Measurements of Non-Metallic Targets for the Austin RCS Benchmark Suite

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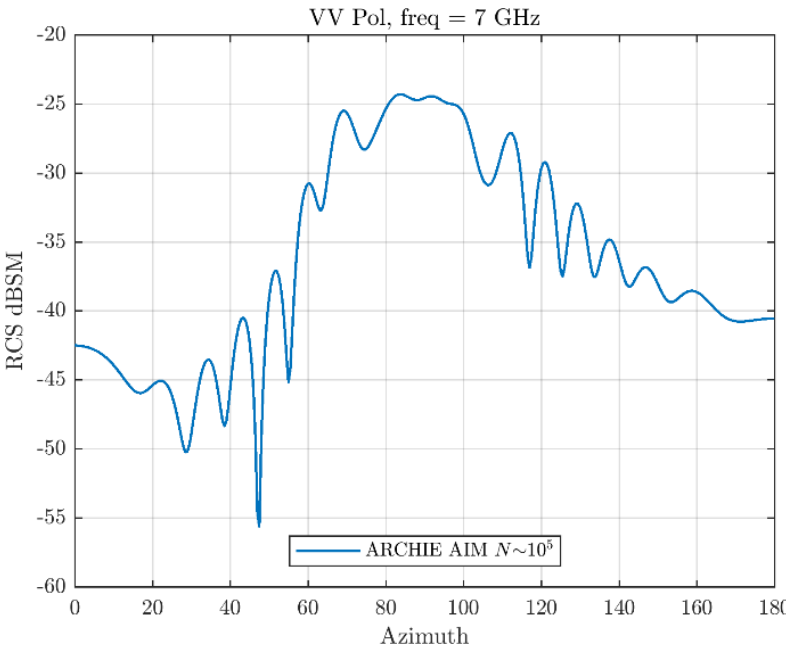
Outline

- Motivation
  - The Austin RCS Benchmark Suite
  - Characterization of common additive manufacturing materials
- Material Characterization
  - Material description
  - Measurement process
- Target Preparation
  - Description of targets
  - Target manufacturing
- Monostatic RCS Measurement
  - Measurement setup
  - Data collection
- Measurement Post-Processing
  - RCS measurement processing
  - Validation by simulation
  - Uncertainty quantification
- Conclusion

Motivation

❑ The Austin RCS Benchmark Suite

- Improve on established CEM benchmarks
  - Many problems scaling from easy to very difficult
  - Centrally located in an internet repository: https://github.com/UTAustinCEMGroup/AustinCEMBenchmarks



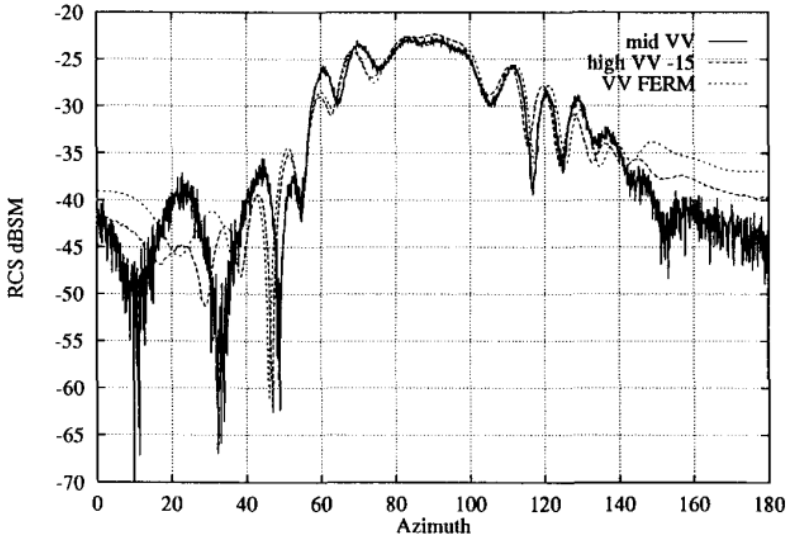
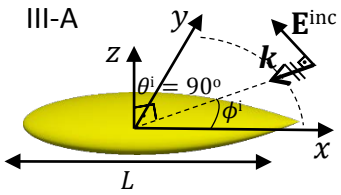
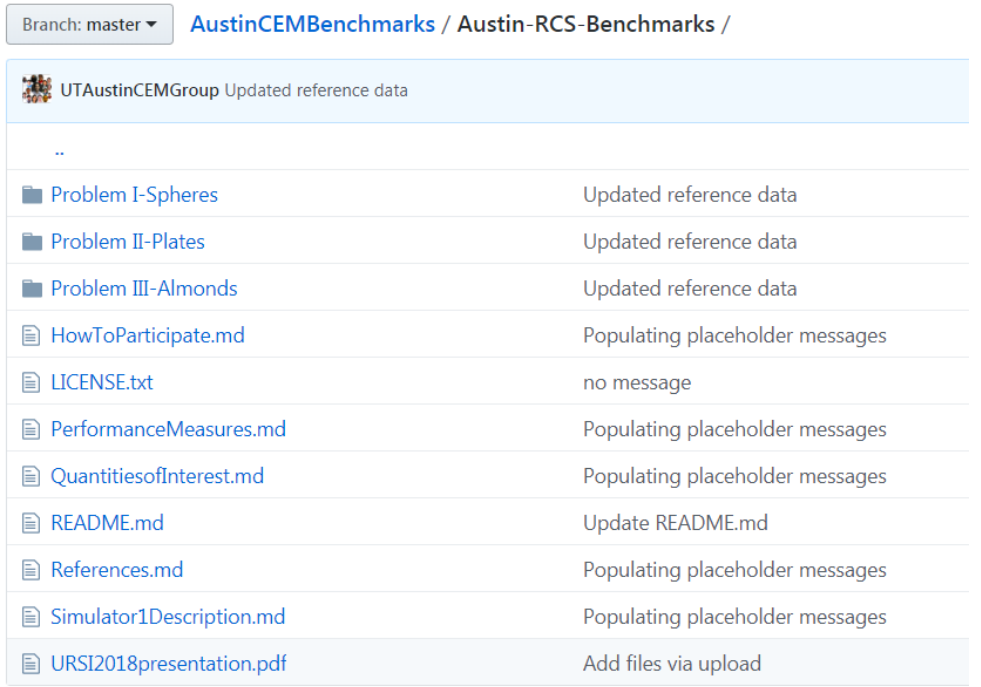


Figure 5. The 9.936 inch NASA almond at 7 GHz, for vertical polarization. The curves are labeled the same as in Figure 4.





