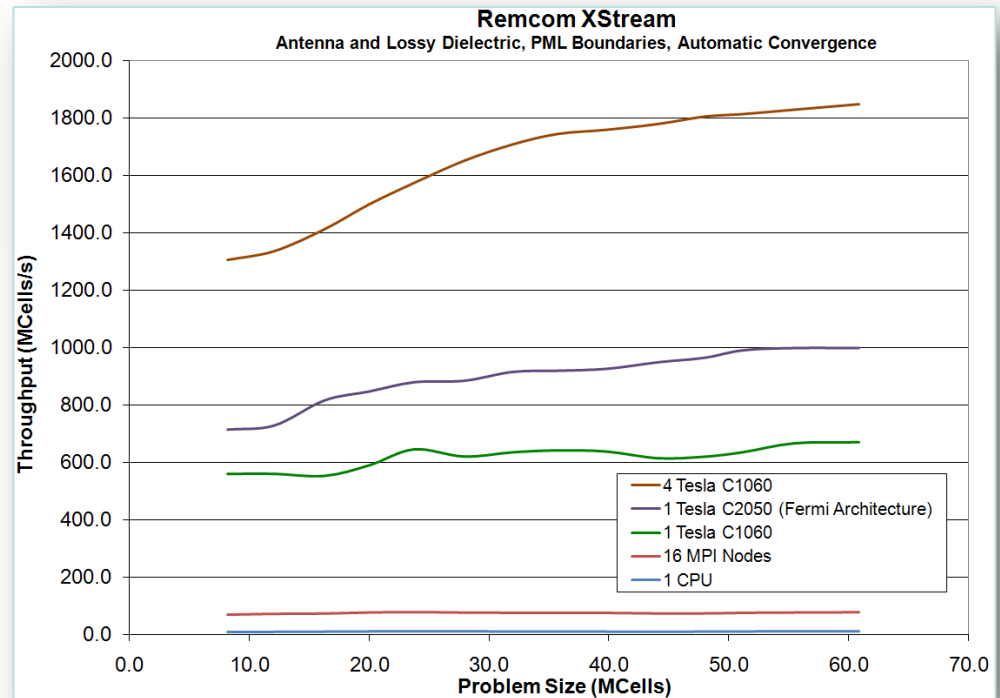
Initializing parameters ...
Initializing CUDA for calculation
XStream PTD Accelerator Initializing...
XStream PTD Accelerator Initialized Successfully.
Completing XStream PTD Accelerator Setup.
One XStream GPU license provided. (3 tokens still required)
4 XStream CPU(s) successfully authenticated.
Time stepping beginning. Maximum non-convergent time step will be 200000.
* Time and percent estimates are based on the maximum number of time steps

Percent Complete	Time step	Current/Max	Convergence (dB)	Current/Target	Time Elapsed/Max	Time Remaining
0.00%	10	200000	0.00 / -40.00	0.00 / 40.00	1s / 5hrs, 33m, 19s	
0.01%	20	200000	0.00 / -40.00	0.00 / 40.00	1s / 5hrs, 46m, 39s	
0.01%	30	200000	0.00 / -40.00	0.00 / 40.00	1s / 1hr, 51m, 5s	
0.02%	40	200000	0.00 / -40.00	0.00 / 40.00	1s / 1hr, 23m, 19s	
0.03%	50	200000	0.00 / -40.00	0.00 / 40.00	2s / 2hrs, 13m, 18s	
0.03%	60	200000	0.00 / -40.00	0.00 / 40.00	2s / 1hr, 51m, 4s	
0.04%	70	200000	0.00 / -40.00	0.00 / 40.00	2s / 1hr, 35m, 12s	
0.04%	80	200000	0.00 / -40.00	0.00 / 40.00	3s / 2hrs, 4m, 57s	
0.05%	90	200000	0.00 / -40.00	0.00 / 40.00	3s / 1hr, 51m, 3s	
0.05%	100	200000	0.00 / -40.00	0.00 / 40.00	3s / 1hr, 39m, 57s	
0.05%	110	200000	0.00 / -40.00	0.00 / 40.00	4s / 2hrs, 1m, 8s	
0.06%	120	200000	0.00 / -40.00	0.00 / 40.00	4s / 1hr, 51m, 2s	
0.06%	130	200000	0.00 / -40.00	0.00 / 40.00	4s / 1hr, 42m, 29s	
0.07%	140	200000	0.00 / -40.00	0.00 / 40.00	5s / 1hr, 58m, 57s	
0.08%	150	200000	0.00 / -40.00	0.00 / 40.00	5s / 1hr, 51m, 1s	
0.08%	160	200000	0.00 / -40.00	0.00 / 40.00	5s / 1hr, 44m, 5s	
0.09%	170	200000	0.00 / -40.00	0.00 / 40.00	6s / 1hr, 57m, 32s	

