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Analysis of a W-Band Edge-Coupled Bandpass Filter in HFSS

Bernie Schmanski
BAE Systems
Nashua, NH

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Outline

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- W-band filter design
  - In-house filter design program
  - ADS simulation
- Measured Results
- HFSS Simulation
  - Model generation
  - Mesh generation with virtual objects
- HFSS Backfit Model Results
- Conclusions

Filter Design

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----------------------------------------------------------------
Synthesis of Parallel-Coupled Line microstrip BandPass
Filters with DXF and Touchstone file generation.
Rev. 3.1 D.M. Dugas Gr. 63 X3906
----------------------------------------------------------------

Would you like some information? nIs the filter Butterworth (1), Tchebyscheff (2)? >> 2
What is the ripple (dB) >> .3
Number of poles >> 7
Impedance >> 50
Center frequency (GHz) >> 88.2
What is the ripple bandwidth in >> 6.9
Substrate thickness (mils) >> 5
Height from substrate to top cover (mils) >> 1000000
Thickness of substrate metalization (mils) >> 0.15
Relative dielectric constant of substrate >> 10
Etch factor (mils) >> 0
Generate Touchstone CKT file (y or n) >> n
Calculating filter dimensions . . . .Filter type:  Tchebyscheff
Ripple: 0.300 dB
Ripple bandwidth: 6.900
Poles:    7
Impedance:  50.00
Center Frequency:  88.200 GHz
Substrate thickness: 5.00 mils
Cover height: 1000000.00 mils
Metalization thickness:  0.15 mils
Relative dielectric constant:  10.00
Etch factor:  0.00 mils

SECTION      Zoe       Zoo      WIDTH     SPACING    LENGTH
-------      ---       ---      -----     -------    ------
  1,8      66.959    40.201    3.99      3.15       10.96
  2,7      54.103    46.478    4.74      10.90       10.75
  3,6      53.202    47.163    4.76      13.03       10.75
  4,5      53.076    47.262    4.76      13.40       10.75
Overall filter length: 86.43
D:\>
```

- Initial design performed using an in-house program which generates physical dimensions based on electrical parameters. These numbers are used as a starting point in the ADS analysis.
- Substrate material is 5 mil alumina.
  - Er=9.8
  - Tand=0.0001

Filter Design - Linear Analysis and Optimization

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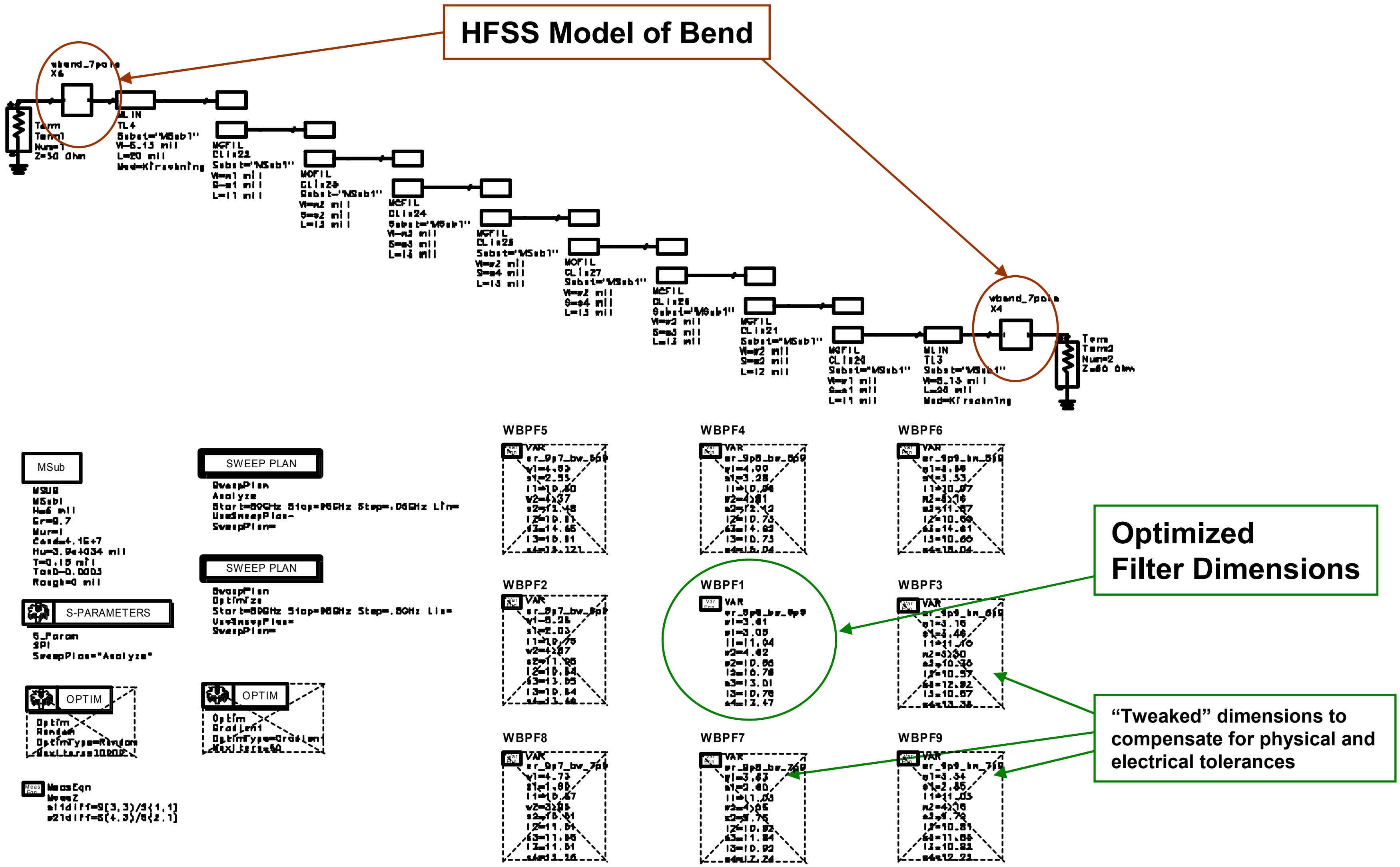
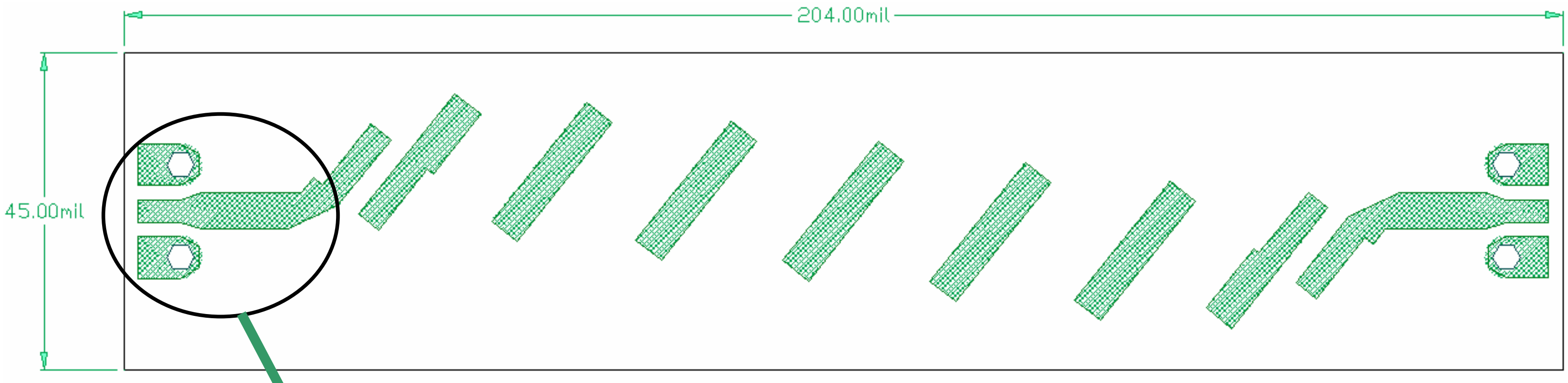
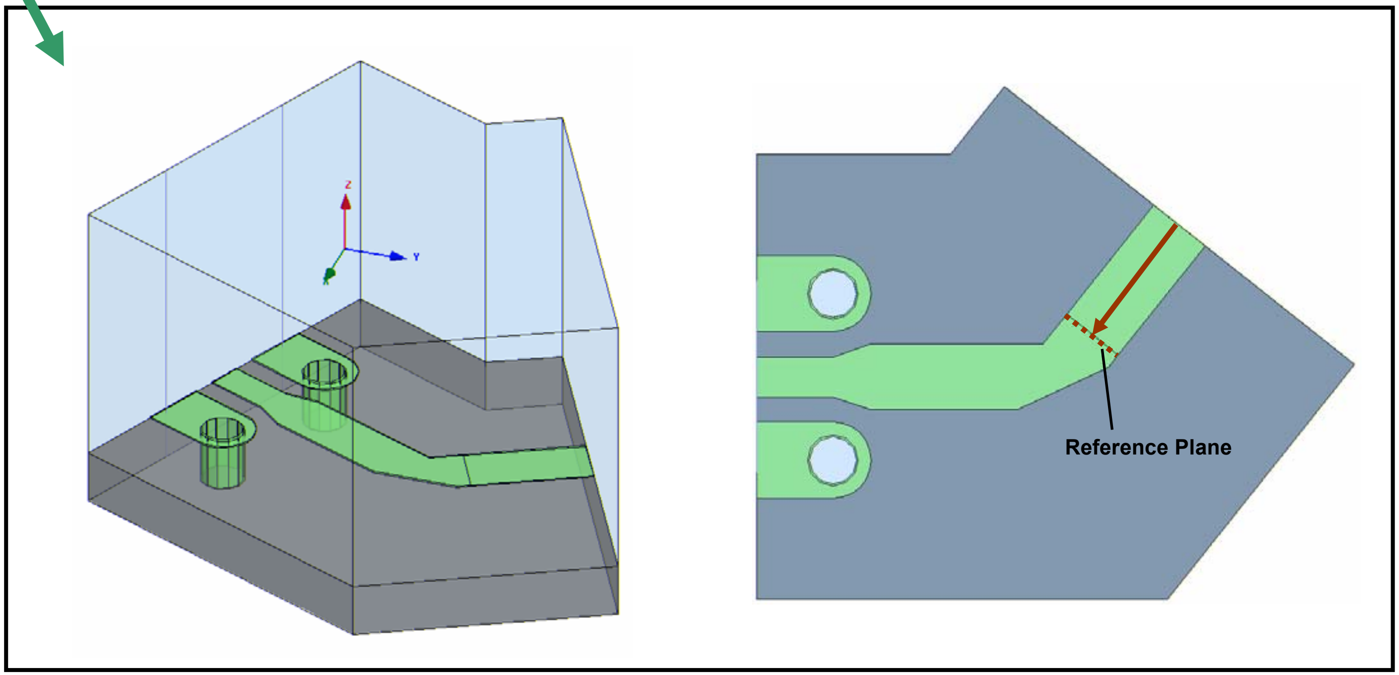


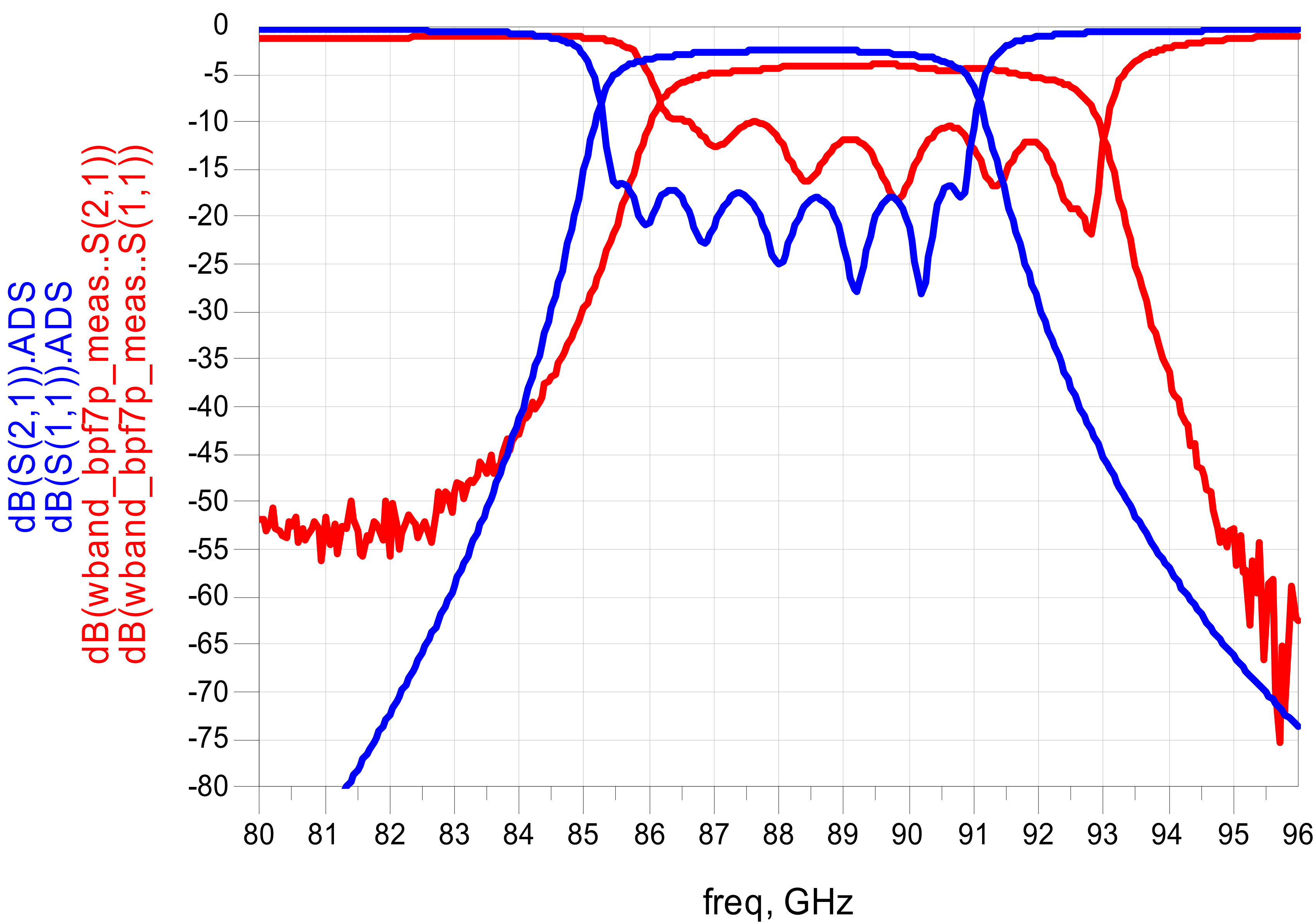
AutoCAD Filter Layout





Initial analysis included an HFSS simulation of the coplanar probe launch and mitered bend.