Reference:

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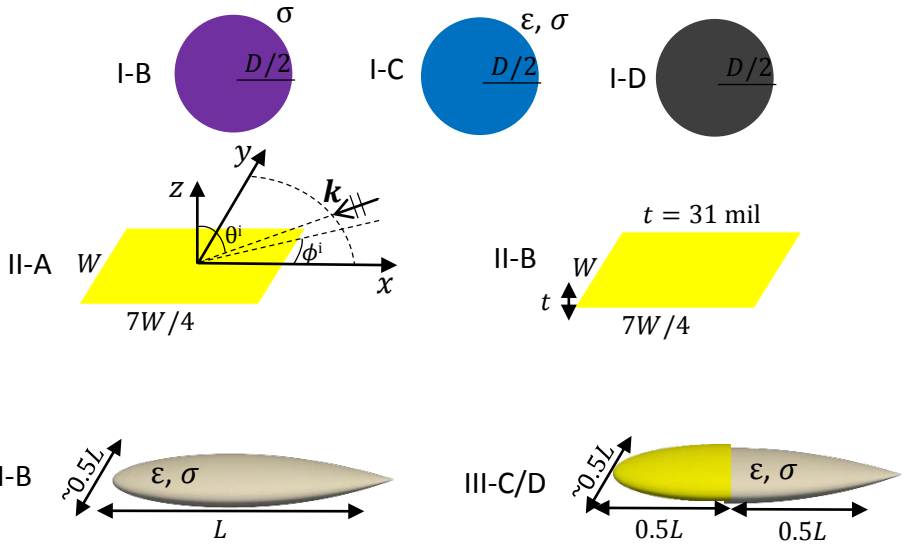
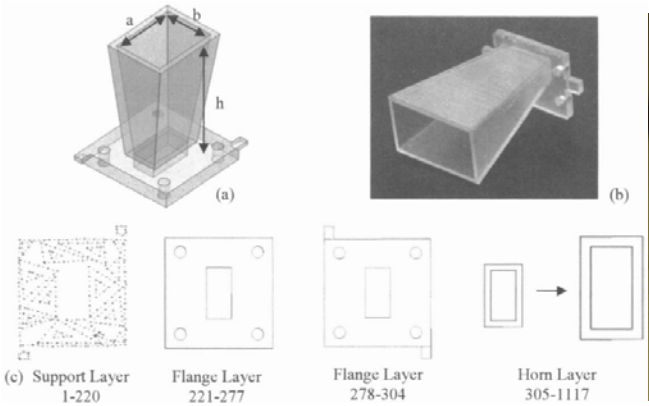
Motivation

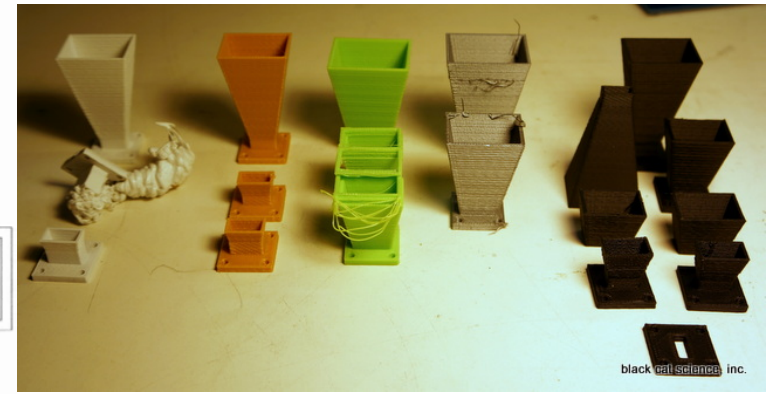
❑ The Austin RCS Benchmark Suite

- Improve on established CEM benchmarks
  - o Many problems scaling from easy to very difficult
  - o Centrally located in an internet repository: https://github.com/UTAustinCEMGroup/AustinCEMBenchmarks
- Create next generation benchmarks for CEM validation
  - o Challenging problems that exceed modern modeling/simulation abilities
  - o Emphasis on reproducibility





Antennas manufactured via stereolithography



Antennas manufactured via 3D printing

Original Images from:
http://www.blackcatscience.com/3d-printing-horn-antennas/

Motivation

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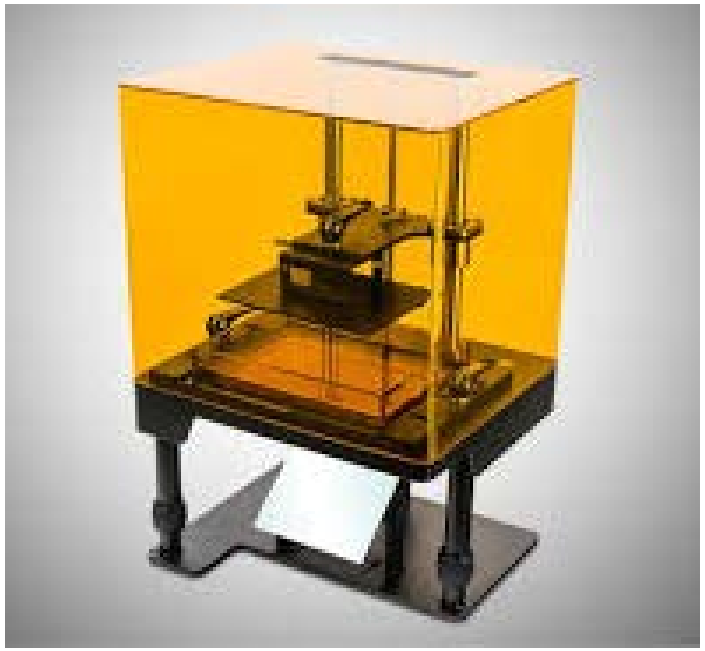
❑ Material characterization

- Thermoset 3D Printing
  - o Widespread and inexpensive
  - o Low model fidelity
  - o Polylactic Acid (PLA) (very common thermoset plastic)
- Stereolithography
  - o Widespread in industry, more expensive
  - o High model fidelity
  - o Photochemical process



Original Images from:
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https://www.3ders.org/articles/20140924-high-resolution-3d-dlp-printer-solus-to-hit-indiegogo.html

