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Virtual Acoustic Prototyping for Loudspeaker Horn Development

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Outline

1. 2D (Axisymmetric) Horn Simulations

   -Figure of merit

   -Method

   -Example

2. 3D Horn Simulations

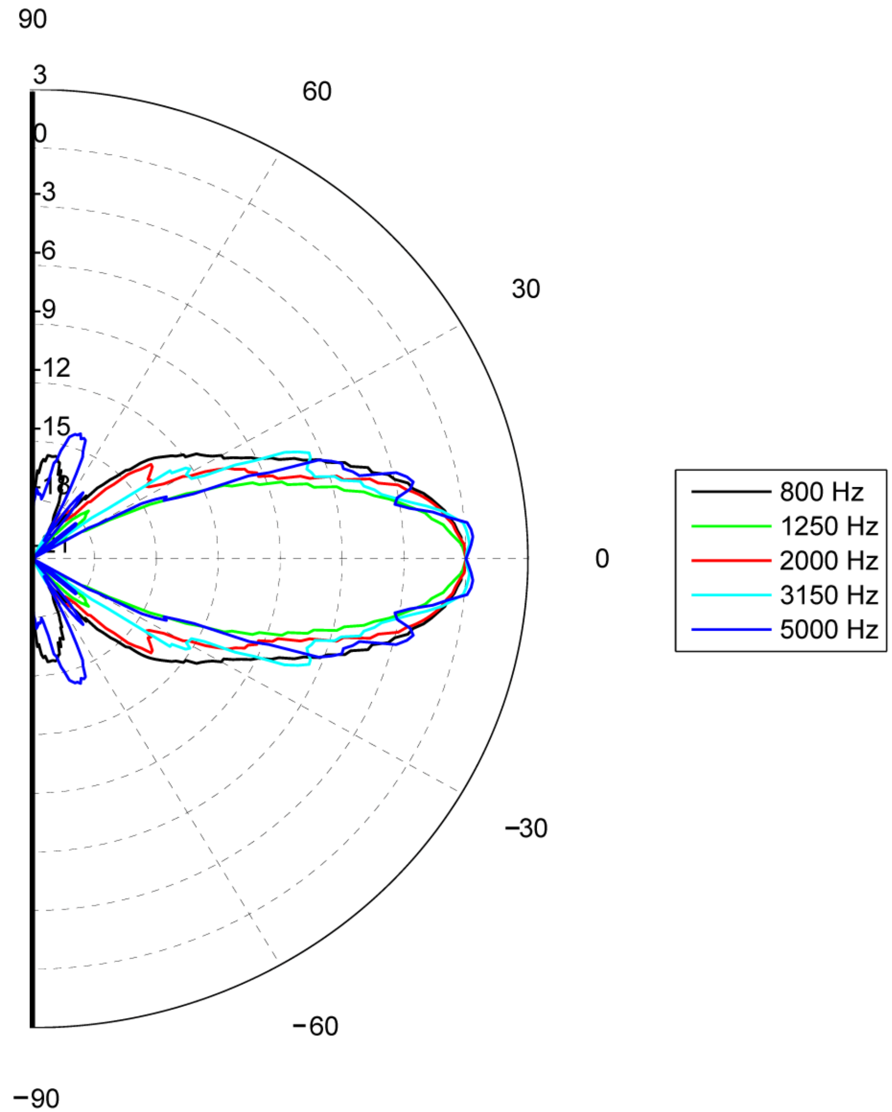
   -Pitfalls and solutions

   -Case Study

Beamwidth Calculation

One way to evaluate horn dispersion is to plot the polar pattern at multiple frequencies.

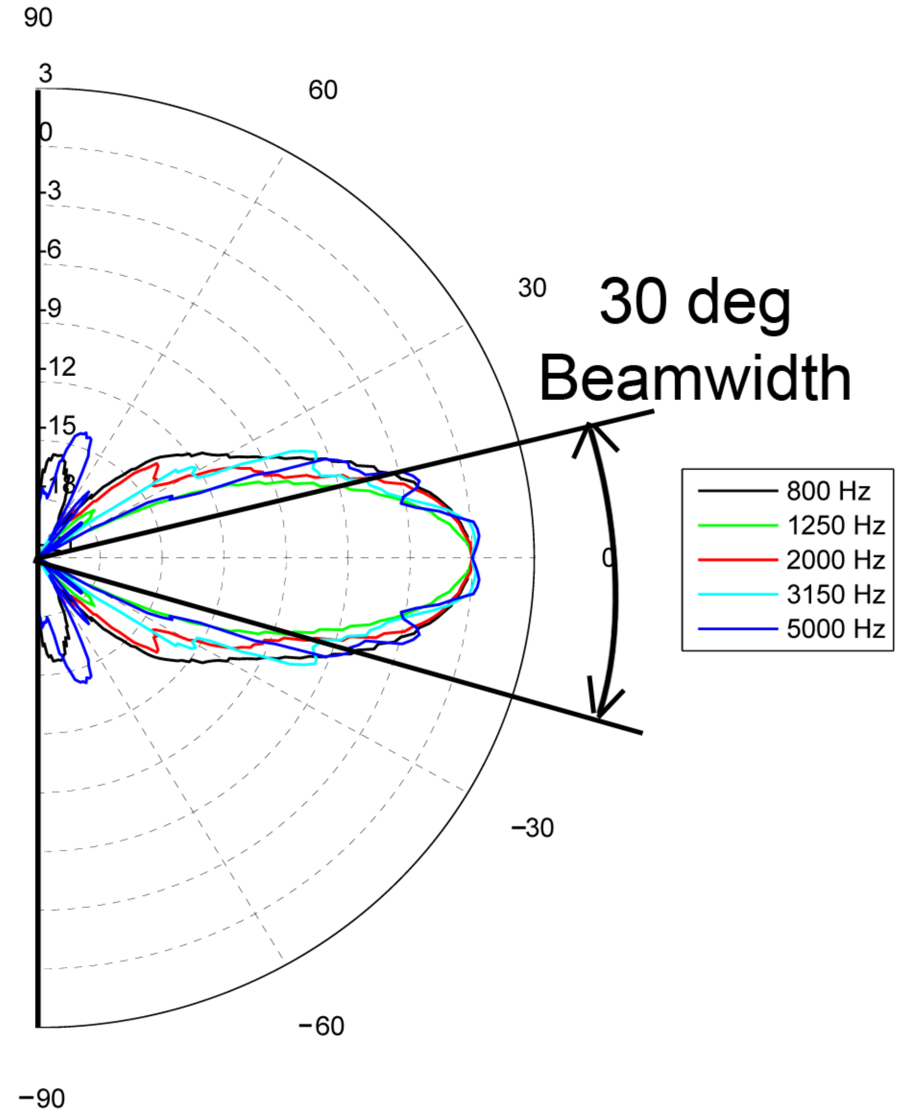
Ideally the polars should be similar over a wide frequency range



Beamwidth Calculation

An alternate way to evaluate this data is to find the 6dB down angles – called the beamwidth.

Plotting the beamwidth angle vs frequency as an XY graph is the most common way to show this data



Beamwidth Calculation

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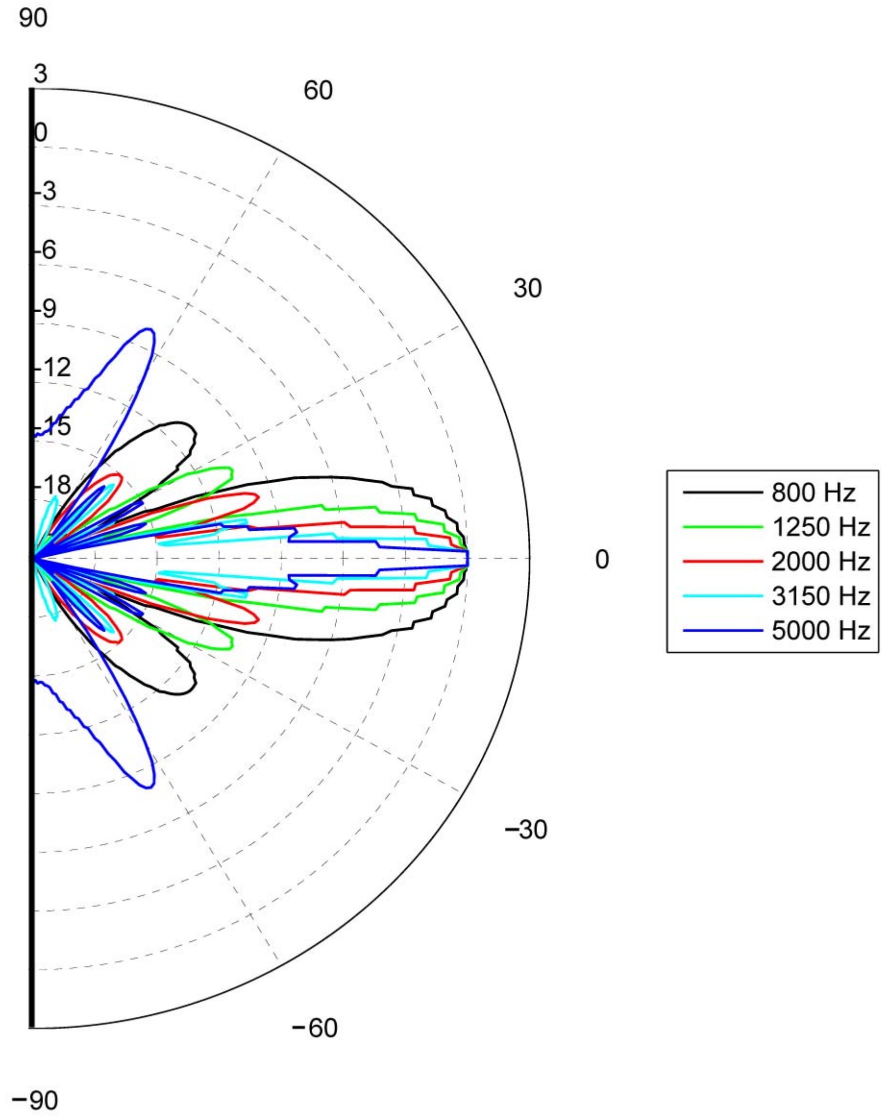
Example of a non-constant beamwidth