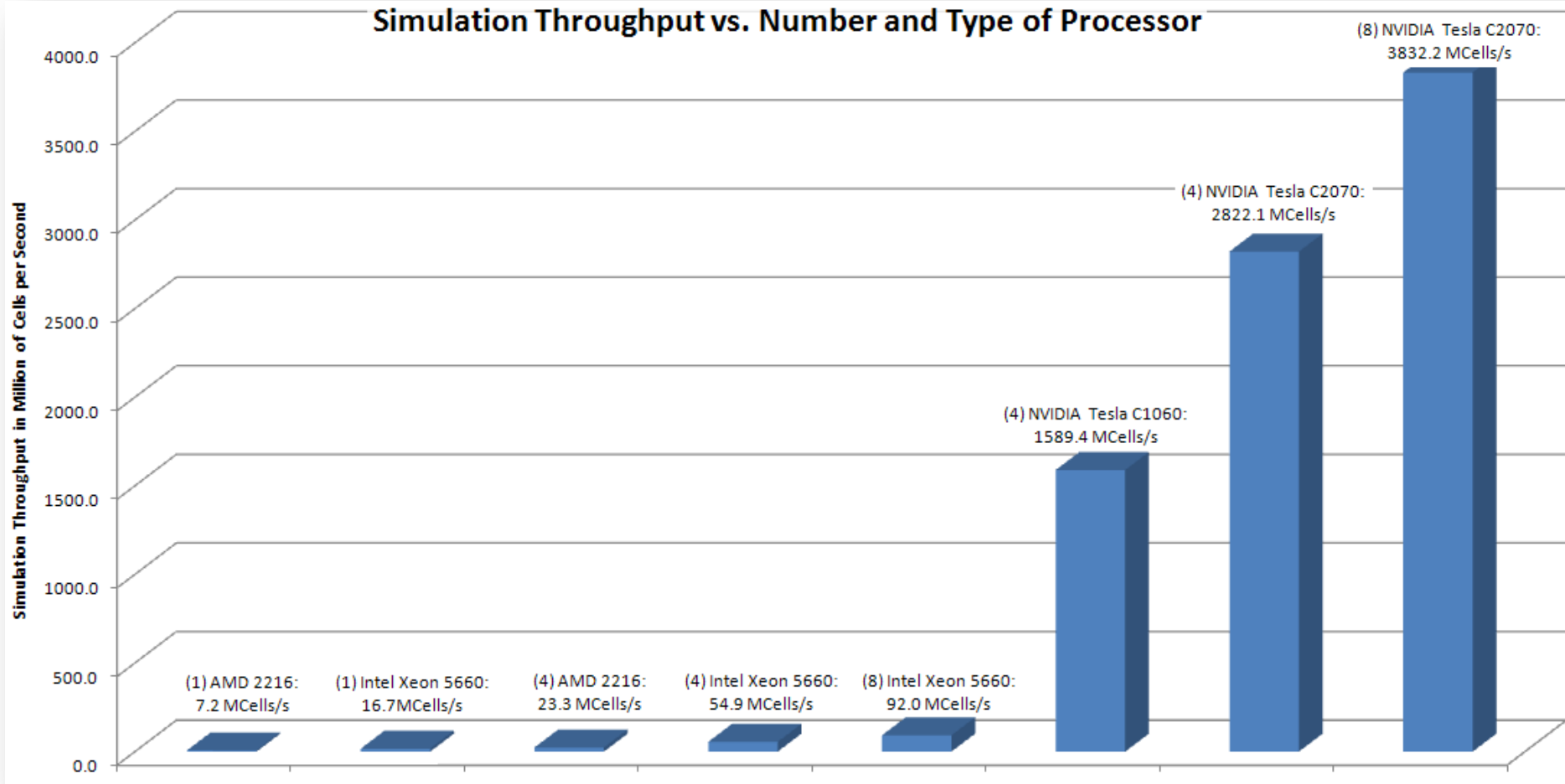
- Built-in iterative project management
 - Can queue multiple projects to simulate automatically
 - Can view results from many projects simultaneously
 - Parameterization allows users to record key settings, sweep variables, and later return to best simulation