Material Characterization

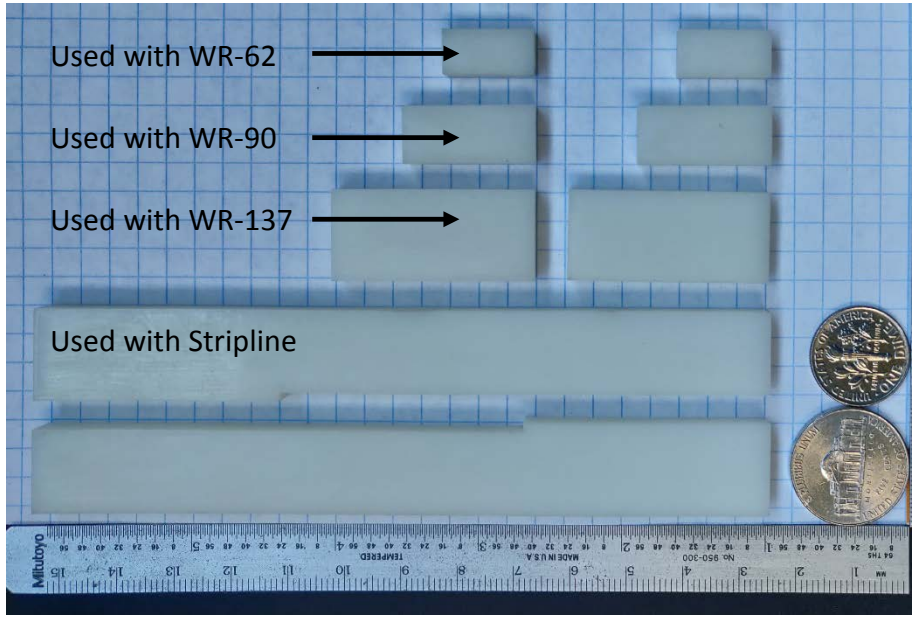
ODEN INSTITUTE FOR COMPUTATIONAL ENGINEERING & SCIENCES
UT ECE

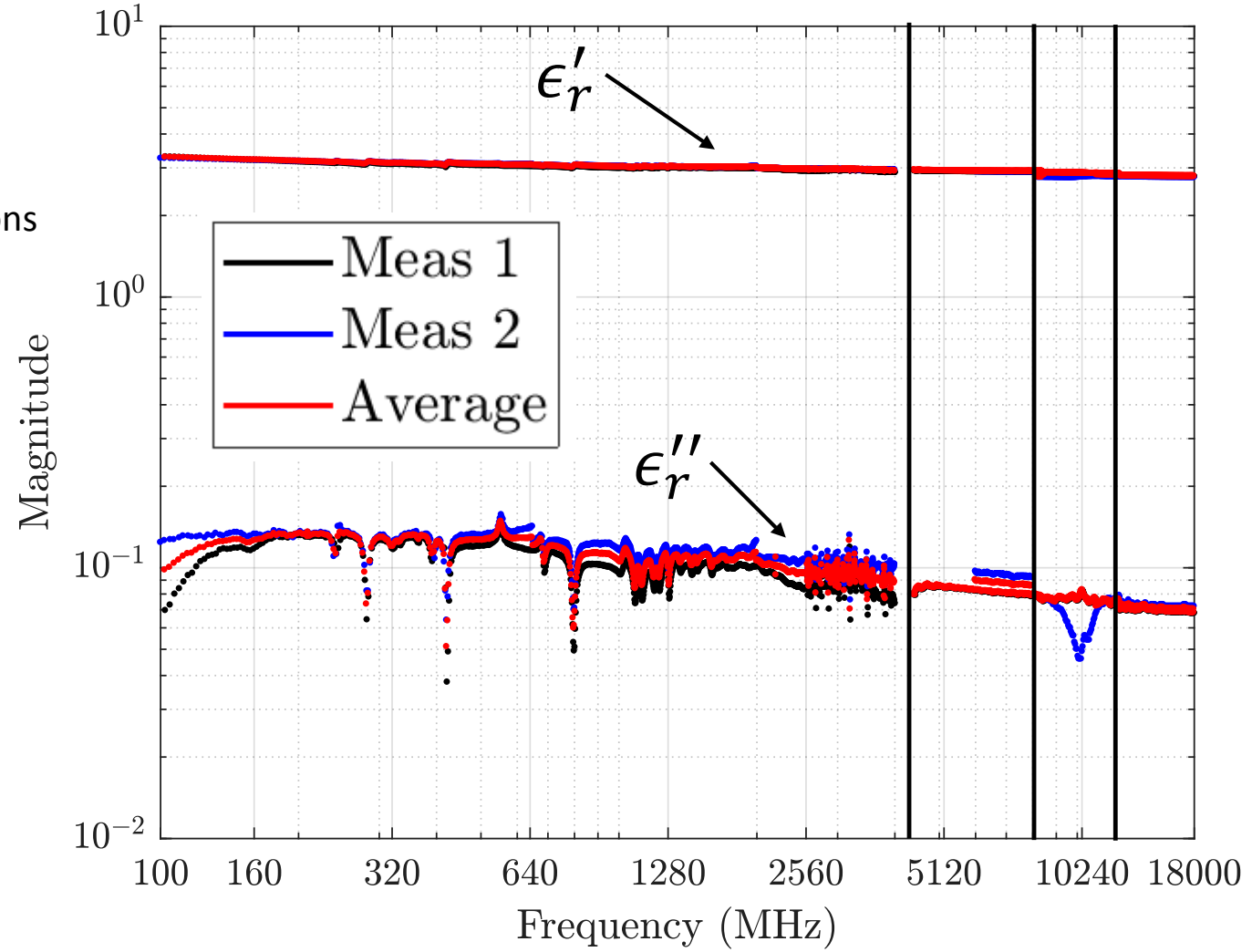
❑ Material Description

1. Accura Xtreme White 200 photopolymer resin

❑ Measurement Process

- Manufacture test coupons for resin
- Calibrate VNA and validate with standard material coupons
- Measure S parameters of test coupons
- Use NRW algorithm to compute dielectric properties
- Fit measured data to Debye Model