Typical Specification Sheet

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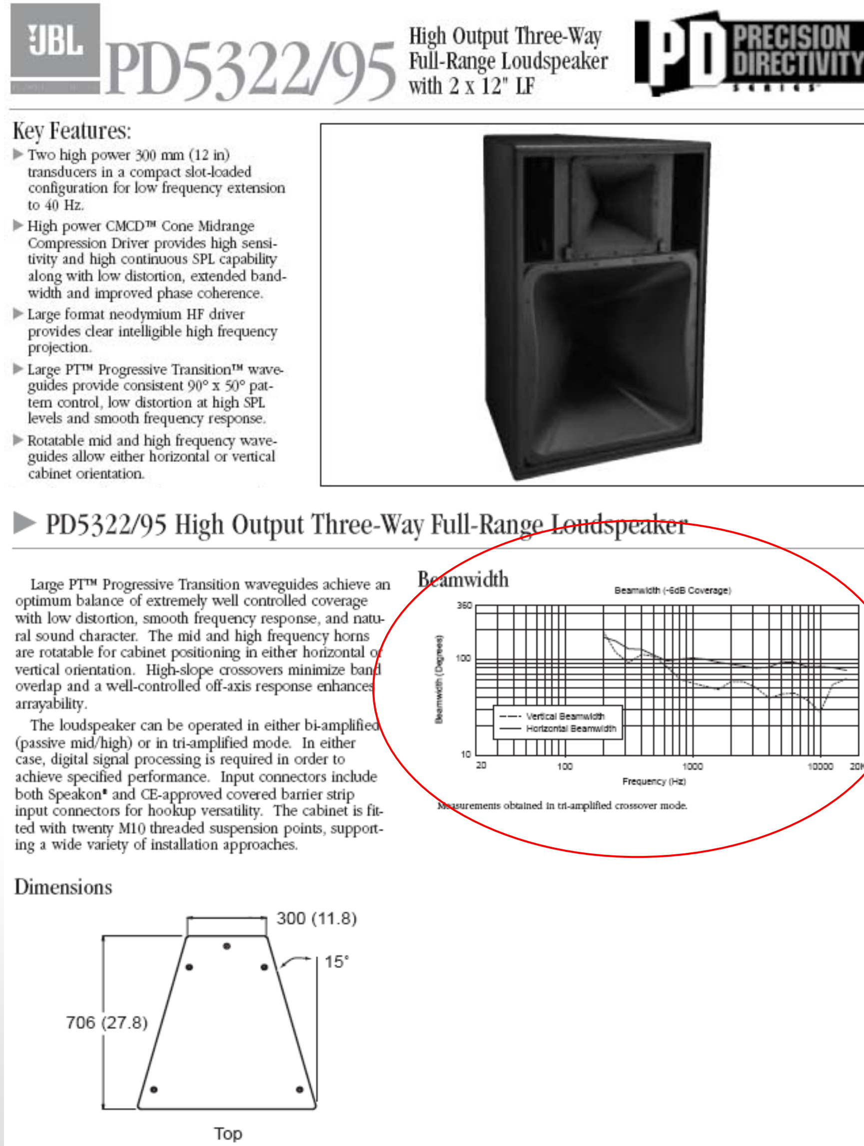
Beamwidth versus frequency is the primary measure of horn performance



JBL PD5322/95 High Output Three-Way Full-Range Loudspeaker with 2 x 12" LF

PRECISION DIRECTIVITY SERIES

Key Features:

- Two high power 300 mm (12 in) transducers in a compact slot-loaded configuration for low frequency extension to 40 Hz.
- High power CMCD™ Cone Midrange Compression Driver provides high sensitivity and high continuous SPL capability along with low distortion, extended bandwidth and improved phase coherence.
- Large format neodymium HF driver provides clear intelligible high frequency projection.
- Large PT™ Progressive Transition™ waveguides provide consistent 90° x 50° pattern control, low distortion at high SPL levels and smooth frequency response.
- Rotatable mid and high frequency waveguides allow either horizontal or vertical cabinet orientation.

PD5322/95 High Output Three-Way Full-Range Loudspeaker

Large PT™ Progressive Transition waveguides achieve an optimum balance of extremely well controlled coverage with low distortion, smooth frequency response, and natural sound character. The mid and high frequency horns are rotatable for cabinet positioning in either horizontal or vertical orientation. High-slope crossovers minimize band overlap and a well-controlled off-axis response enhances arrayability.

The loudspeaker can be operated in either bi-amplified (passive mid/high) or in tri-amplified mode. In either case, digital signal processing is required in order to achieve specified performance. Input connectors include both Speakon® and CE-approved covered barrier strip input connectors for hookup versatility. The cabinet is fitted with twenty M10 threaded suspension points, supporting a wide variety of installation approaches.

Beamwidth

Measurements obtained in tri-amplified crossover mode.

Dimensions

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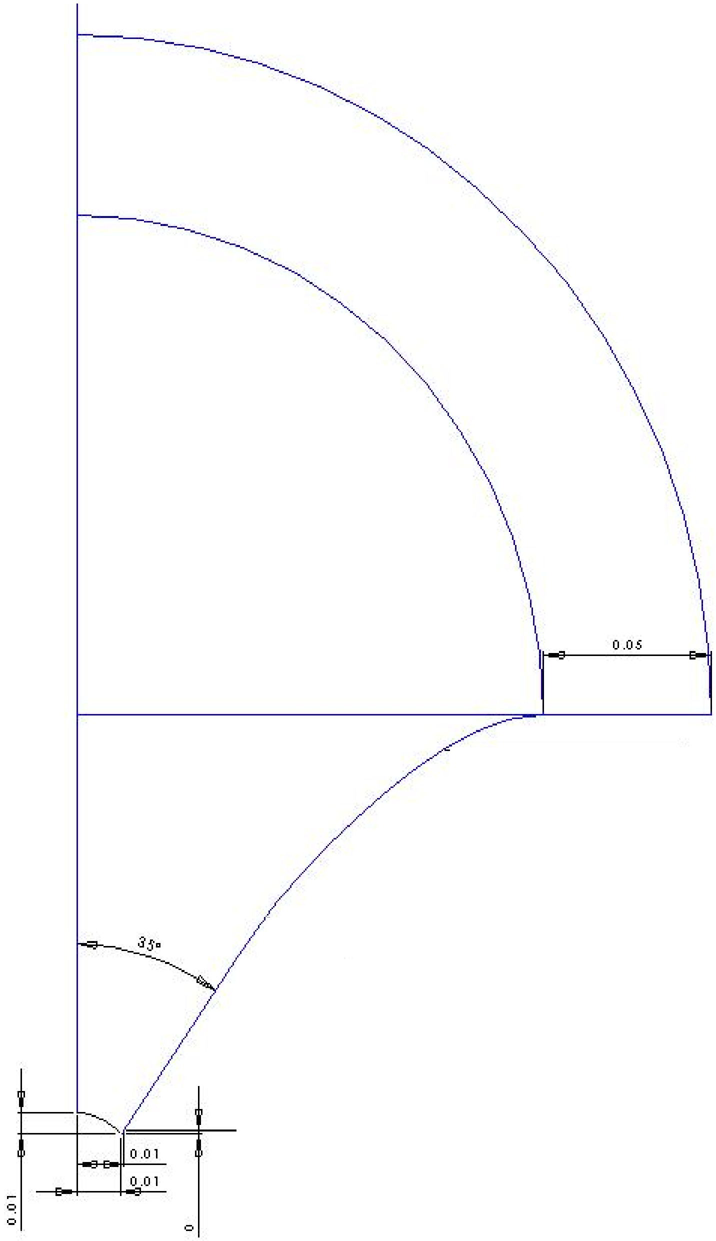
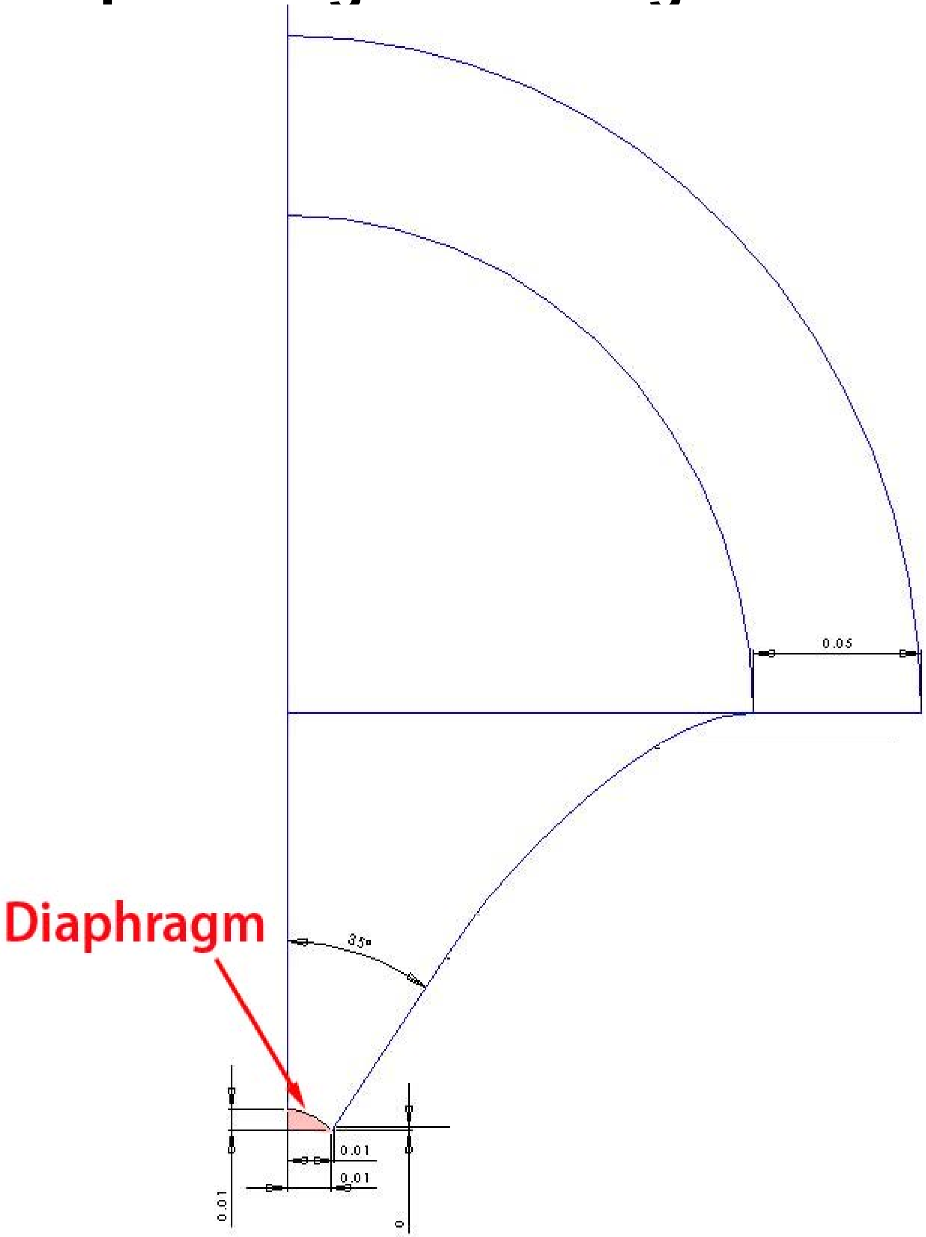
Simulating
axi-symmetric 2D horns