How Can XFtd 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



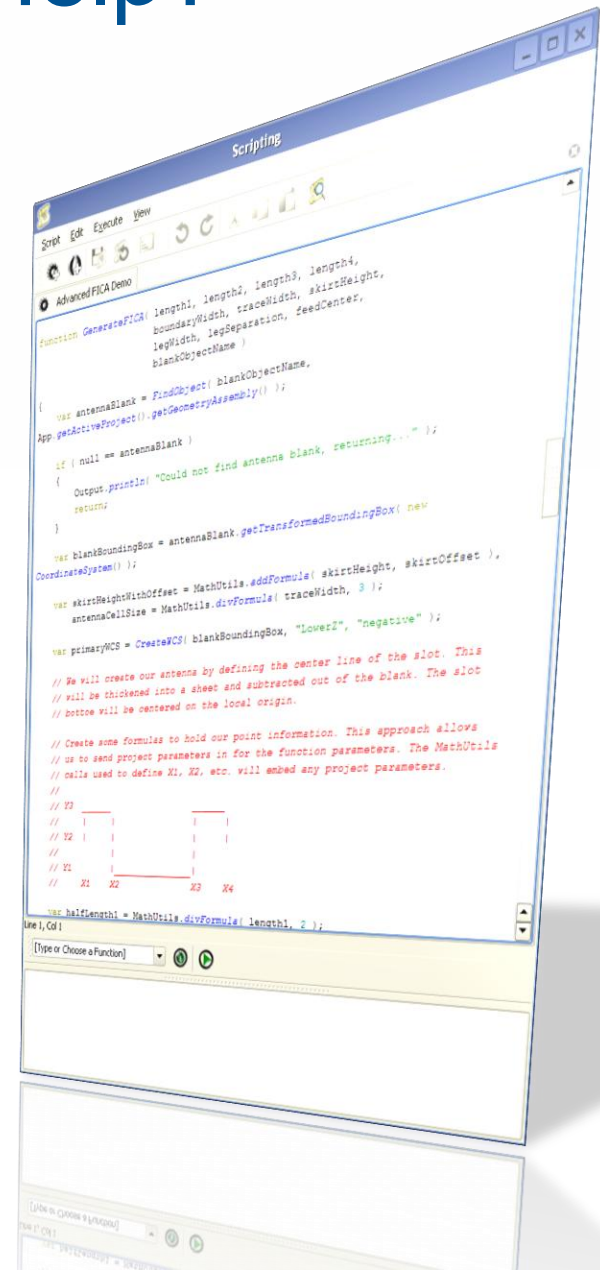
Simulation Throughput vs. Number and Type of Processor



- 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

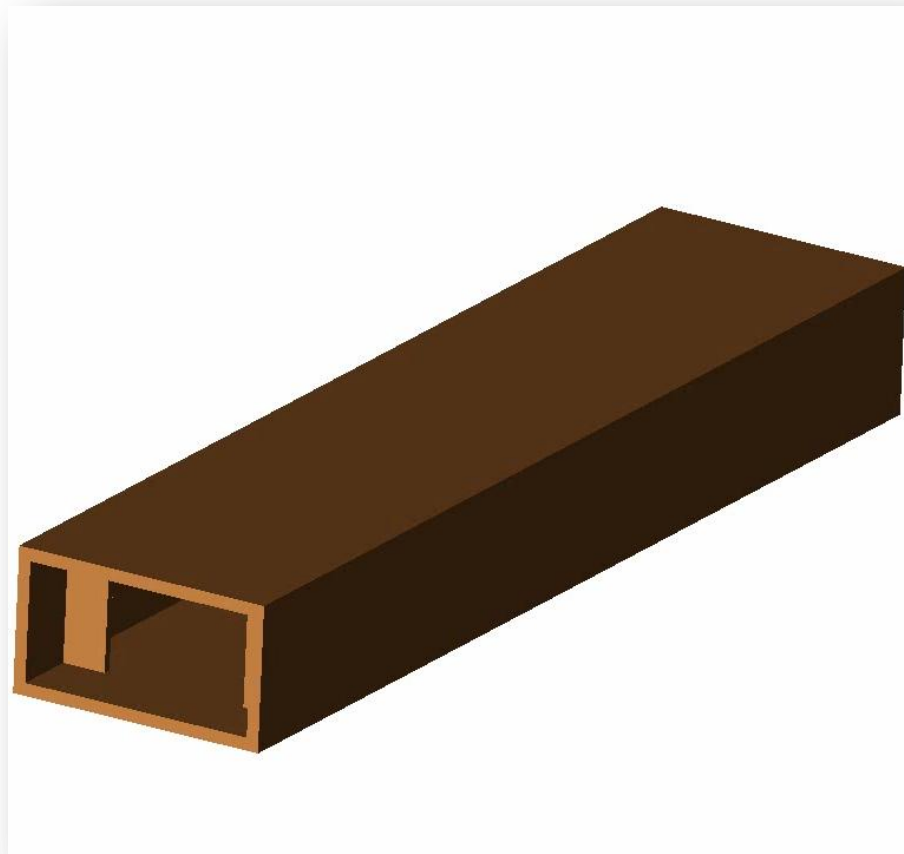
How Can XFtd Help?