Linear Simulation vs. Measurement



Linear Simulation vs. Measurement

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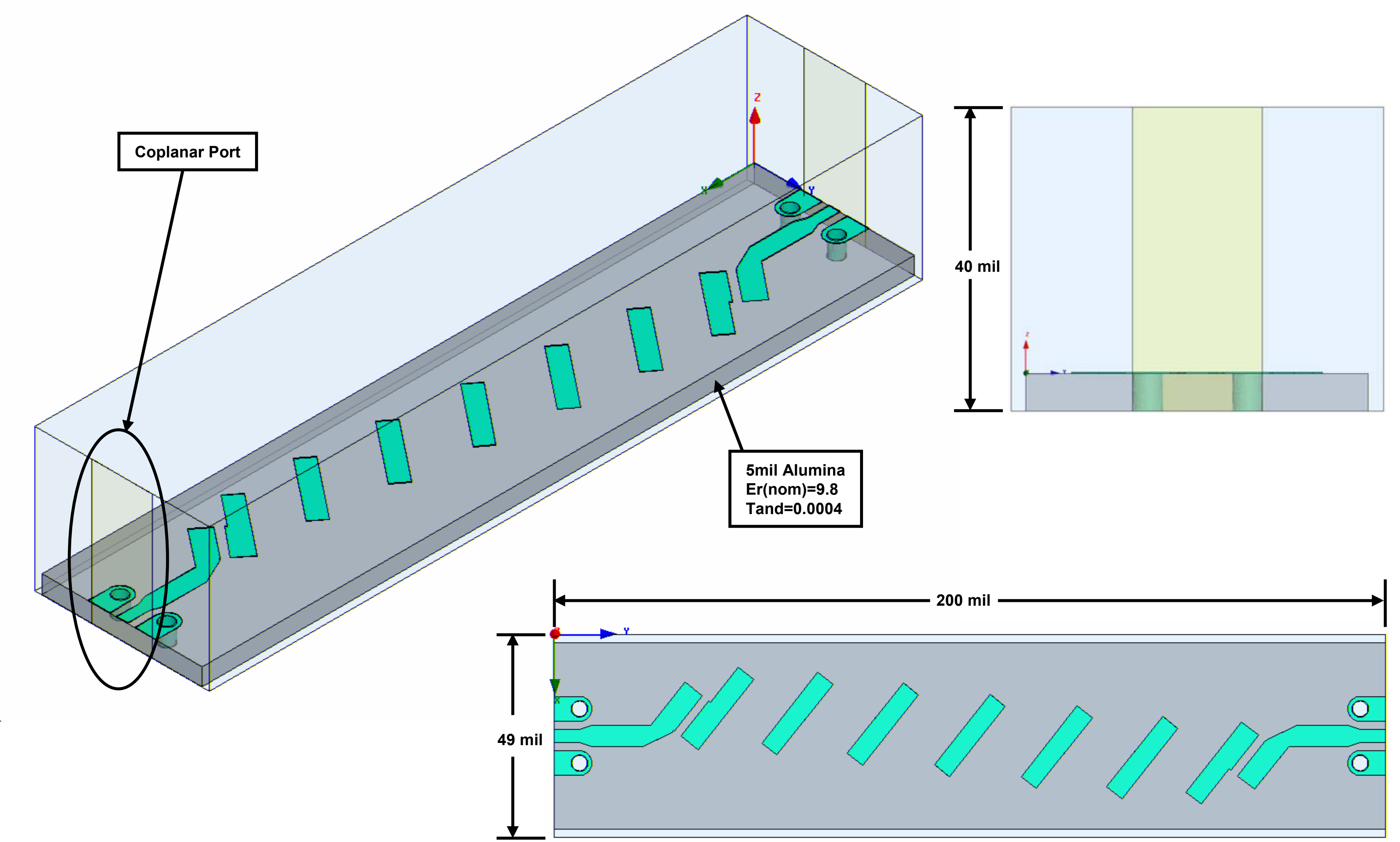
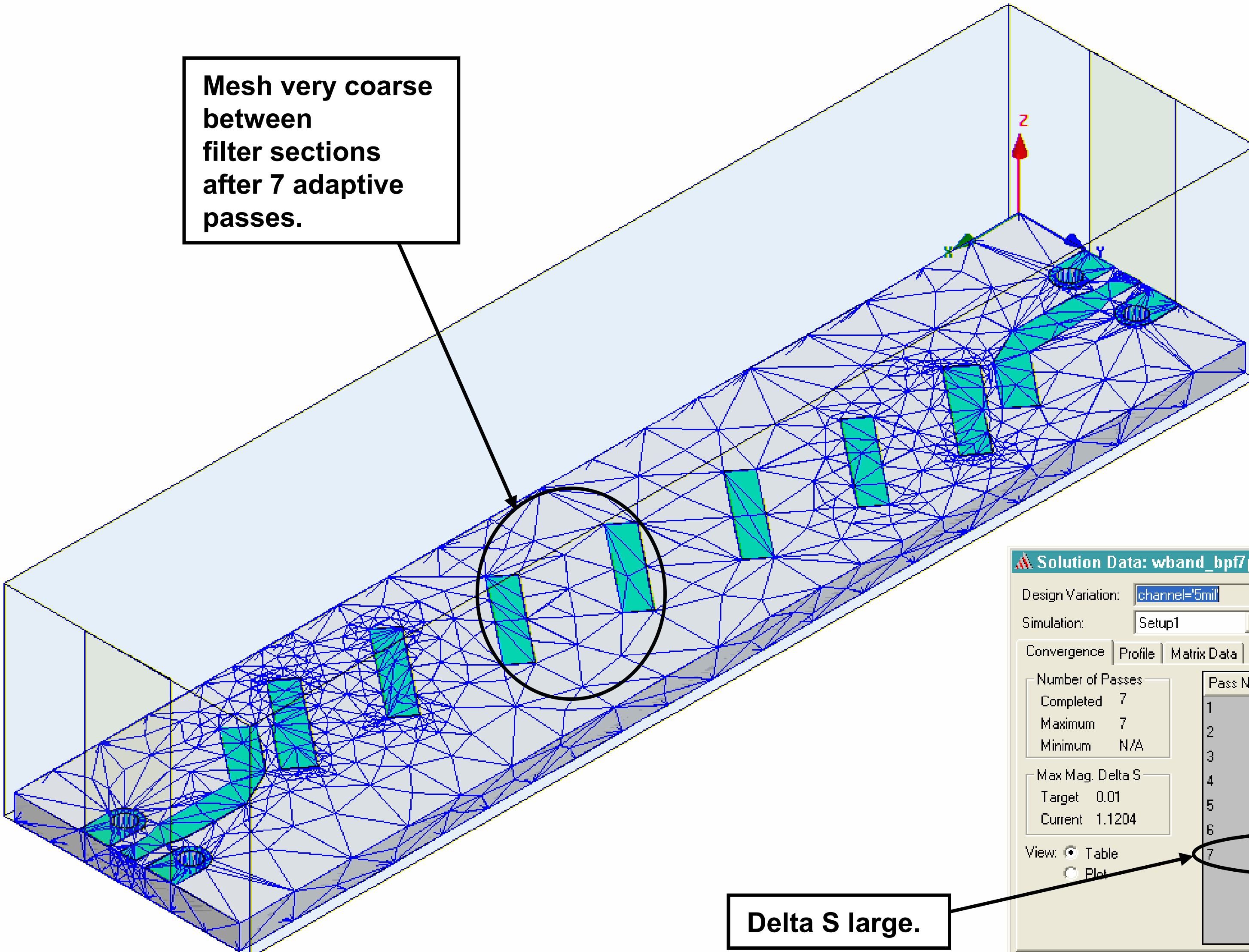
- Measured passband 1 GHz wider than predicted
- Center frequency measured 1.3 GHz low
- Measured loss 1.5 dB higher than predicted.