Deep 70 Degree Waveguide

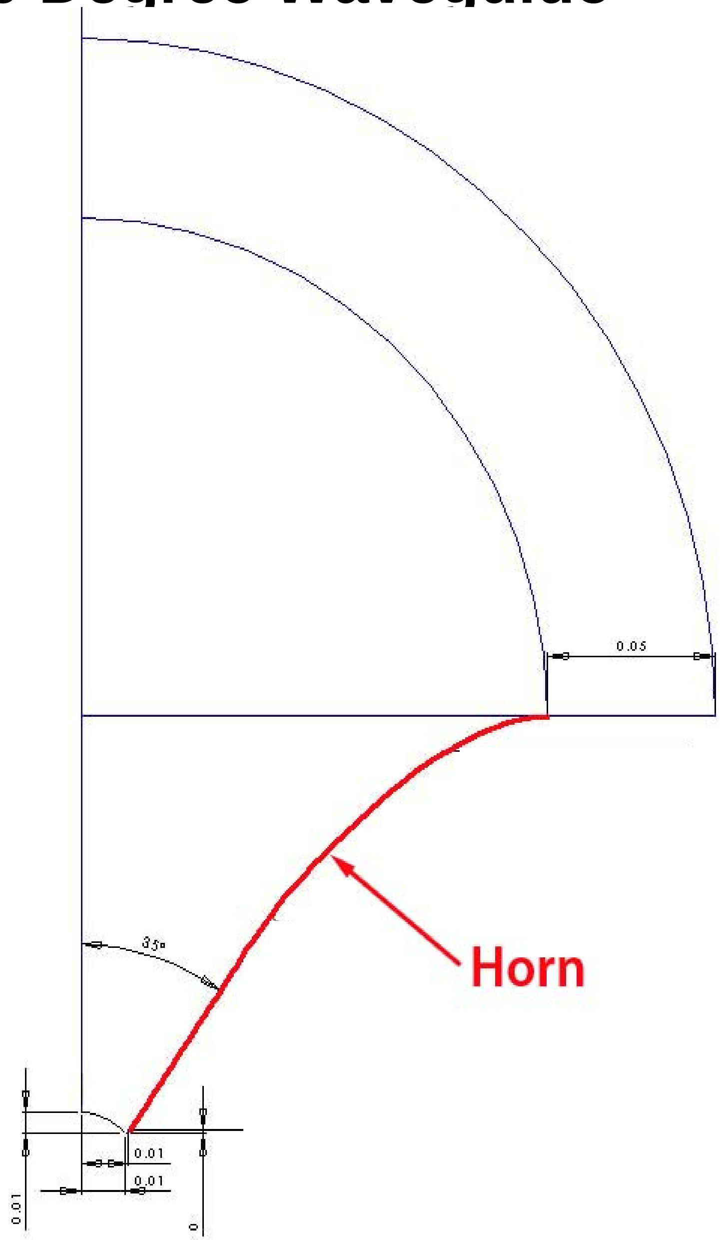


Control 47HC*

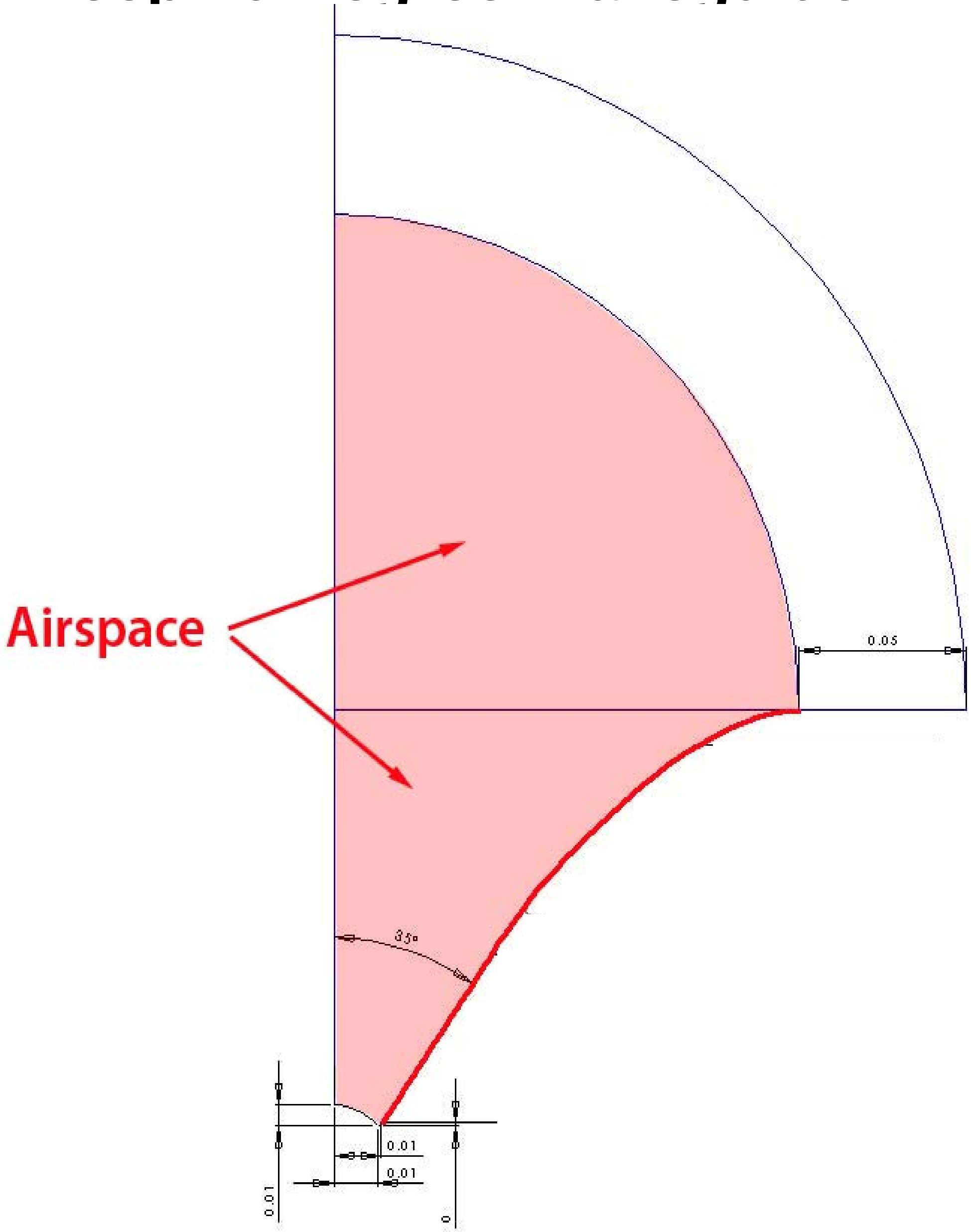
Deep 70 Degree Waveguide



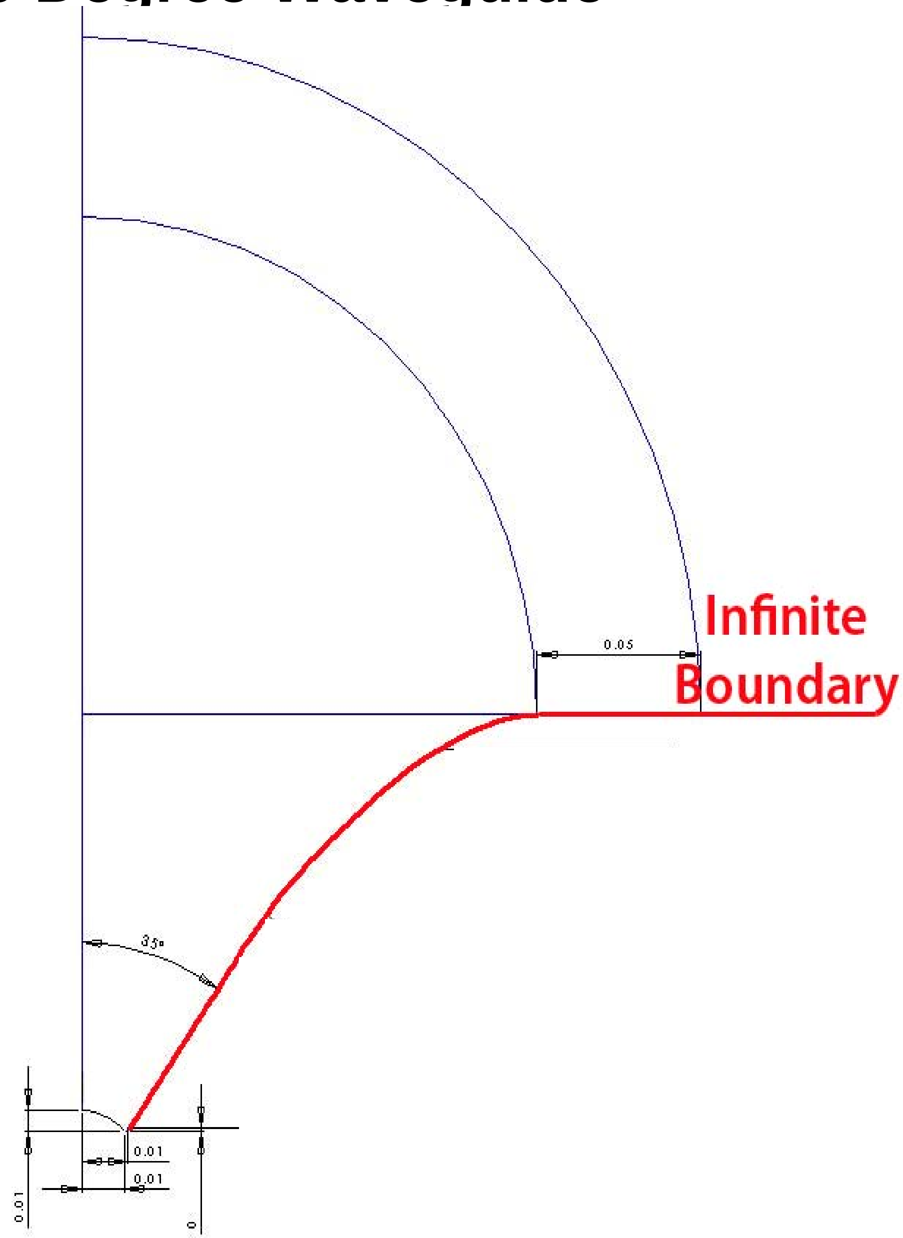
Deep 70 Degree Waveguide



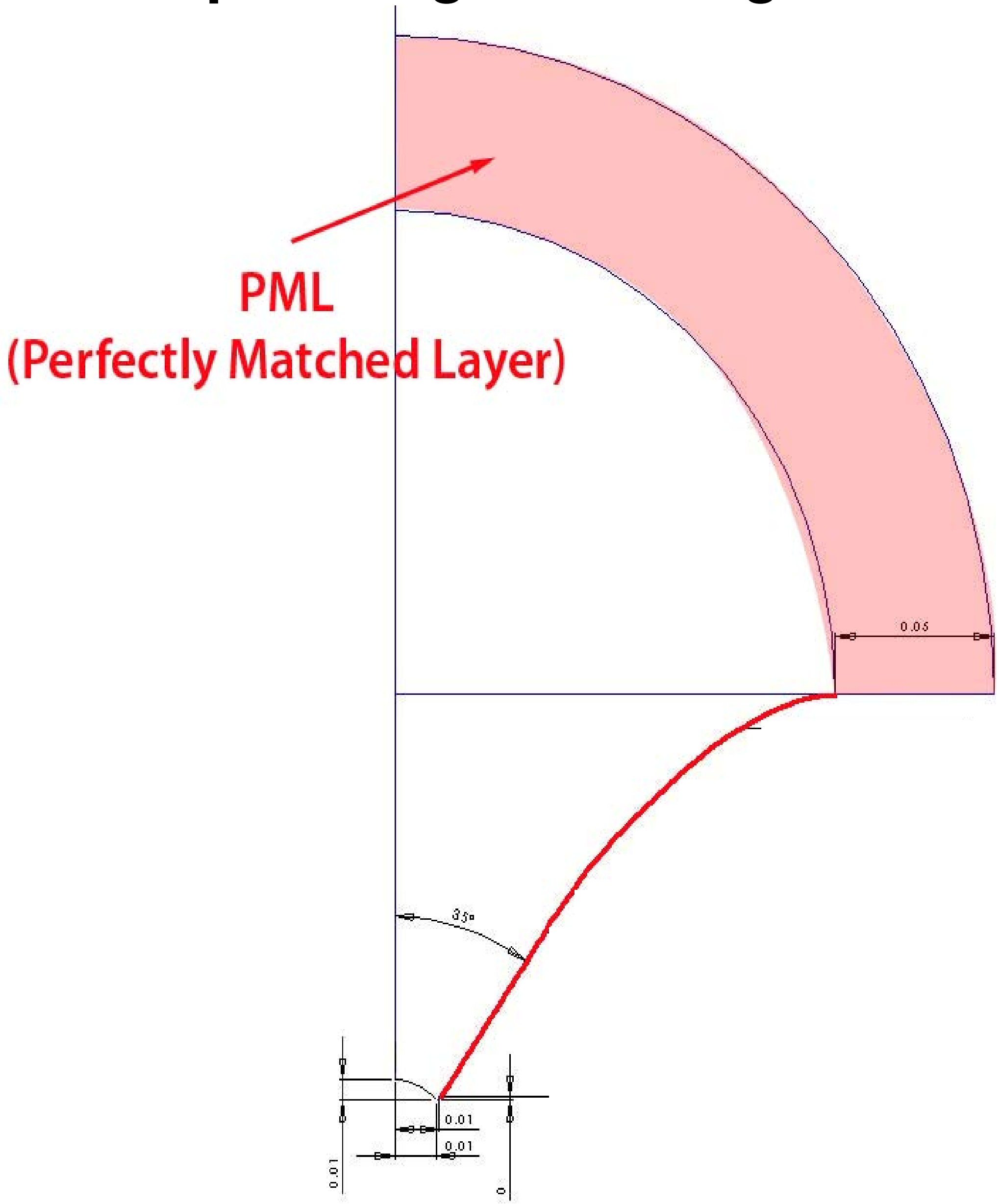
Deep 70 Degree Waveguide



Deep 70 Degree Waveguide



Deep 70 Degree Waveguide