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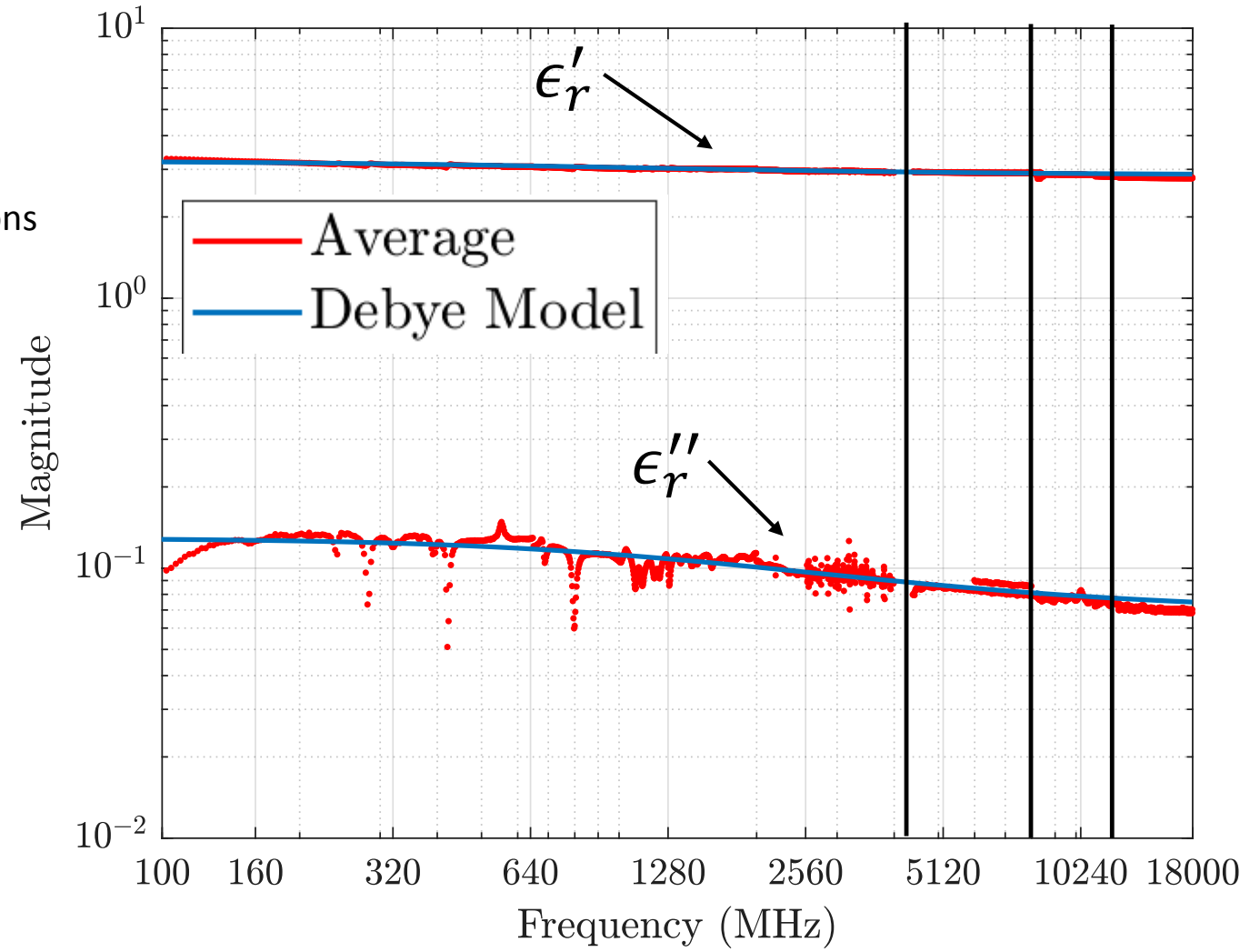
$$\epsilon_r(f) = A + \frac{B}{1 - jfC}$$