  - Fabricated parts had known metalization problems which increased loss.
- Implement a full-wave HFSS simulation to backfit measured results.
  - Include cavity geometry
  - Model substrate placement in cavity
  - Model coplanar launch and bends
  - Adjust Er and metal loss to match measured results

HFSS Geometry

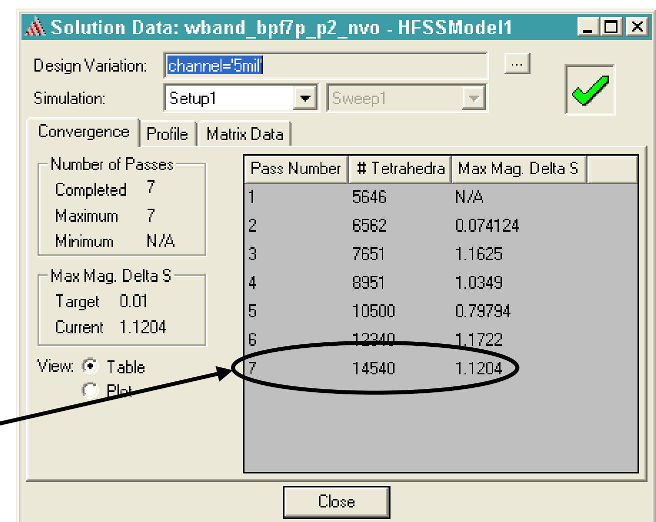


HFSS Initial Analysis - Mesh and Conversion

Mesh very coarse between filter sections after 7 adaptive passes.



Delta S large.



HFSS Initial Analysis - S-parameters After 7 Adaptive Passes

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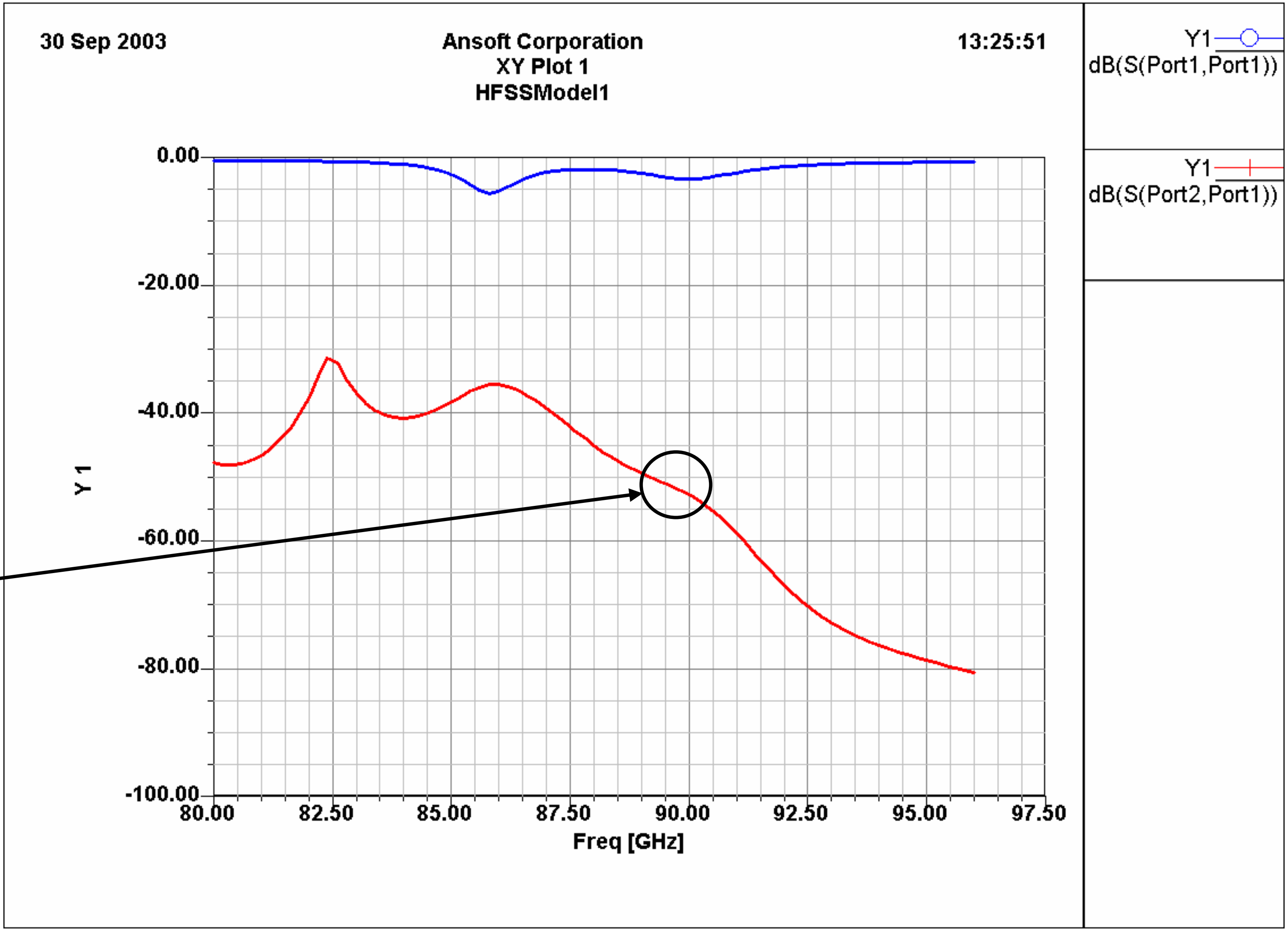

Results do not show expected filter passband.

HFSS Initial Analysis

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- Initial analysis failed due to a large number of adaptive simulations required to converge on solution.
  - Data after 7 passes showed significant attenuation at the expected passband.
  - Model would required more memory and time to significantly improve convergence.
- Initial mesh did not have enough tetrahedra between filter sections to capture coupling effects.
- A seeded mesh would be required to help mesher increase the number of tetrahedra between coupled filter sections.