Meshing

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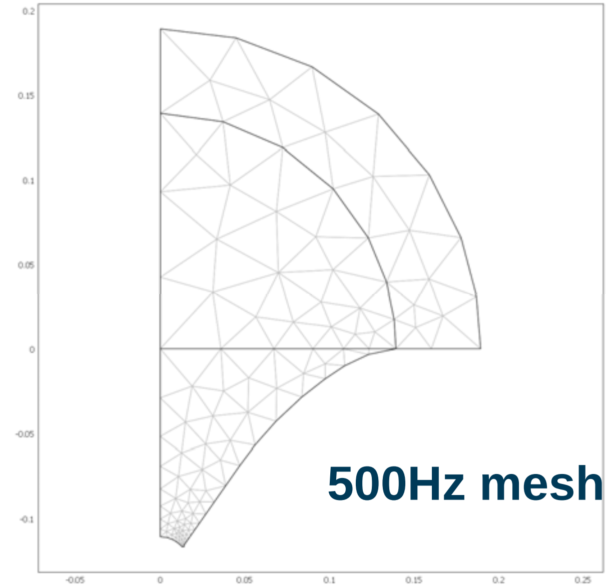
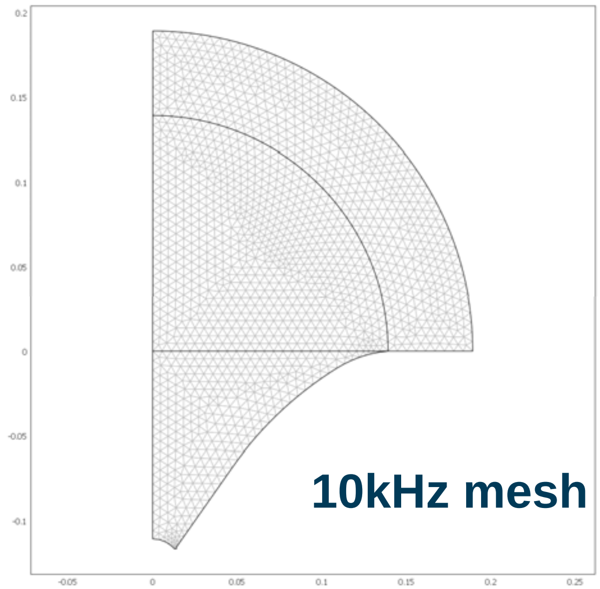
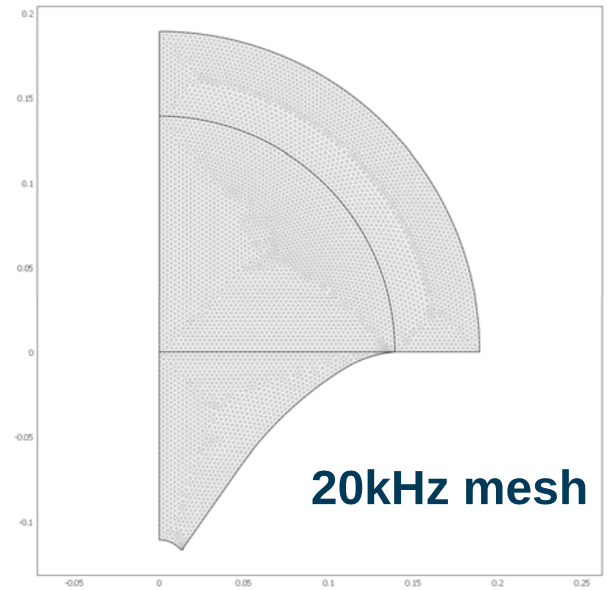
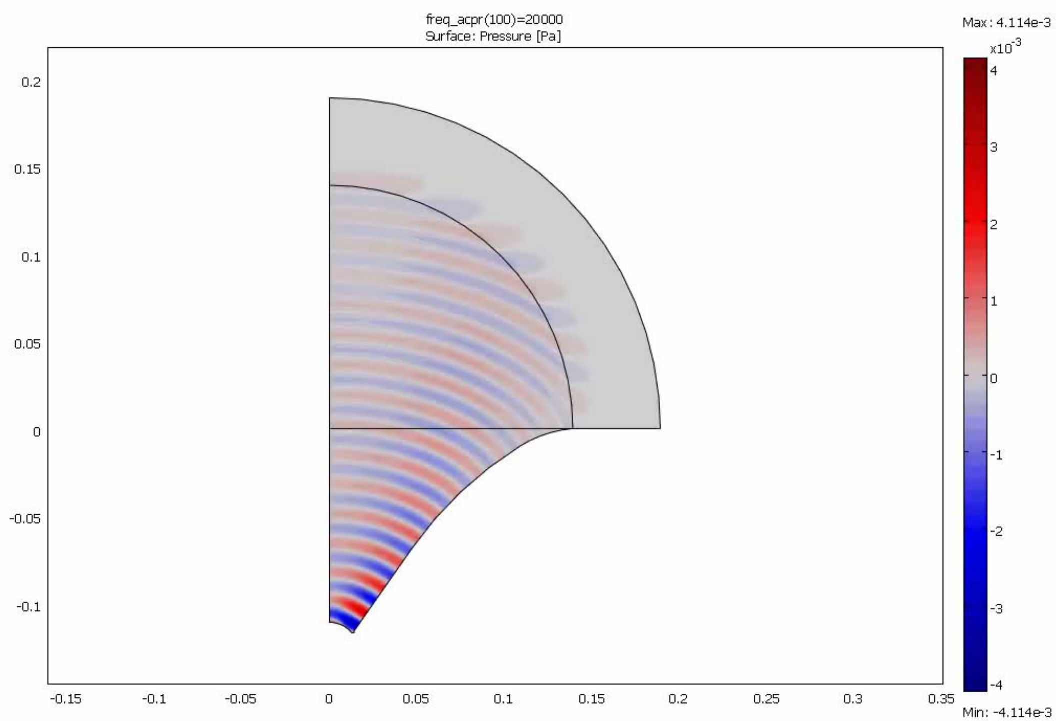
To resolve the pressure wave and get accurate results, we use about 6 elements per wavelength