- 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”



Waveguide Cavity Filter

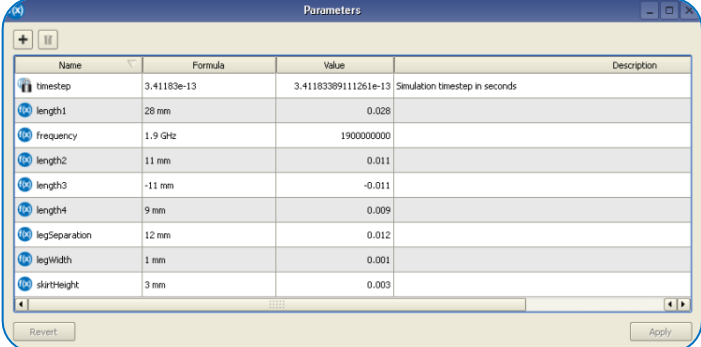
- Want bandpass filter for Ka band
- $|S_{11}| < -20$ dB for f 27.5 GHz to 28.3 GHz
- $|S_{11}| > -0.05$ dB for $f < 27$ GHz and $f > 28.8$ GHz
- Will design filter device with iris coupling windows and cavities
 - Design parameters include window size of irises and length of cavities
 - Can use equations 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



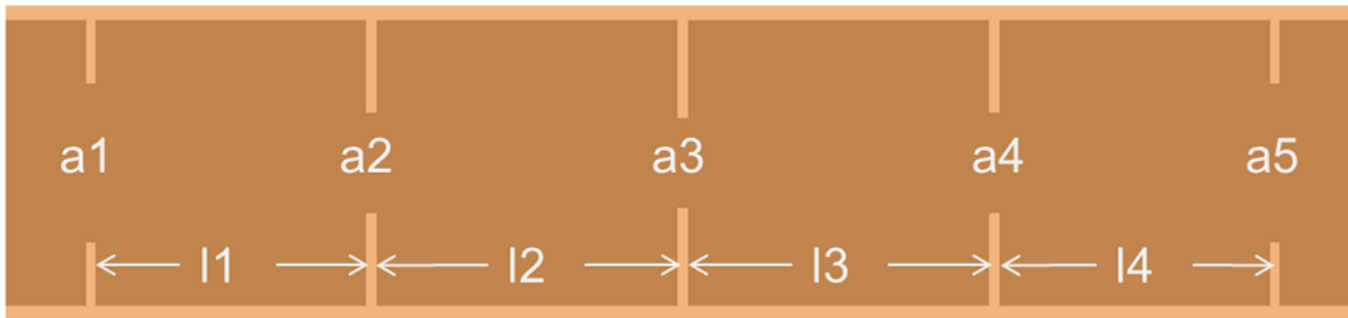
[Click to watch video...](#)