First Seeded Mesh Iteration

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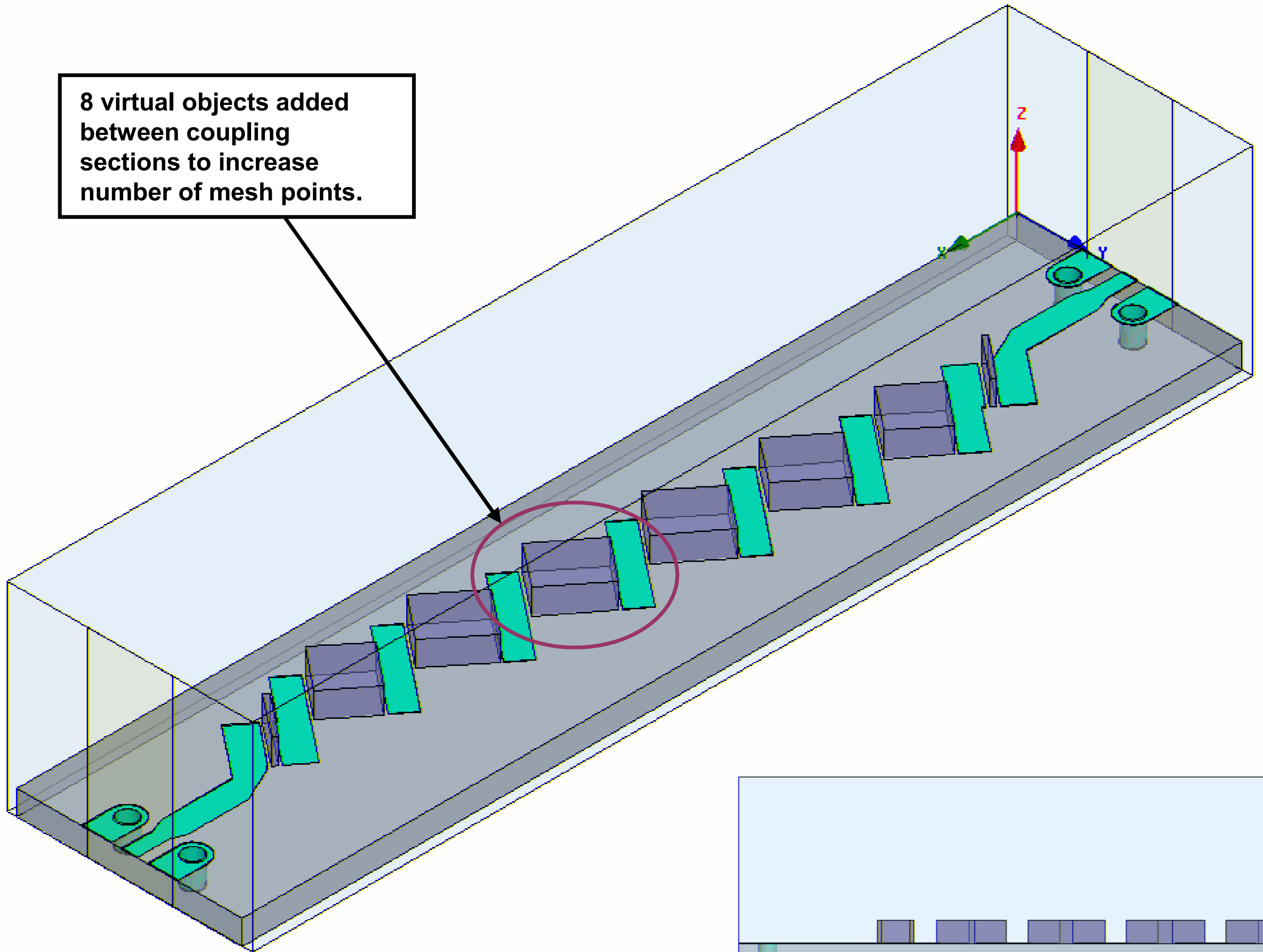

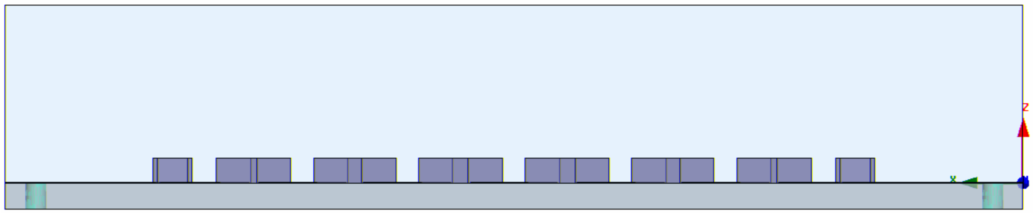

First Seeded Mesh Iteration

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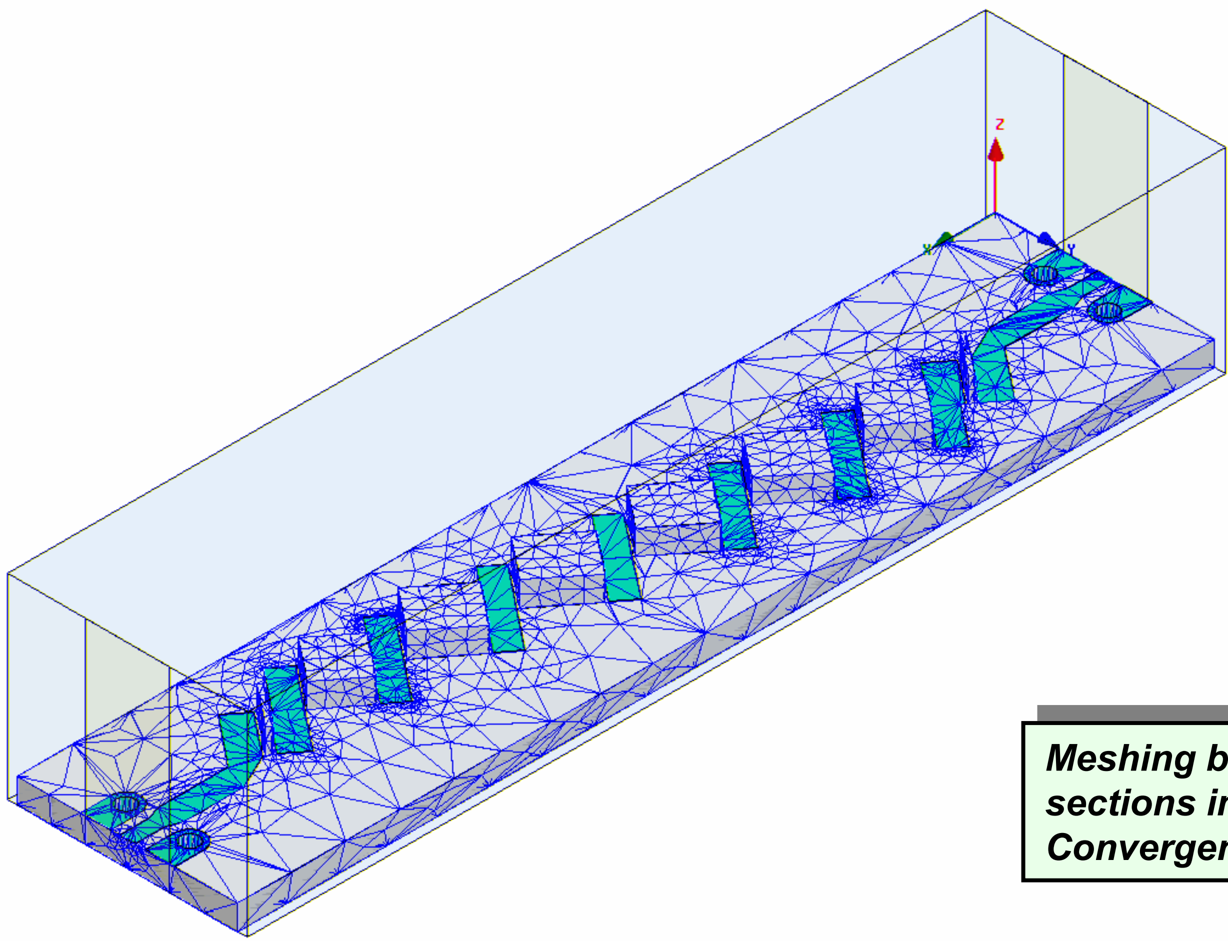

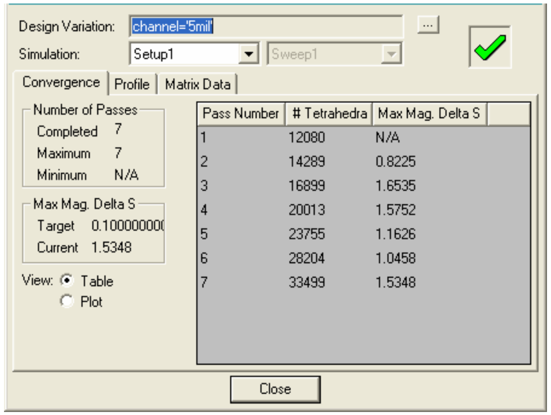

Meshing between coupled sections improved.