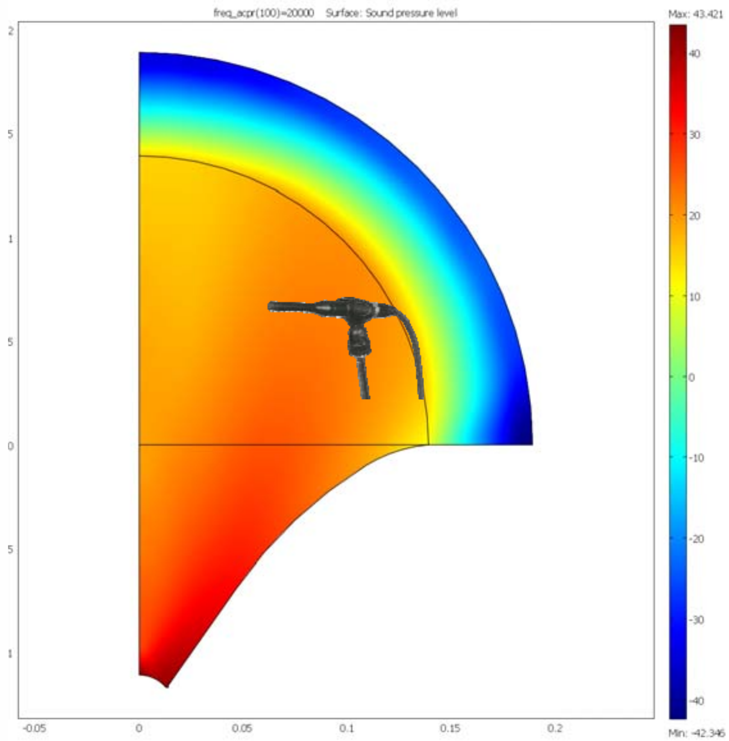






Solution Output (20 kHz)





Matlab Postprocessing

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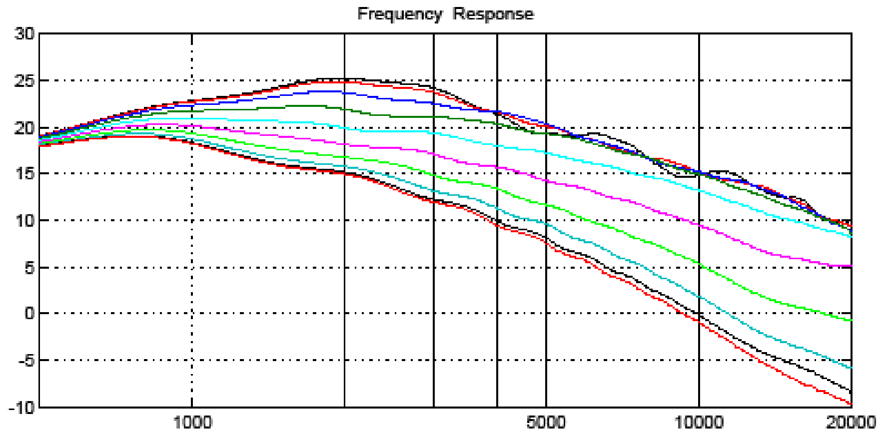
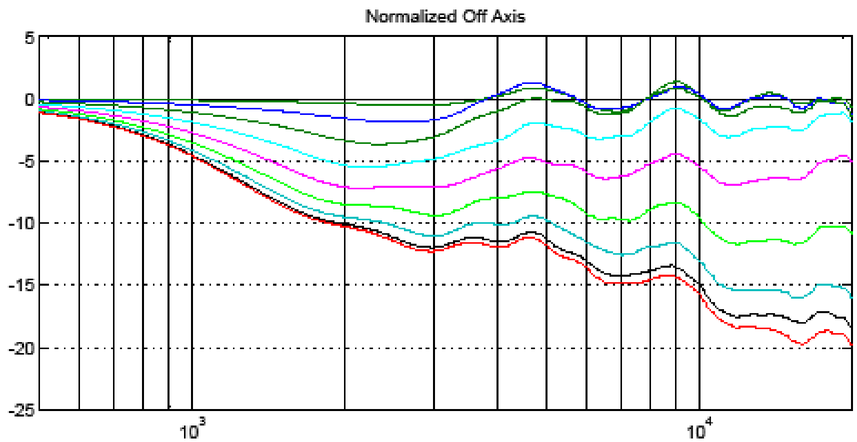
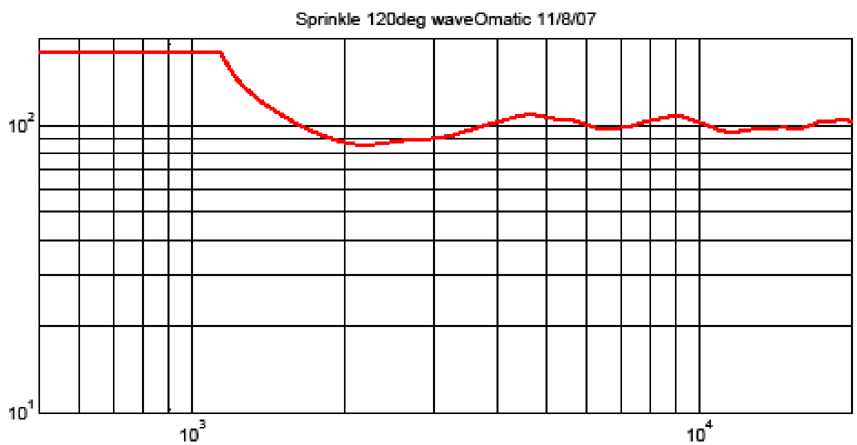


Frequency Response from 0-90 degrees in 10 steps

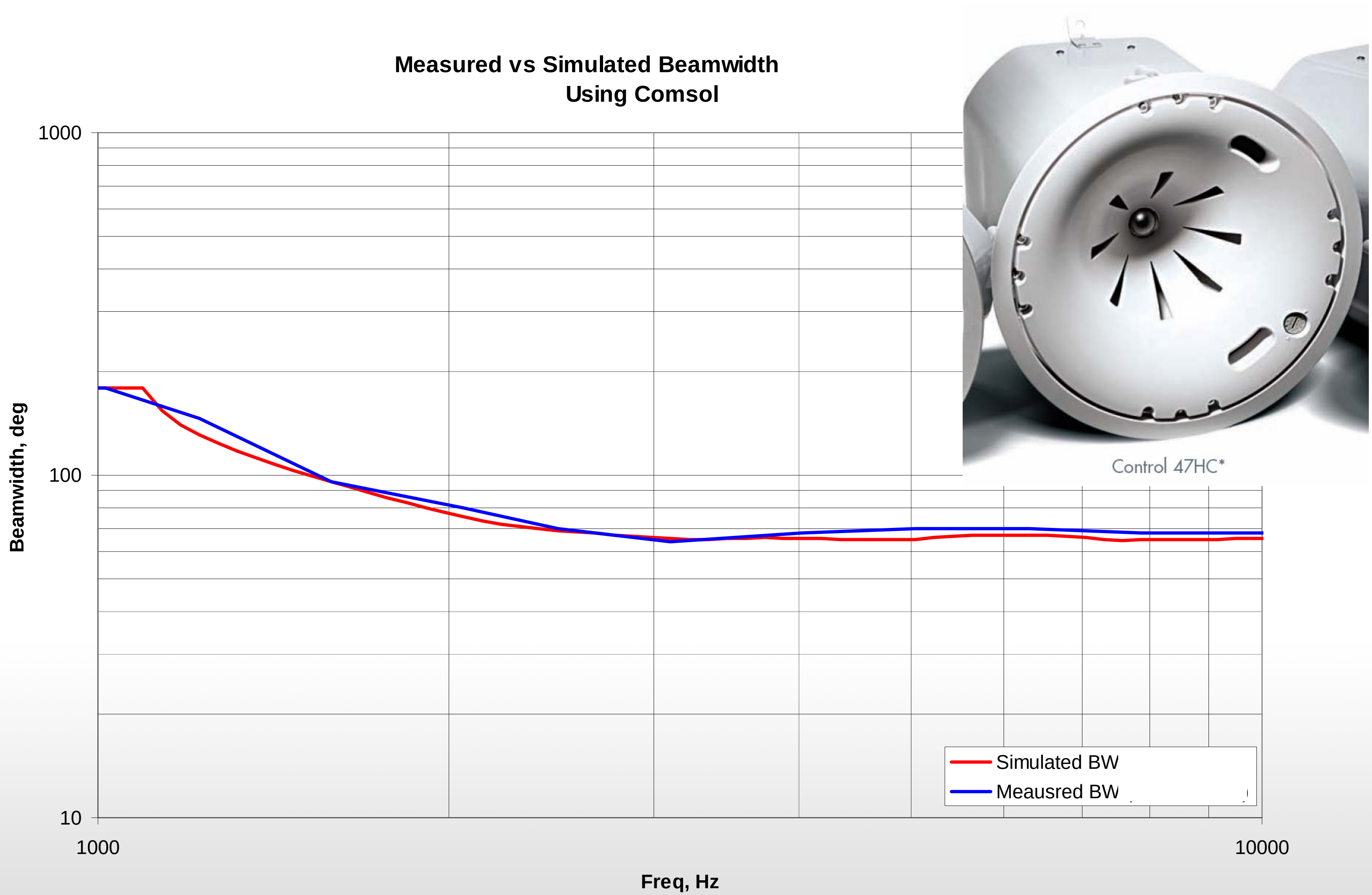


Frequency Response Normalized



Beamwidth in degrees versus frequency

Simulated vs. Measured Beamwidth



Simulating 3D horns with Comsol

3D Horns

3D Geometry takes much longer to run!