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

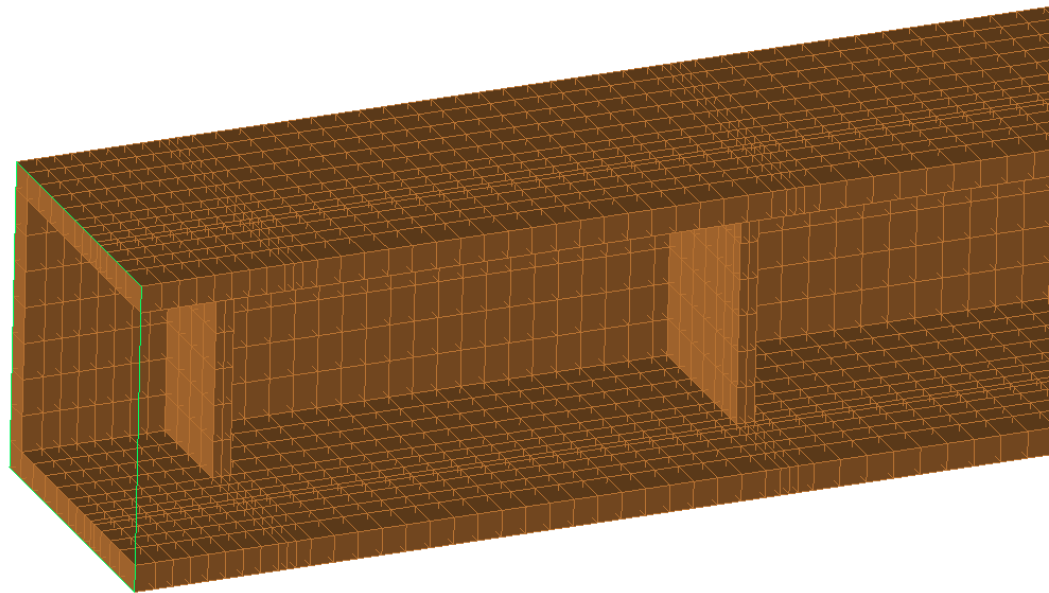


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length2		0.011	
length3		-0.011	
length4		0.009	
legSeparation		0.012	
legWidth		0.001	
skirtHeight		0.003	