Convergence still a problem.

First Seeded Mesh Iteration

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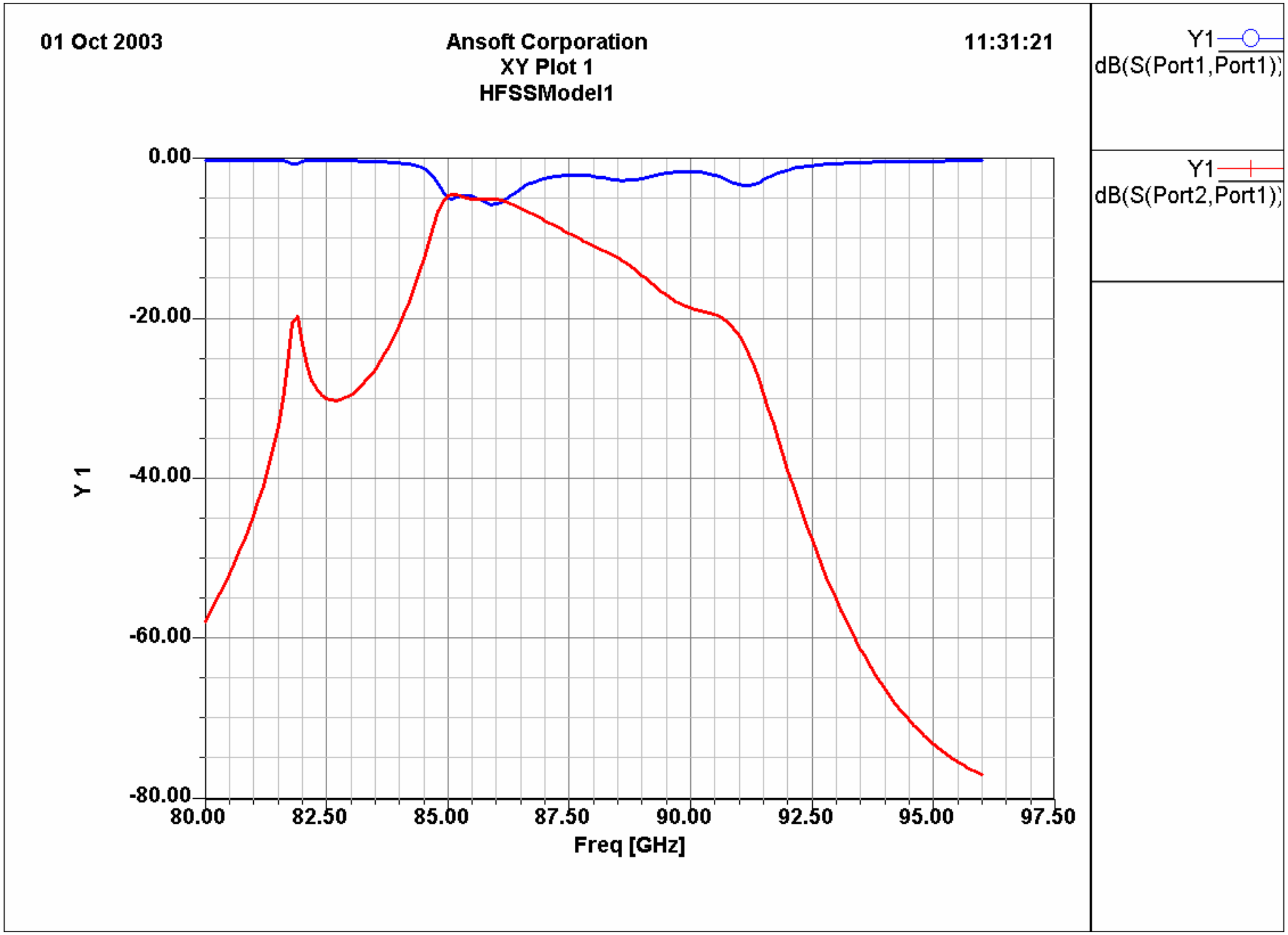

Simulation results improved. Passband is starting to appear.

Improved Geometry for Seeded Mesh

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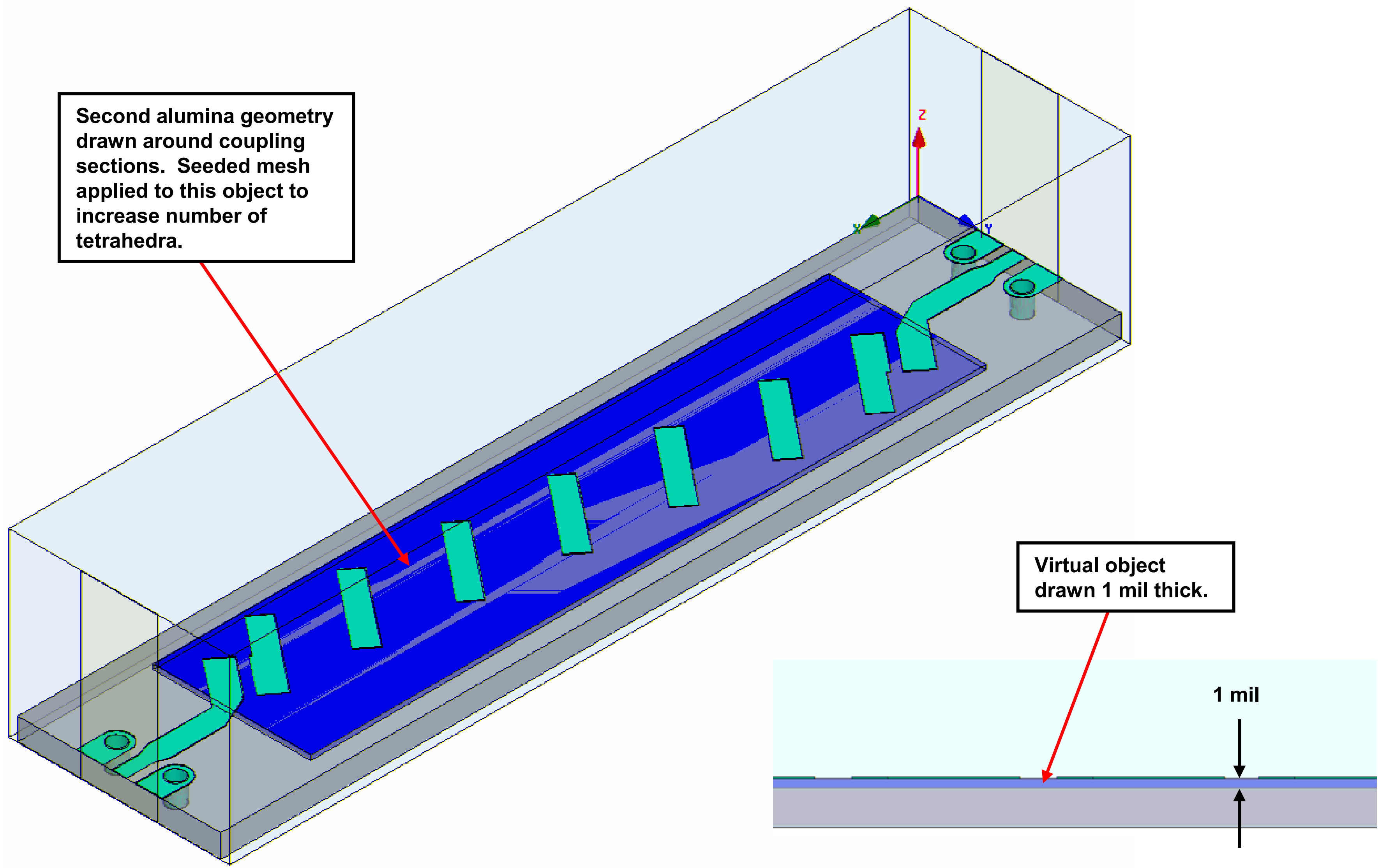

Final Mesh

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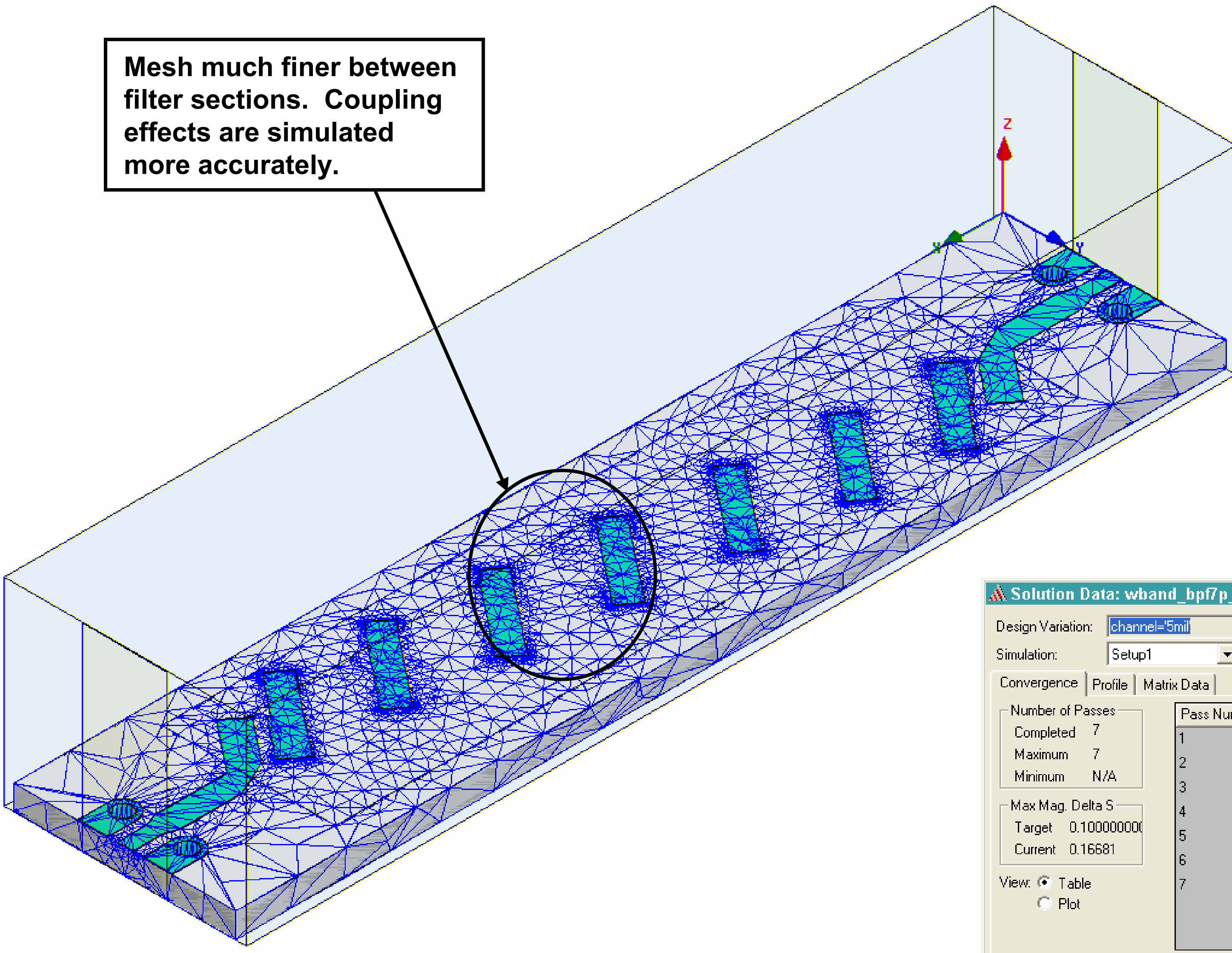

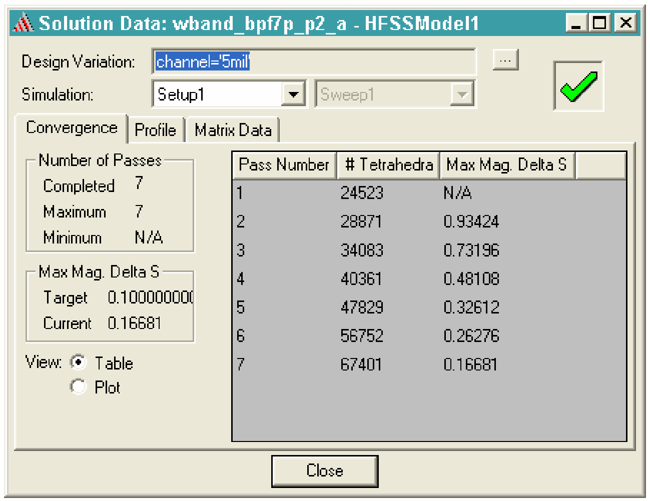

HFSS Analysis vs. Measured

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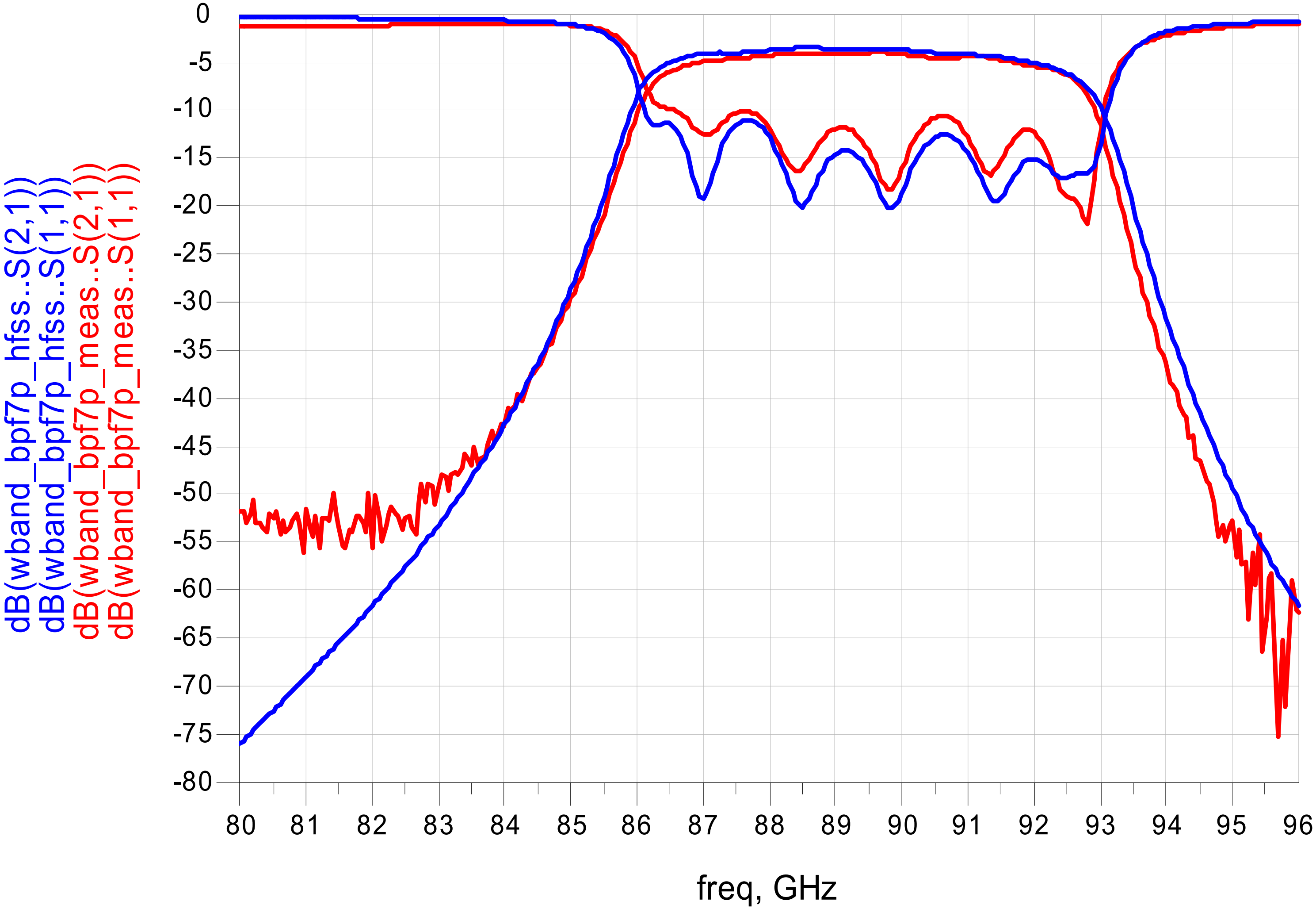