- To speed up solution time, the mesh is recalculated at each frequency to keep the number of elements down
- Since the run time grows with the cube of the number of elements, the solution slows down greatly at the higher frequencies.
- Expanded matlab script performs many functions:

  Remeshing
  Batch processing multiple CAD files
  Calculation and graphing (frequency response, beamwidth, acoustic impedance, etc)
  Saving results (Excel, PDF, Comsol files)

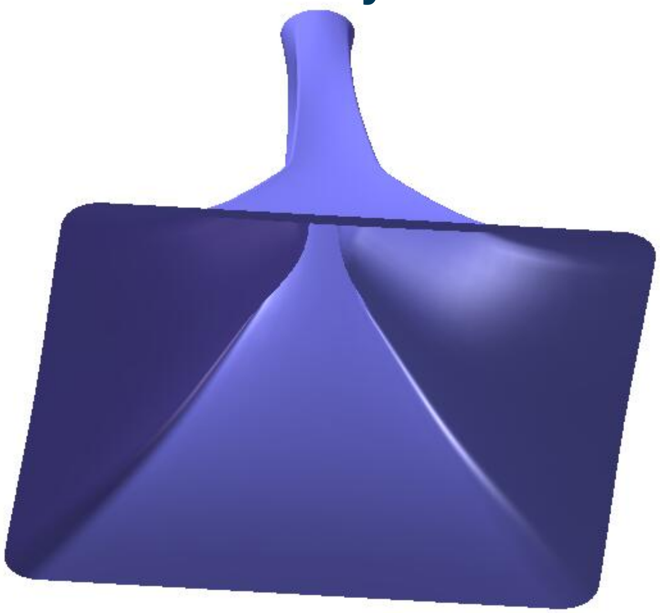
Procedure for 3D horn Simulation

1. Generate CAD file of the horn airspace, add absorbing air layer
2. Load CAD into Comsol, set up piston source and symmetry planes and save the file
3. Open this file in Matlab and cut/paste it into the horn program
4. Run the horn program

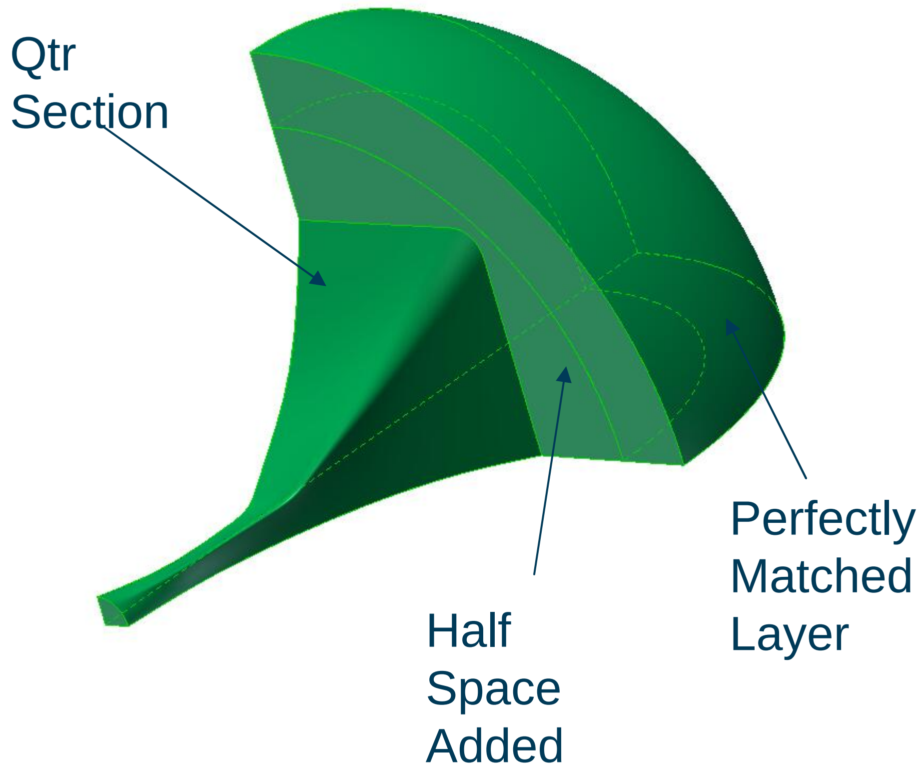
From Geometry to Simulation

Original Geometry

Ready for Simulation



12"x12" Mouth
90X50
coverage



Program Runs and Prints Graphs

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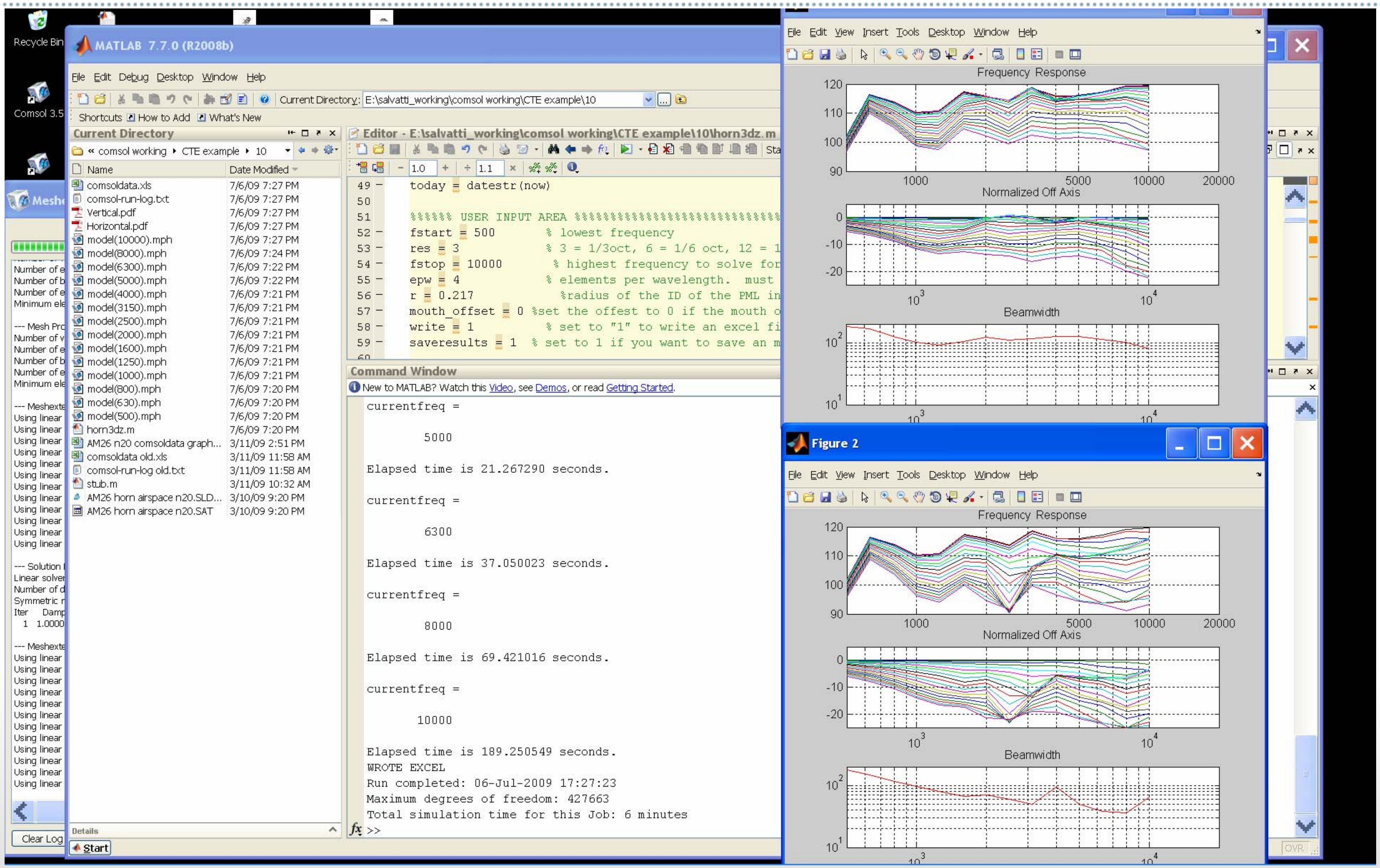
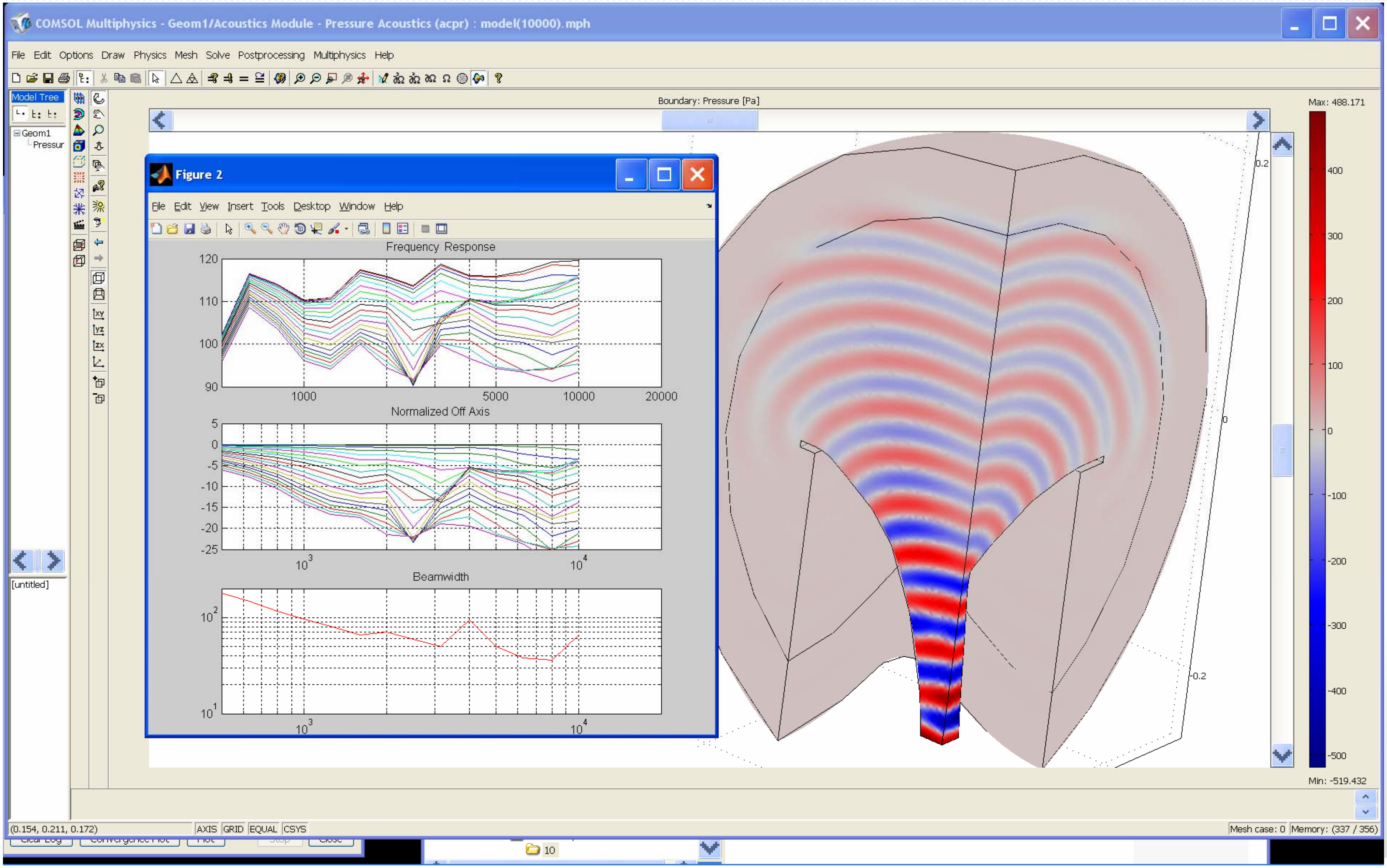