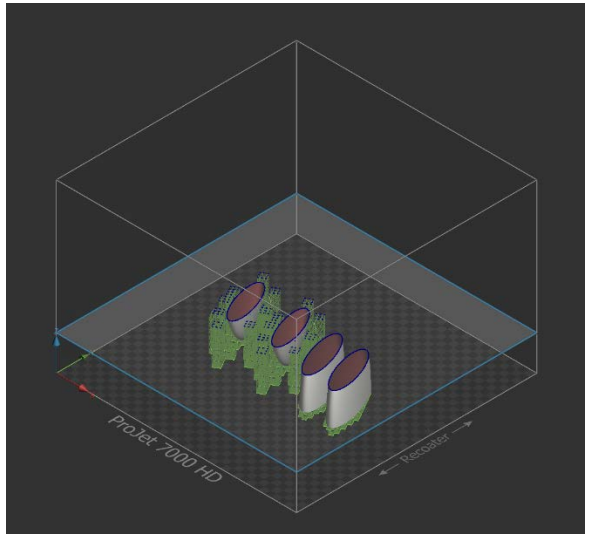
Target Preparation

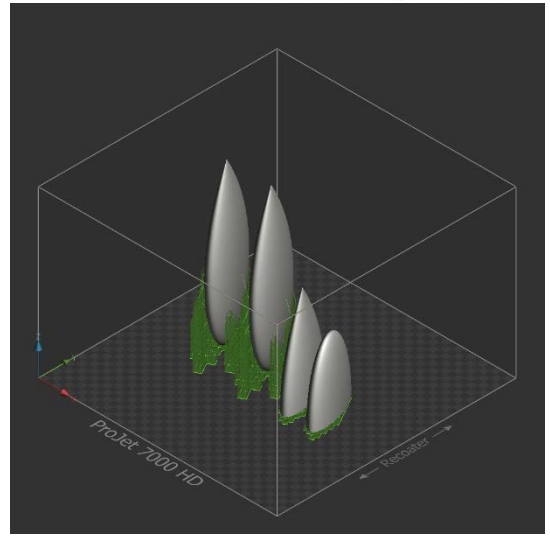
❑ Target Description

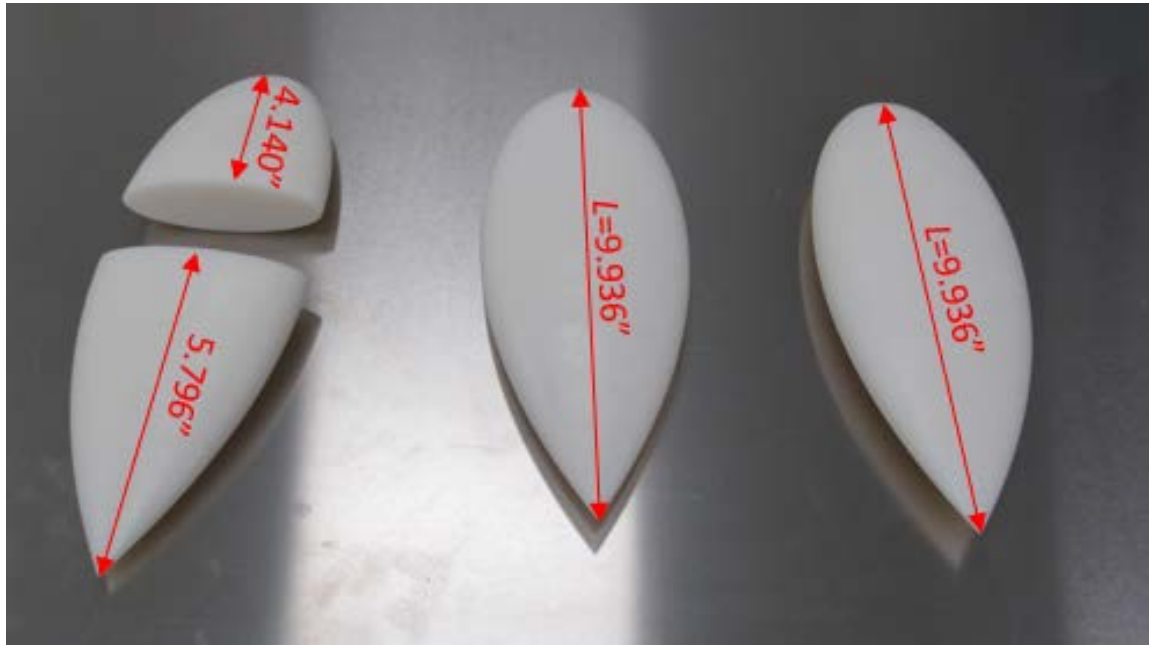
- Three Targets Based on NASA Almond [1] Geometry
  1. Solid Resin Almond
  2. Closed Tail-Coated Almond
  3. Open Tail-Coated Almond

❑ Target Manufacturing

- Additively manufactured via Stereolithography (~29 hr)
- Targets were cured in a UV oven







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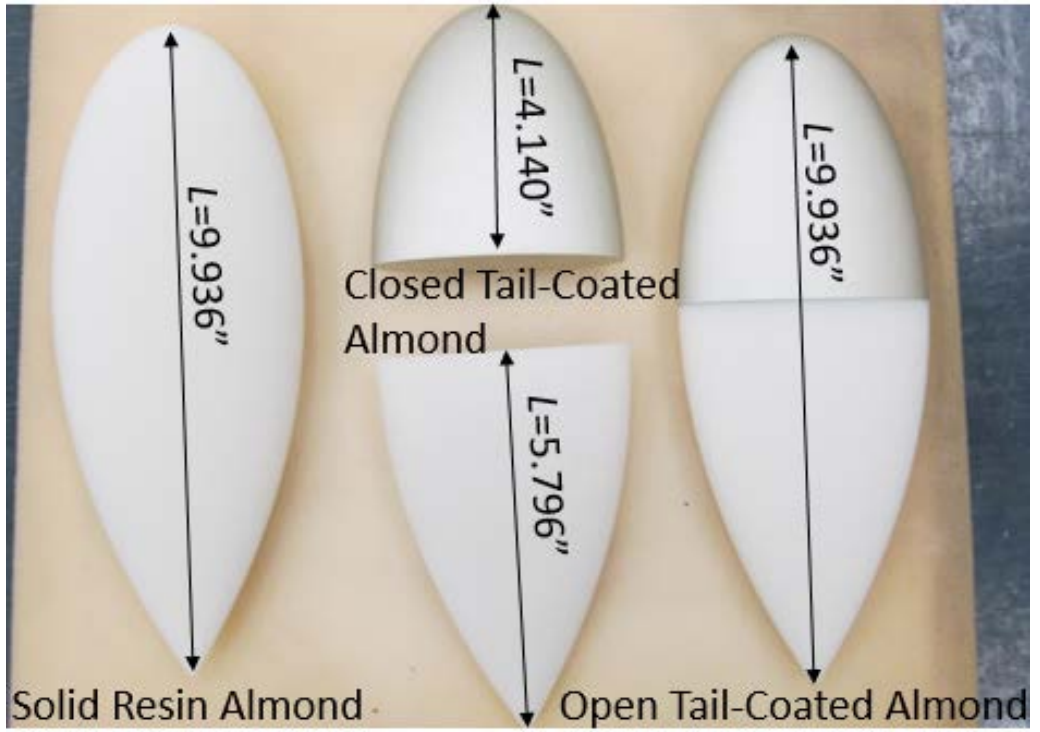
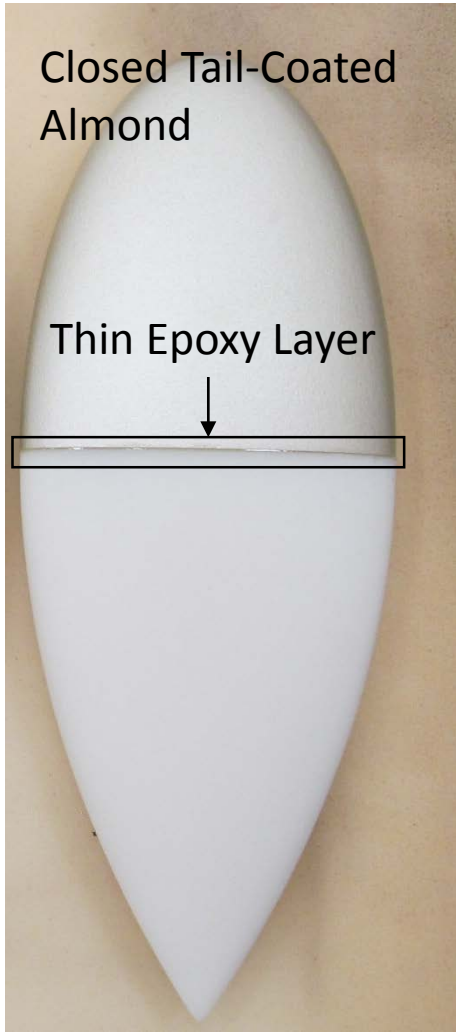
Target Manufacturing

- Additively manufactured via Stereolithography (~29 hr)
- Targets were cured in a UV oven
- Targets were then sanded and the Closed/Open Tail-Coated Almonds were coated with silver paint
- The tip and tail of the Closed Tail-Coated Almond were joined together with an epoxy