Er reduced to 9.575 and conductivity increased by a factor of 3 to backfit center frequency and loss.

HFSS Analysis vs. Measured and ADS

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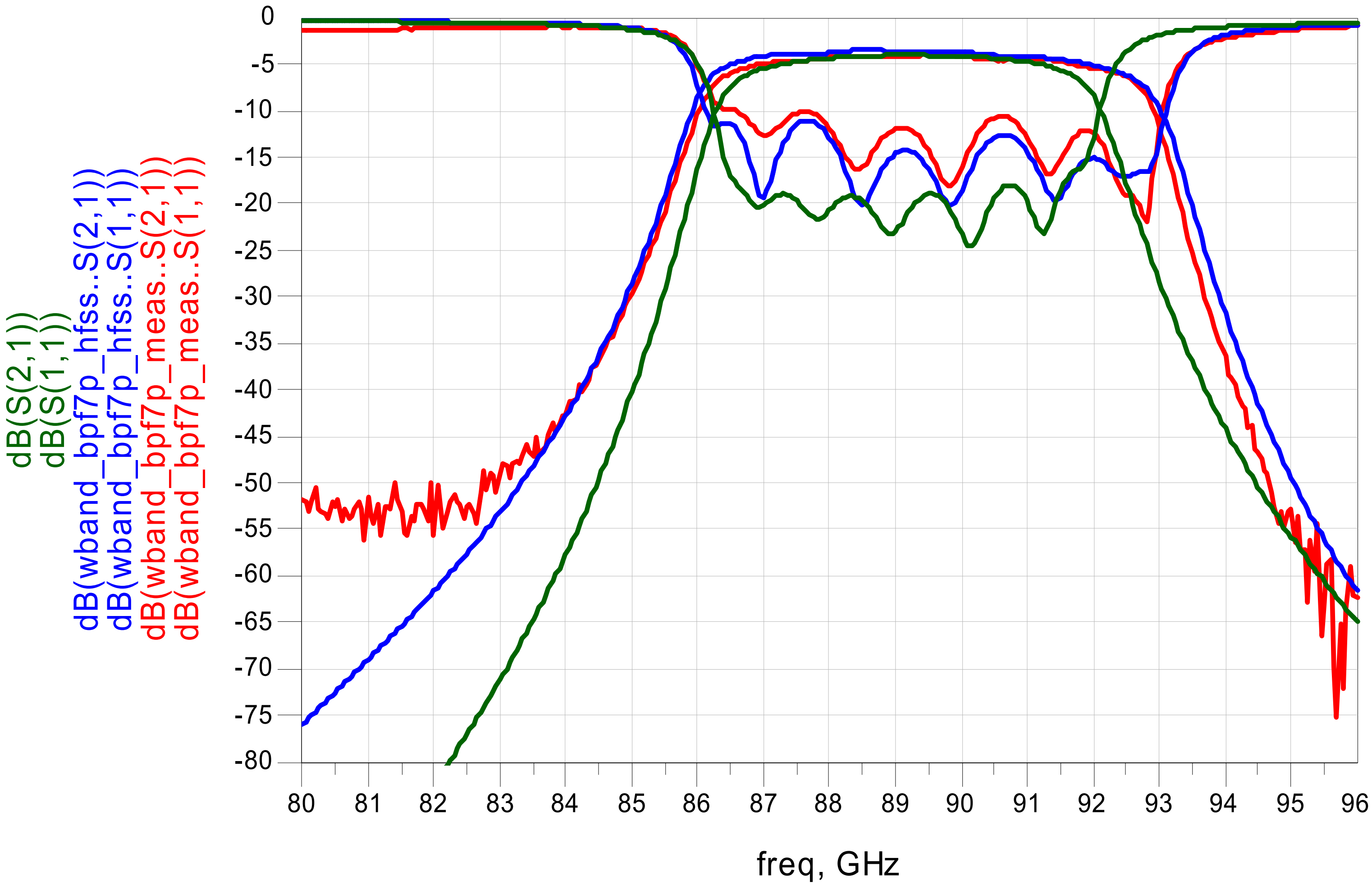

ADS model modified to include Er and metal loss used in HFSS simulation. Center frequency and loss are closer, but the rejection and return loss predicted by ADS still does not match the measured data.

Conclusions

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- HFSS can accurately model edge-coupled microstrip filters up to W-Band.
  - Simulation results closely predict measured response.
    - Bandwidth
    - Rejection
  - Physical parameters critical in edge-coupled filter performance can be modeled.
  - Model can be used to back-fit electrical parameters.
  - First pass success can be greatly improved using HFSS in conjunction with linear simulators.
- Mesh seeding is a useful method to improve accuracy in simulating coupled line filters.
  - Gives simulator better starting point.
  - Reduces number of adaptive passes and speeds up convergence.
- Virtual objects help to define seeded mesh areas inside of model geometries.