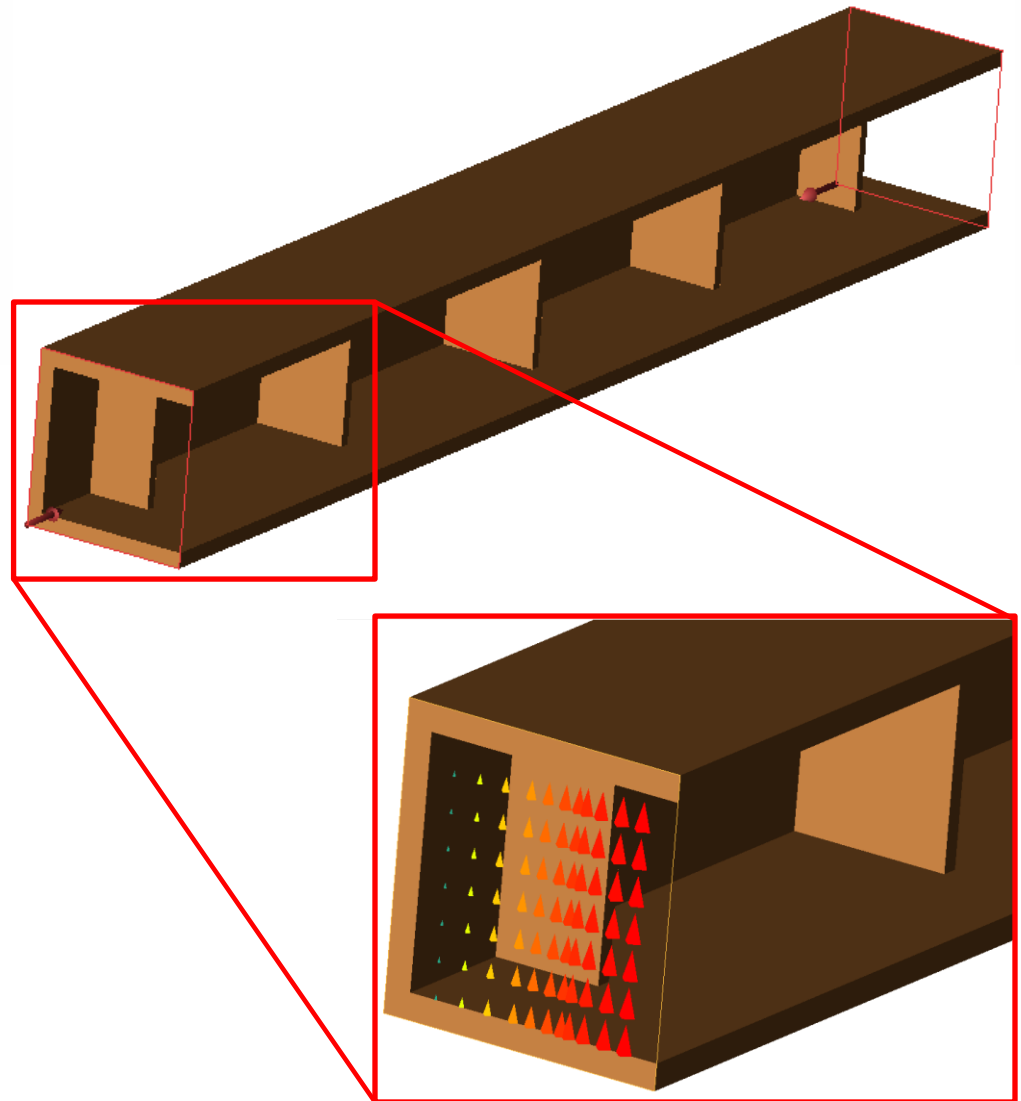
Waveguide Cavity Filter

- 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



Waveguide Cavity Filter

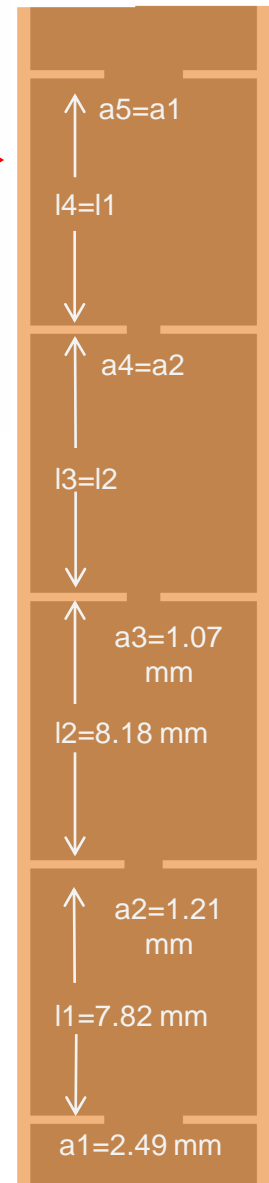
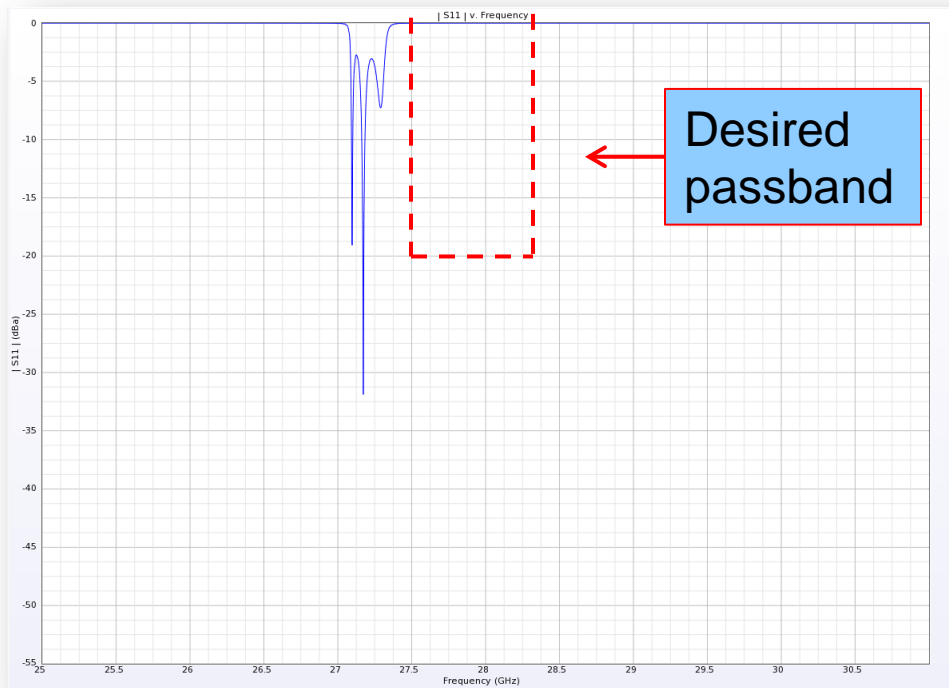
- Waveguide ports were created for input and output
- Active port calculates modes and “injects” energy into the simulated device