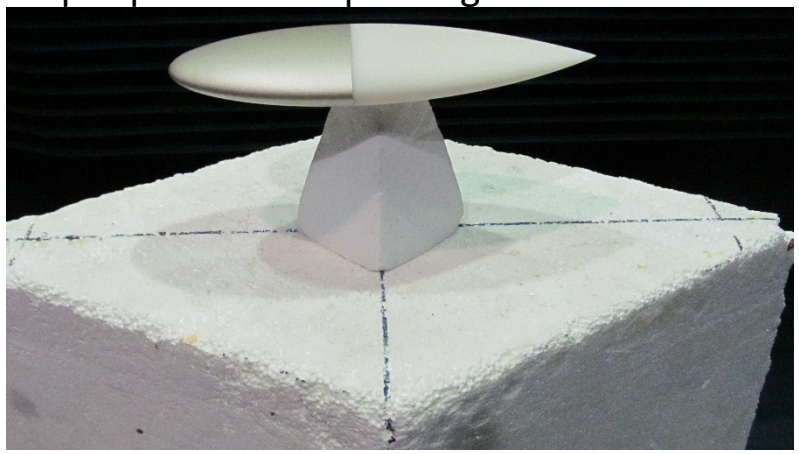
Monostatic RCS Measurement

❑ Measurement Setup

- LMA Rye Canyon Anechoic Chamber
- Dual Calibration Technique
  - 18” and 15” NIST squat cylinders

❑ Data Collection

- Background measurements taken frequently
  - Included small foam mount
- Data collected from $\phi \in [-30°, 390°]$ azimuthal range
- Rotation rate of $0.29°/s$ for a total of 24 minutes per polarization per target



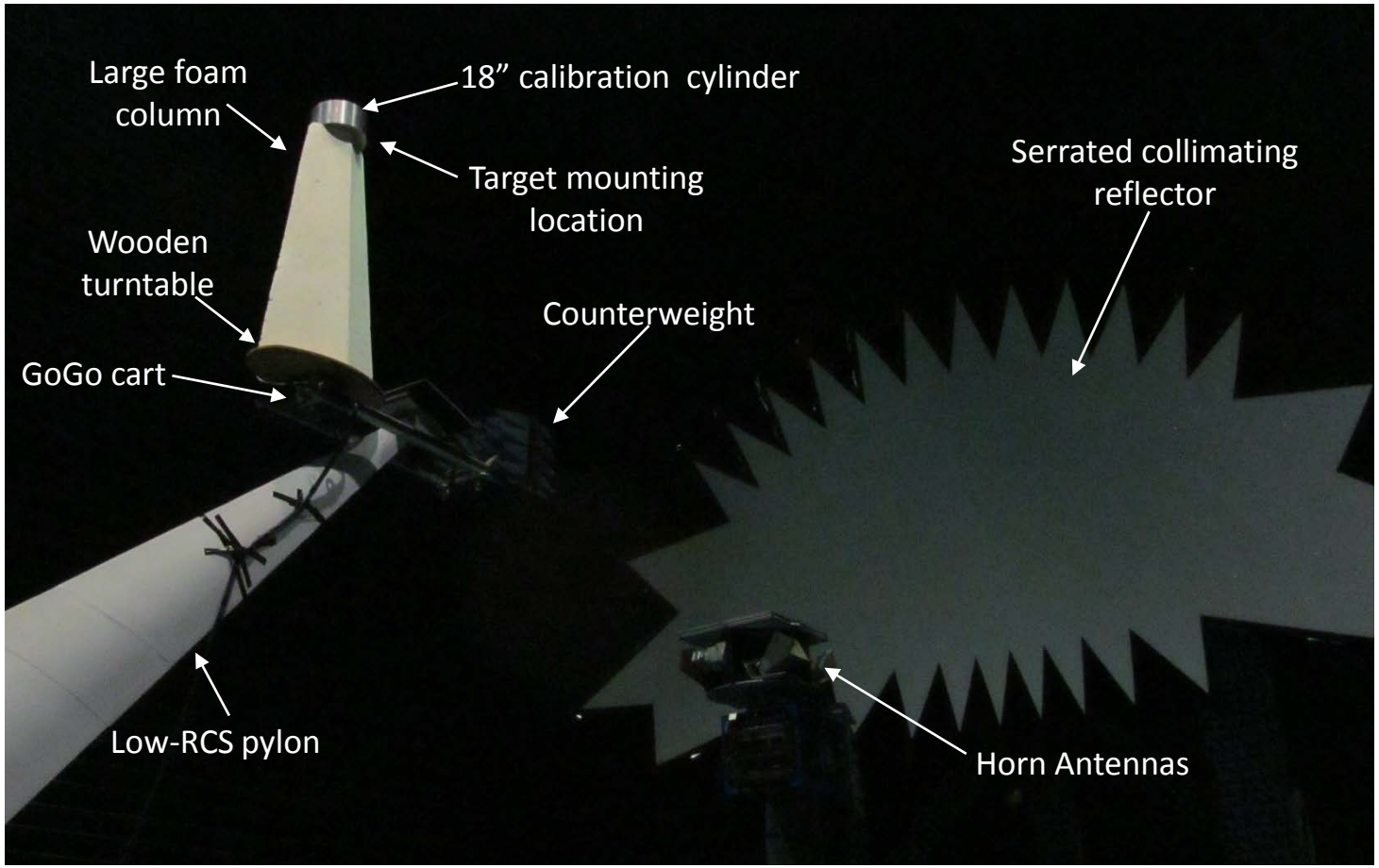
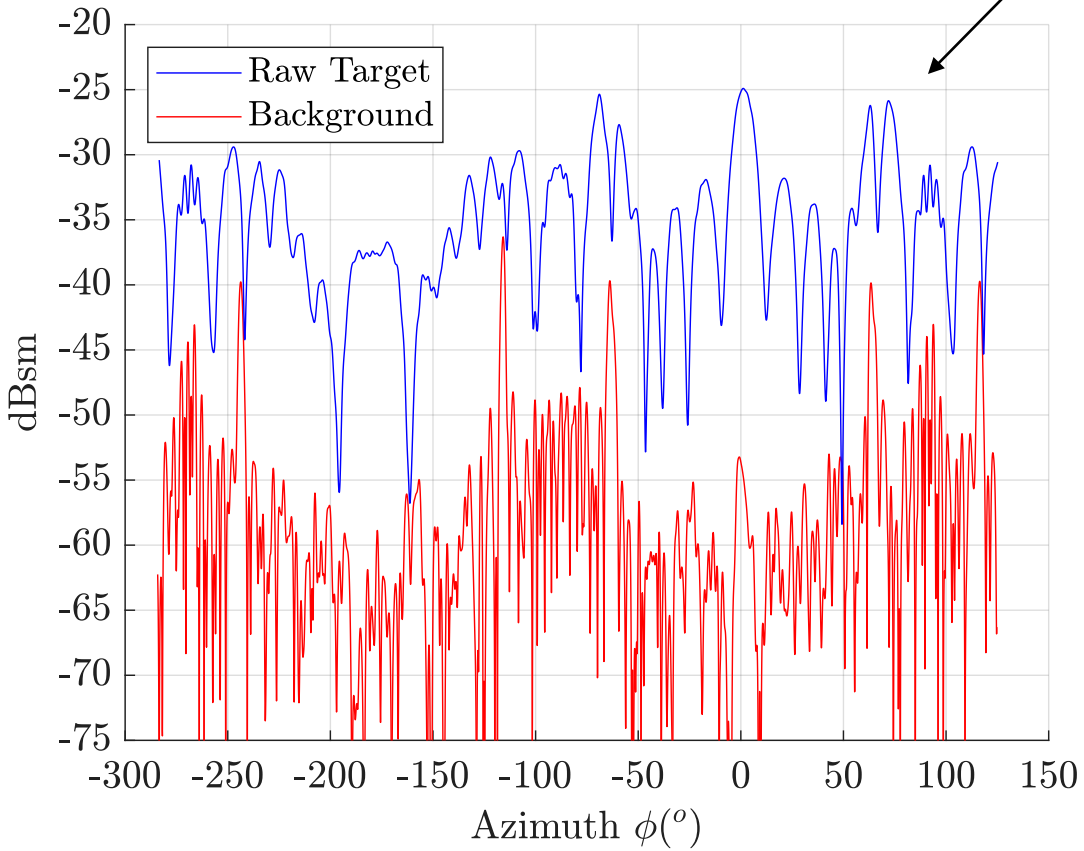
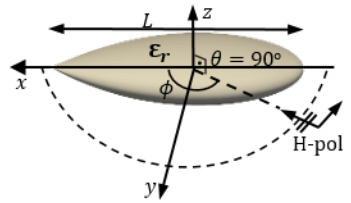