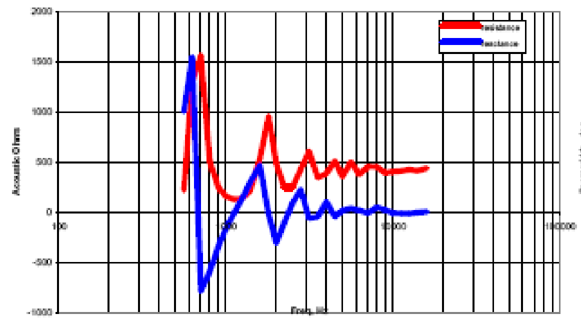
Detailed postprocessing in Comsol Interface



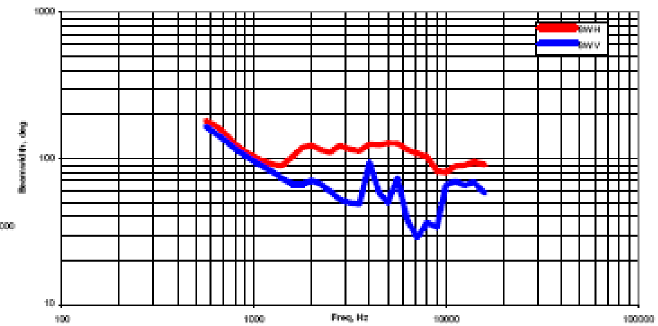
Solution Time: 82 minutes
Maximum DOF 1482672

Horn Program Automatically generates output

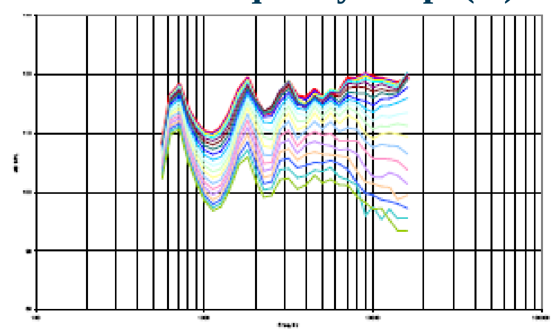
Acoustic Impedance



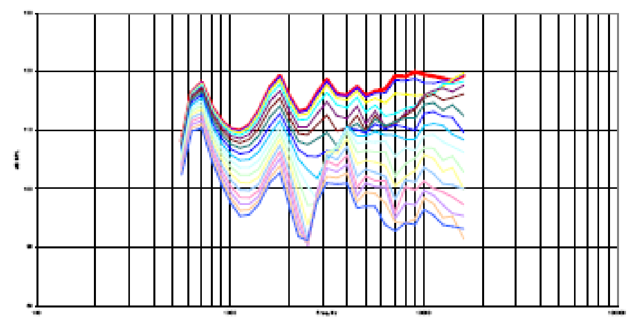
Beamwidth (H and V)



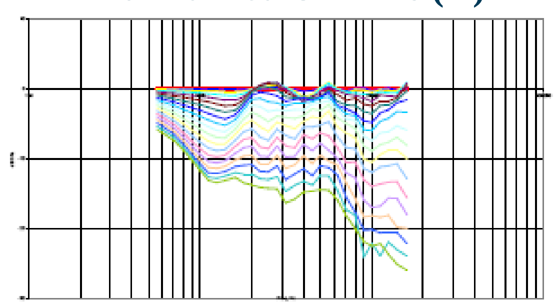
Off Axis Frequency Resp. (H)



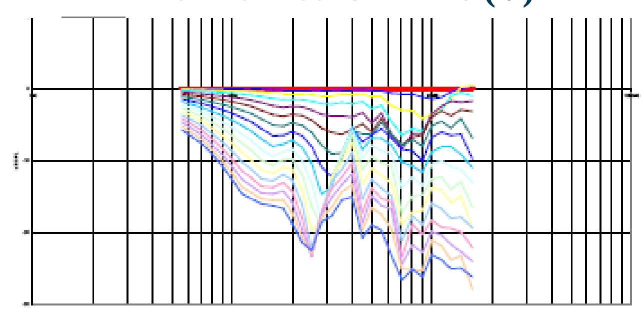
Off Axis Frequency Resp. (V)



Normalized Off Axis (H)



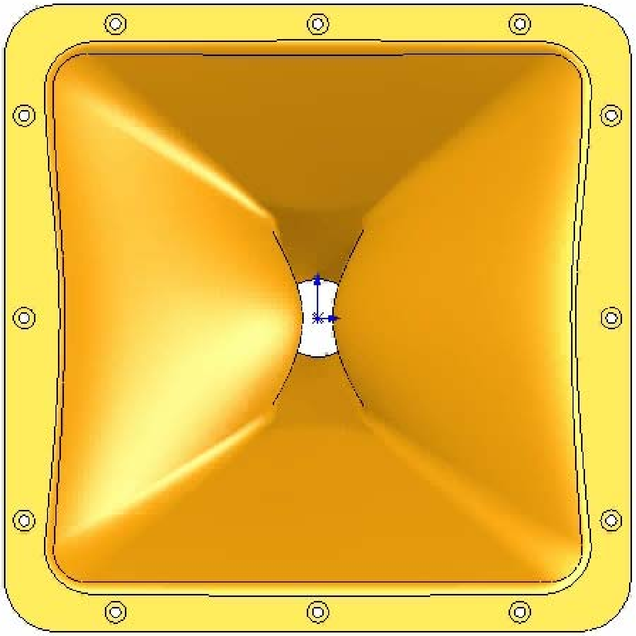
Normalized Off Axis (V)



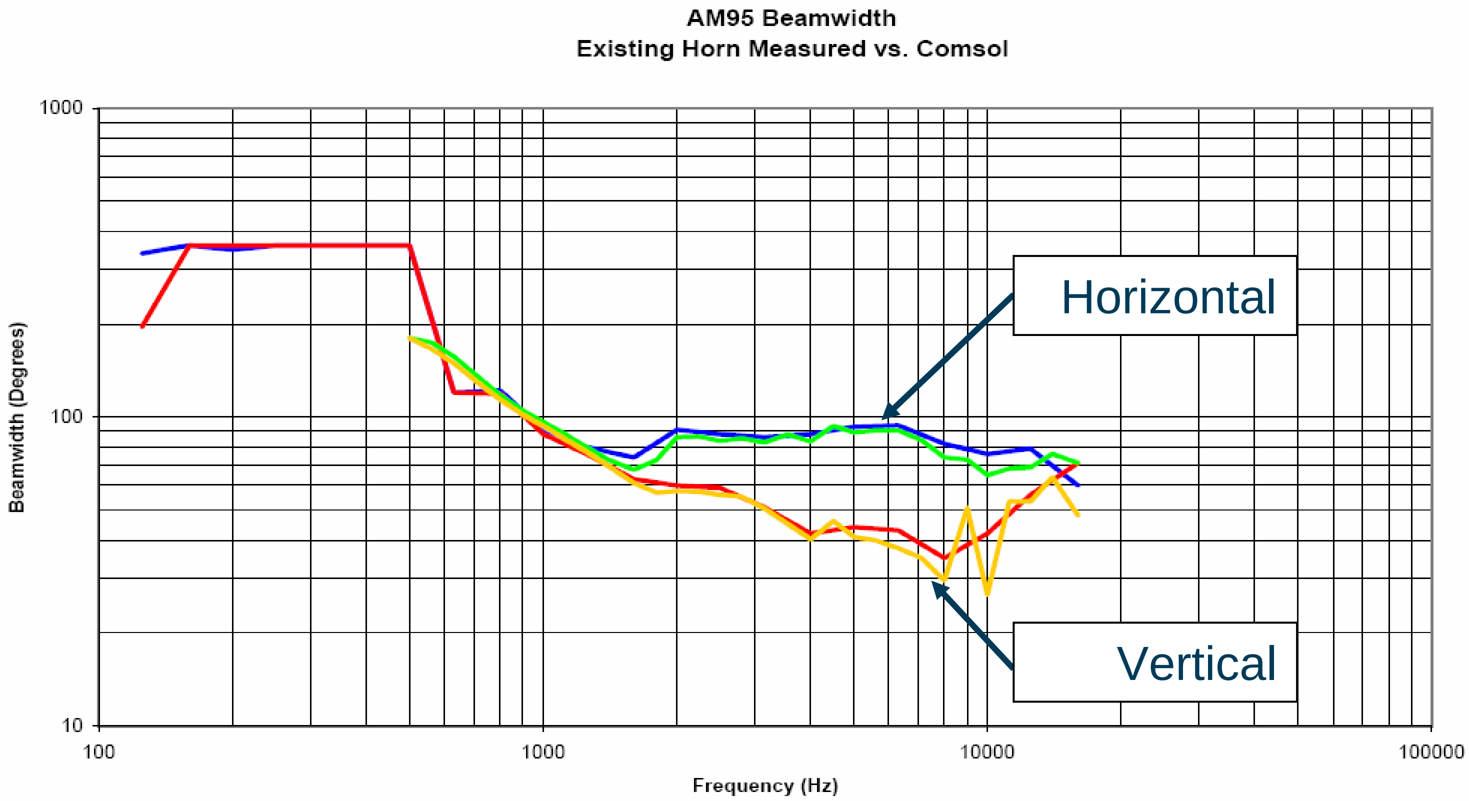
Case Study – Application Engineered "AE" Project

- **2nd generation product required improvements to several different existing horns:**
  - 100 x 100
  - 120 x 60
  - **60 x 40**
  - **90 x 50**
  - 60 x 60

90 x 50 Horn



Original 90 x 50 Performance (Measured vs Simulated)