Waveguide Cavity Filter

- Equations led to the initial design

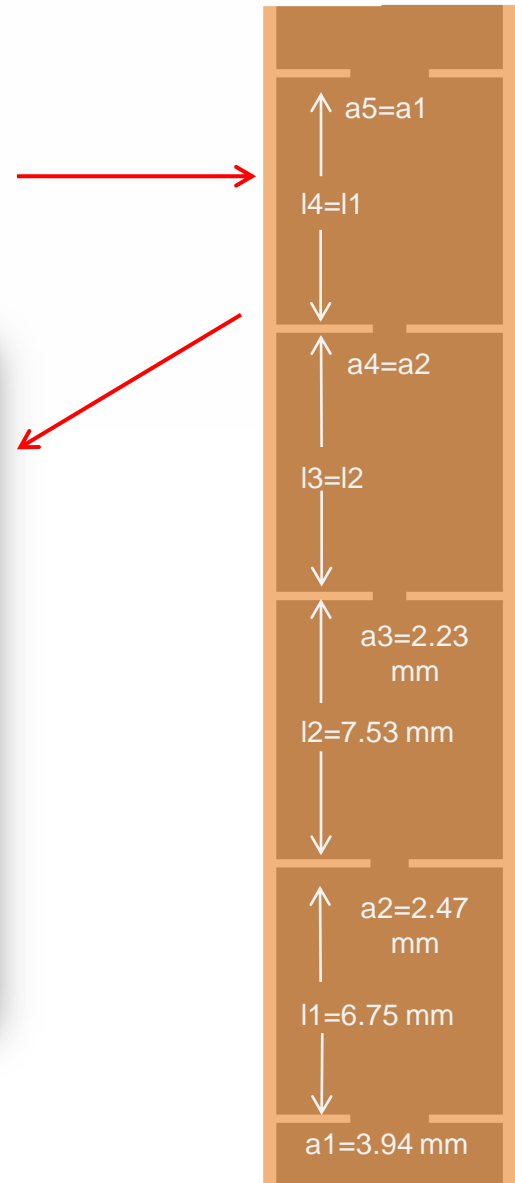
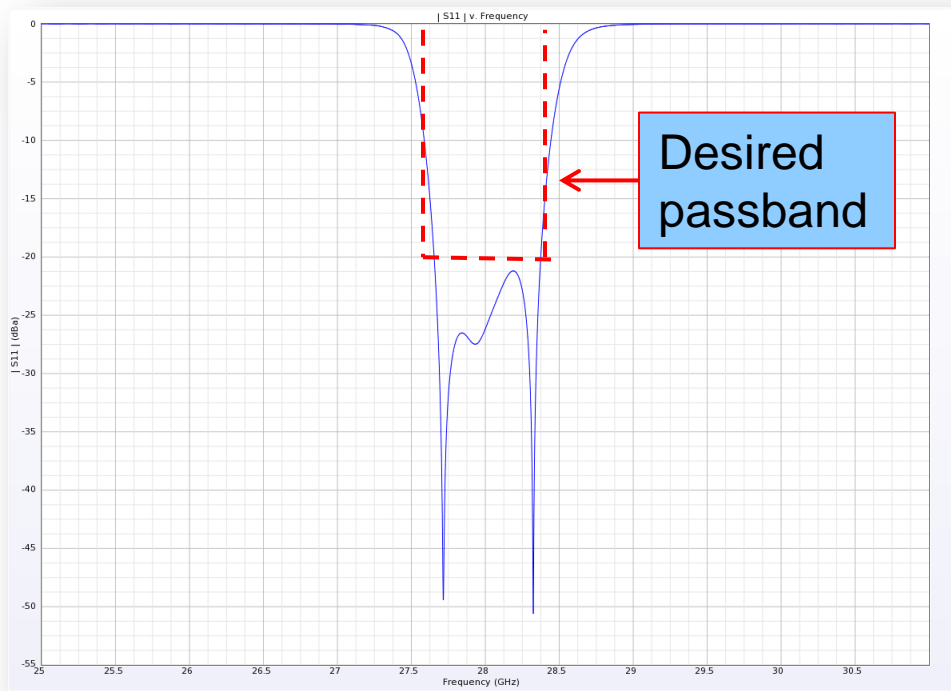
|S11| vs. Frequency



- Good start, but optimization needed

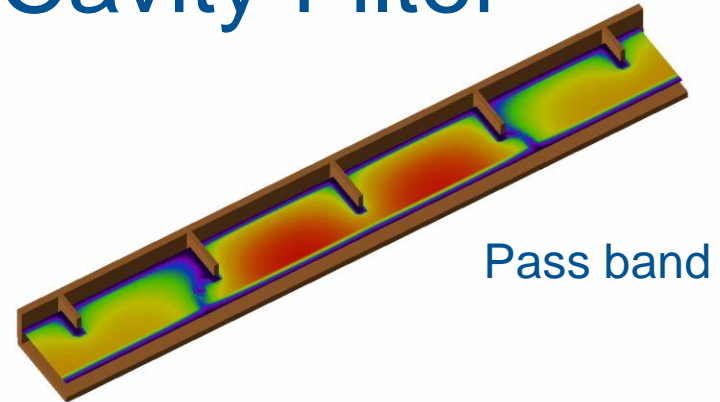
Waveguide Cavity Filter

- Mode matching resulted in better pass-band performance



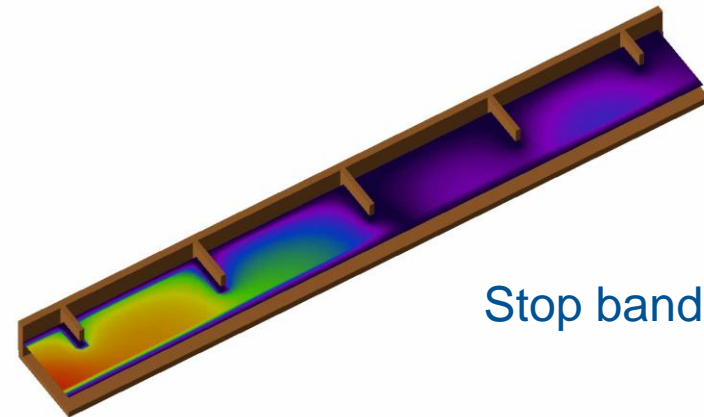
Waveguide Cavity Filter

- 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...](#)