Image from: J. T. Kelley, D. A. Chamulak, C. C. Courtney, and A. E. Yılmaz, “EM programmers notebook-Rye Canyon RCS measurements of benchmark almond targets” in *IEEE Ant. Prop. Soc. Mag.*, 2019.

Measurement Post-Processing

- Measurement Post-Processing
  1. Background Subtraction





$$\sigma^{\text{target}}_{\text{meas,HH}}(f,\phi) = |\mathrm{T}_{\mathrm{HH}}(f)|^2 * \left|V^{\text{raw}}_{\text{meas,HH}}(f,\phi) - V^{\text{background}}_{\text{meas,HH}}(f,\phi)\right|^2 \quad (\mathrm{m}^2)$$

Reference: J. T. Kelley, D. A. Chamulak, C. C. Courtney, and A. E. Yılmaz, "Rye Canyon radar cross-section measurements of benchmark almond targets" *IEEE Ant. Prop. Soc. Mag.*, 2020.

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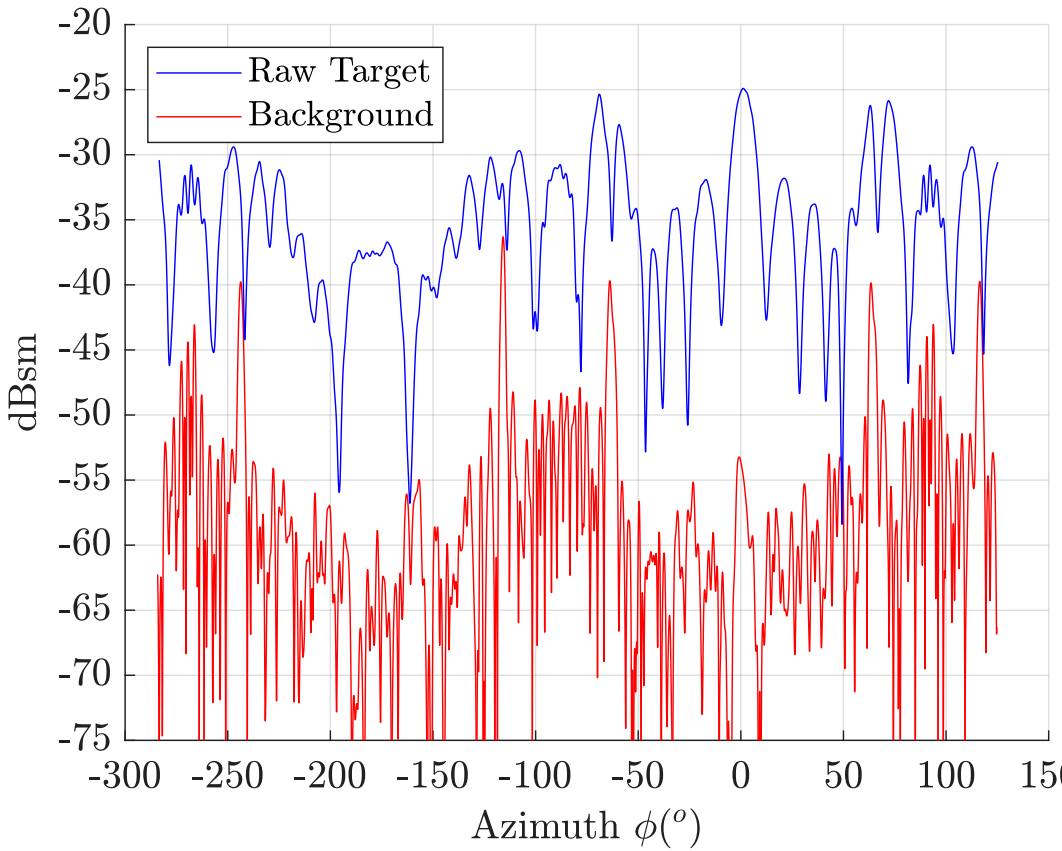