Green and Orange = Simulated

Red and Blue = Measured

After Optimization in Comsol …

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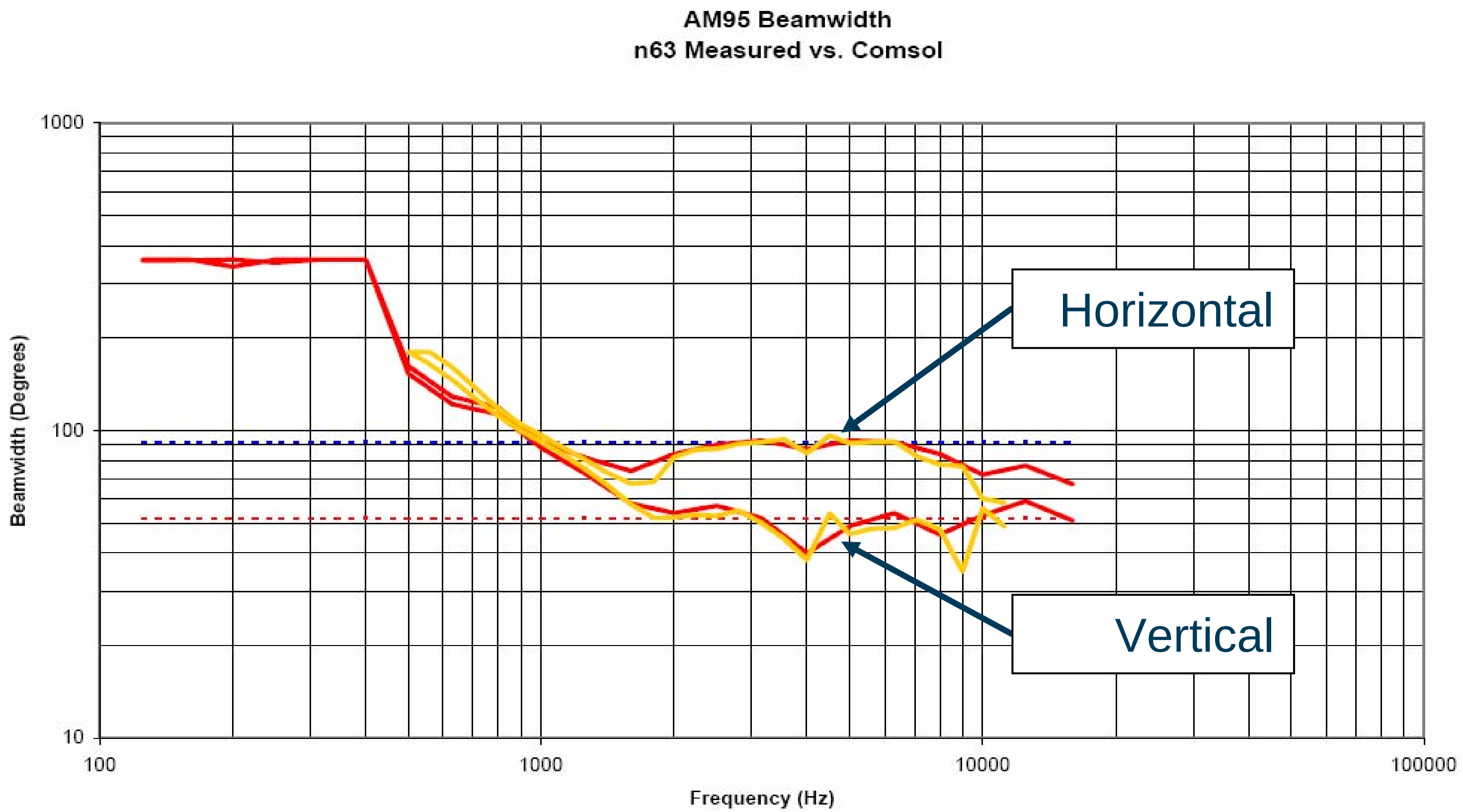
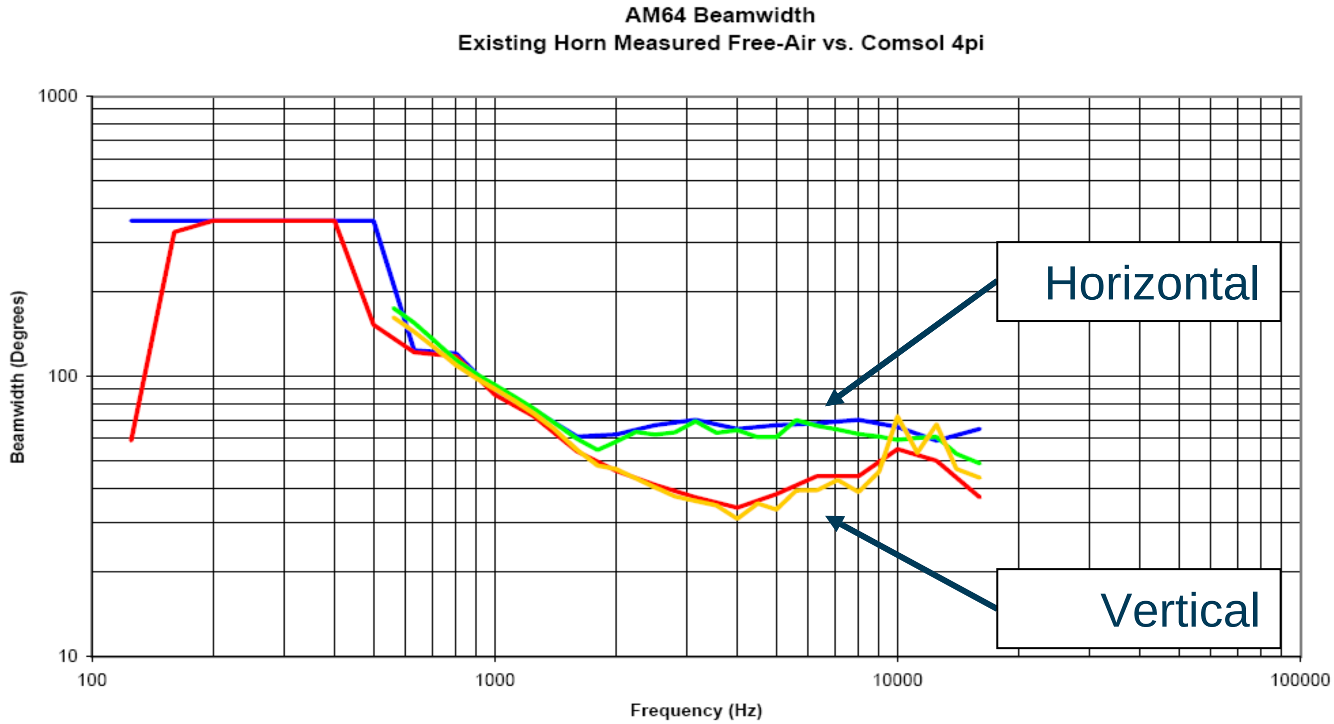


Orange = Simulated

Red = Measured

60 x 40 Horn

Original Horn 60 x 40 (Measured vs Simulated)

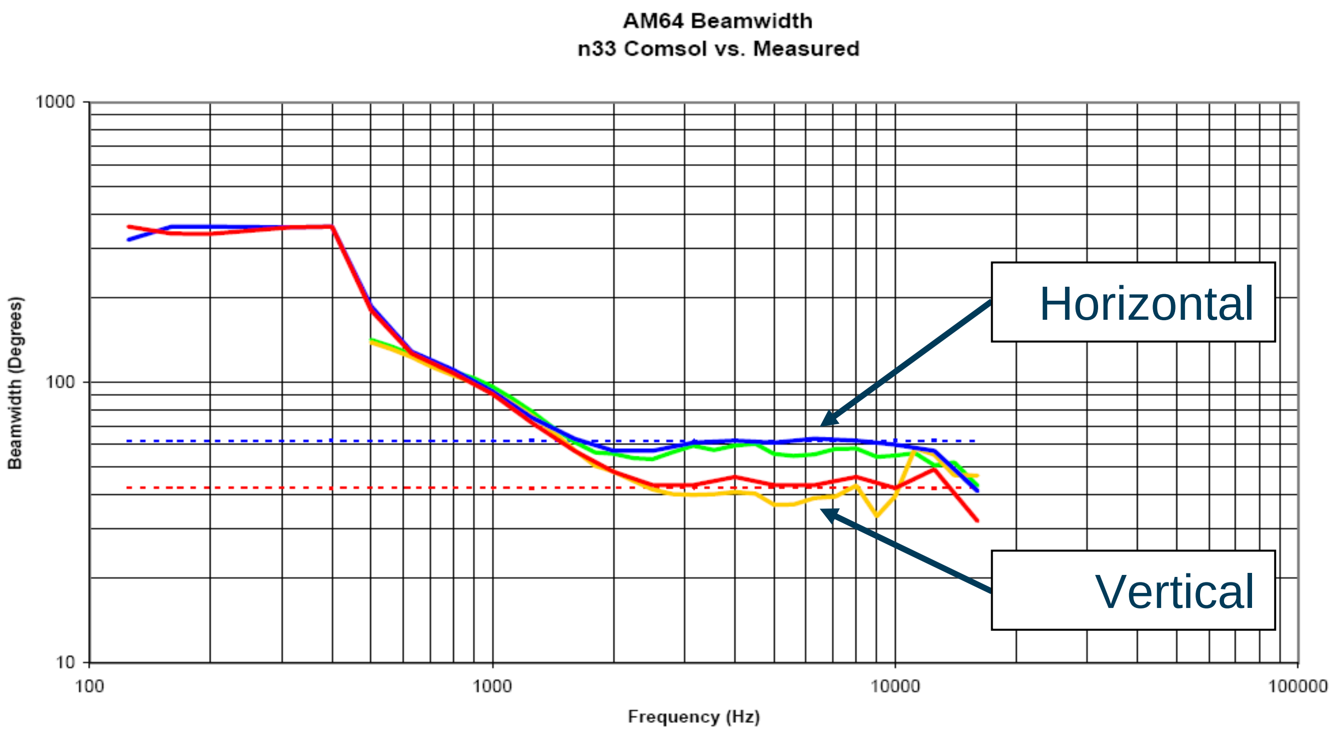


Green and Orange = Simulated

Red and Blue = Measured

After Optimization in Comsol

HARMAN



Green and Orange = Simulated

Red and Blue = Measured

Horn Simulations in Comsol - Summary

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- Comsol shows good predictive power for the virtual prototyping of acoustics of arbitrary horns.
- A high resolution frequency response for 2D Axisymmetric horns can be solved for in a short time, generally a matter of minutes. 3D horns can be solved in hours, depending on physical size and highest frequency of interest.
- The ability to interface with Matlab is a key requirement for both pre and post-processing, and allows a high degree of flexibility to customize the program operation and workflow.

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WHERE SOUND MATTERS

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