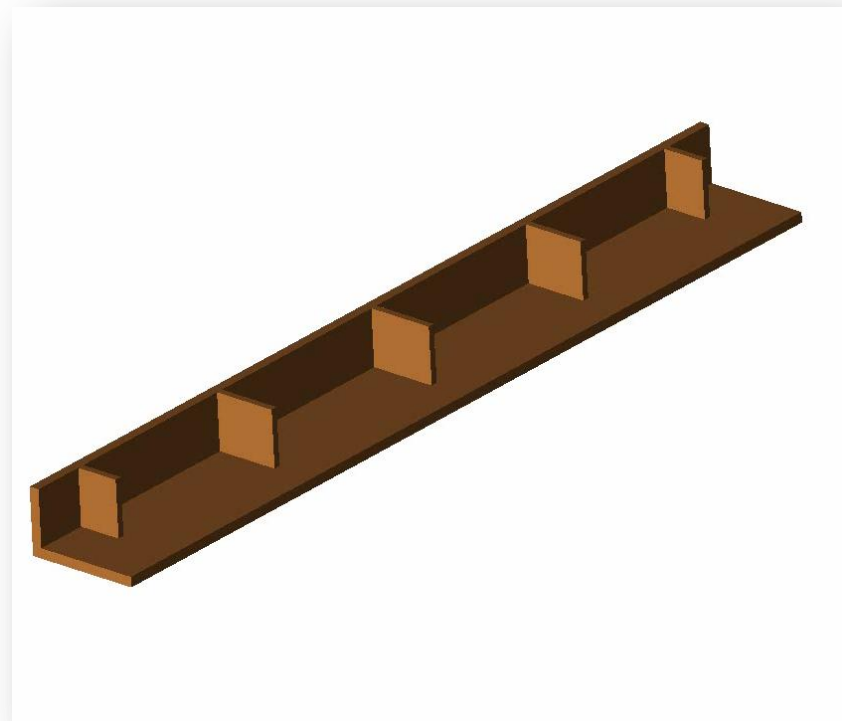


Stop band

[Click to watch video...](#)

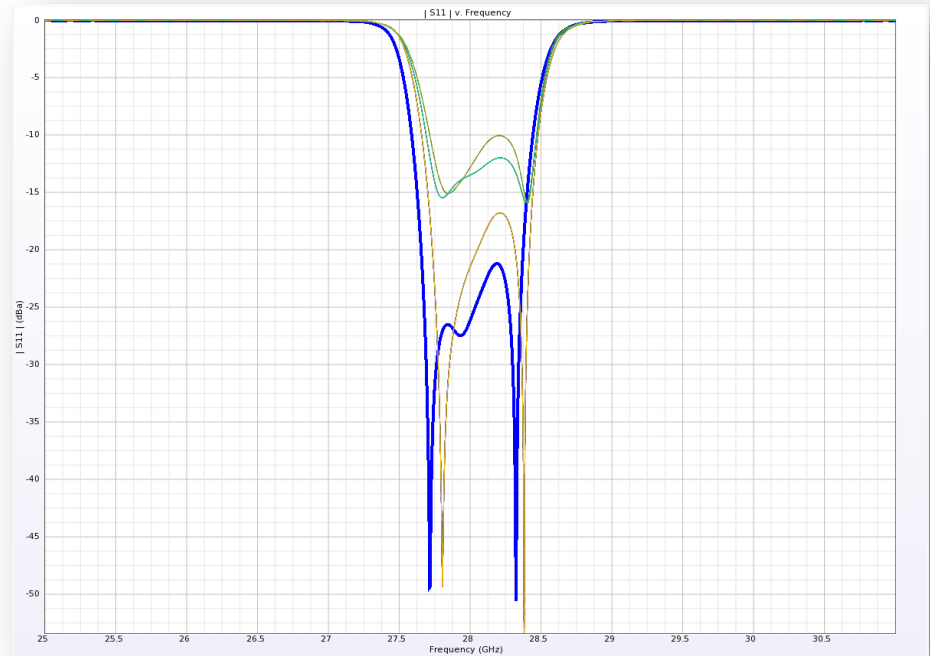
Waveguide Cavity Filter

- 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



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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