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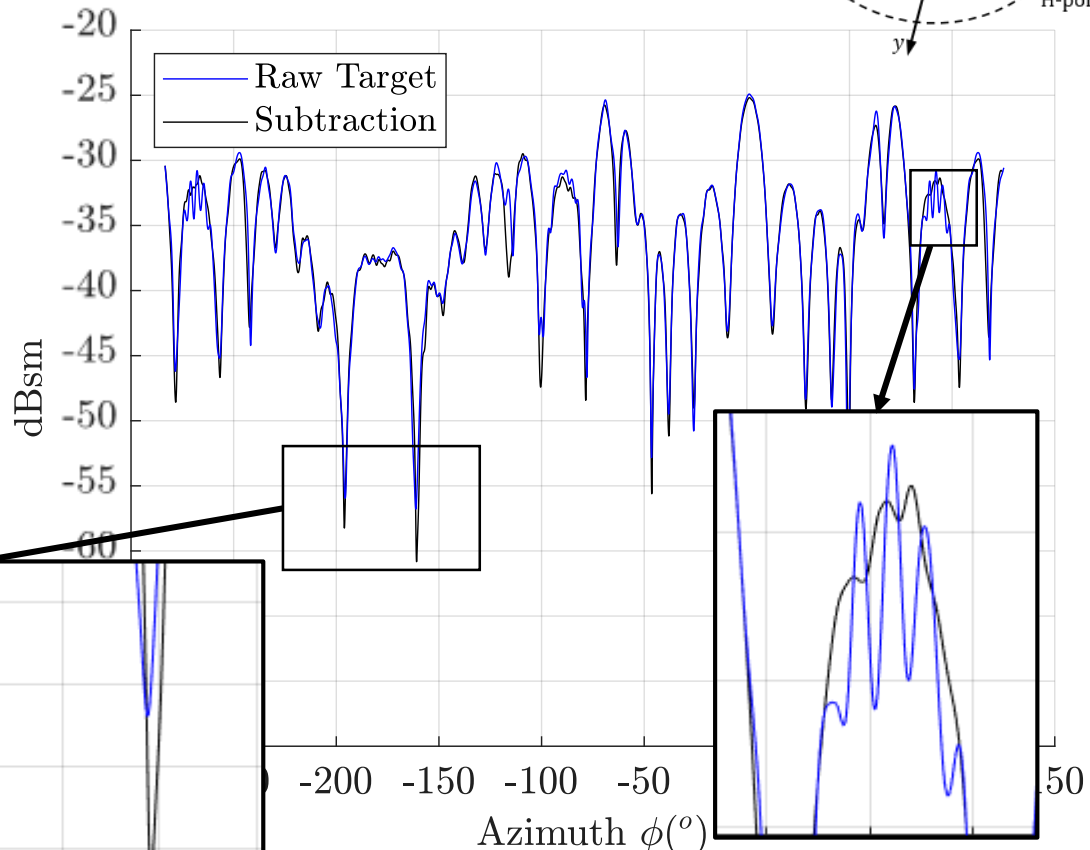
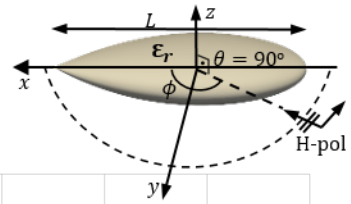
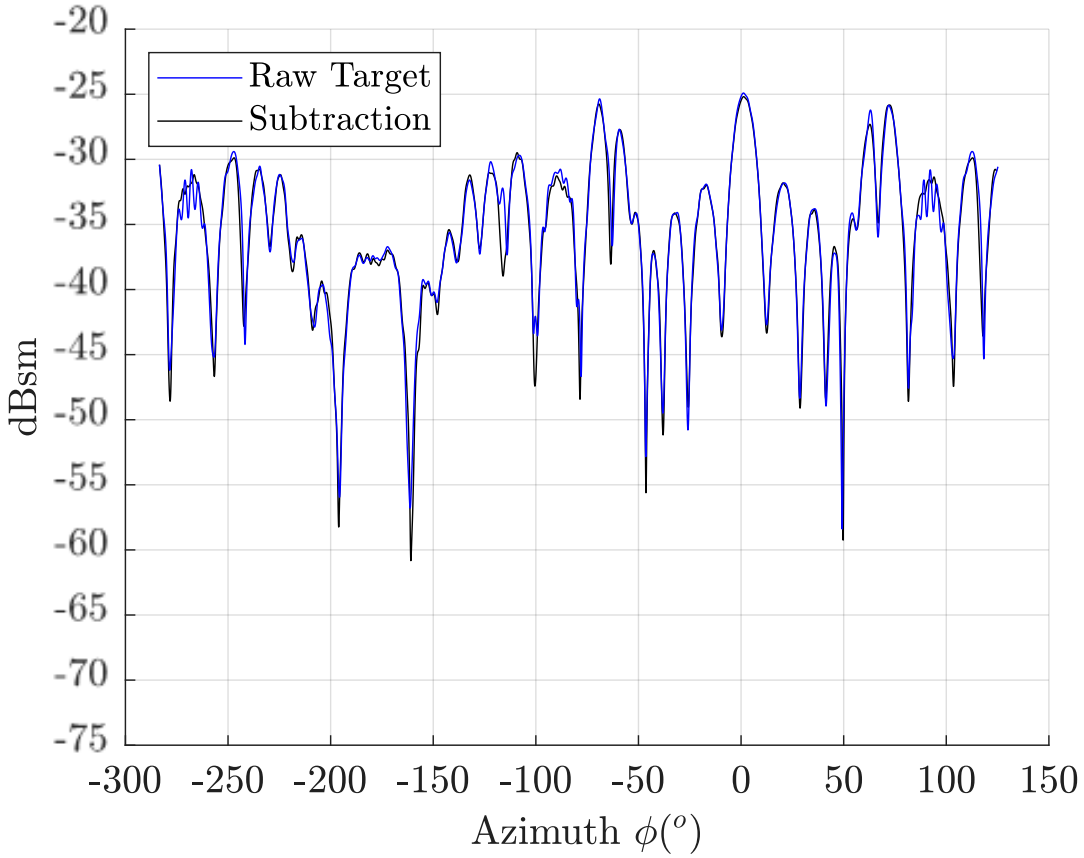
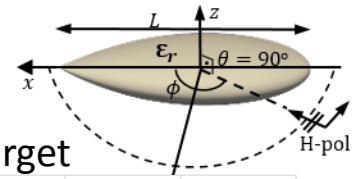




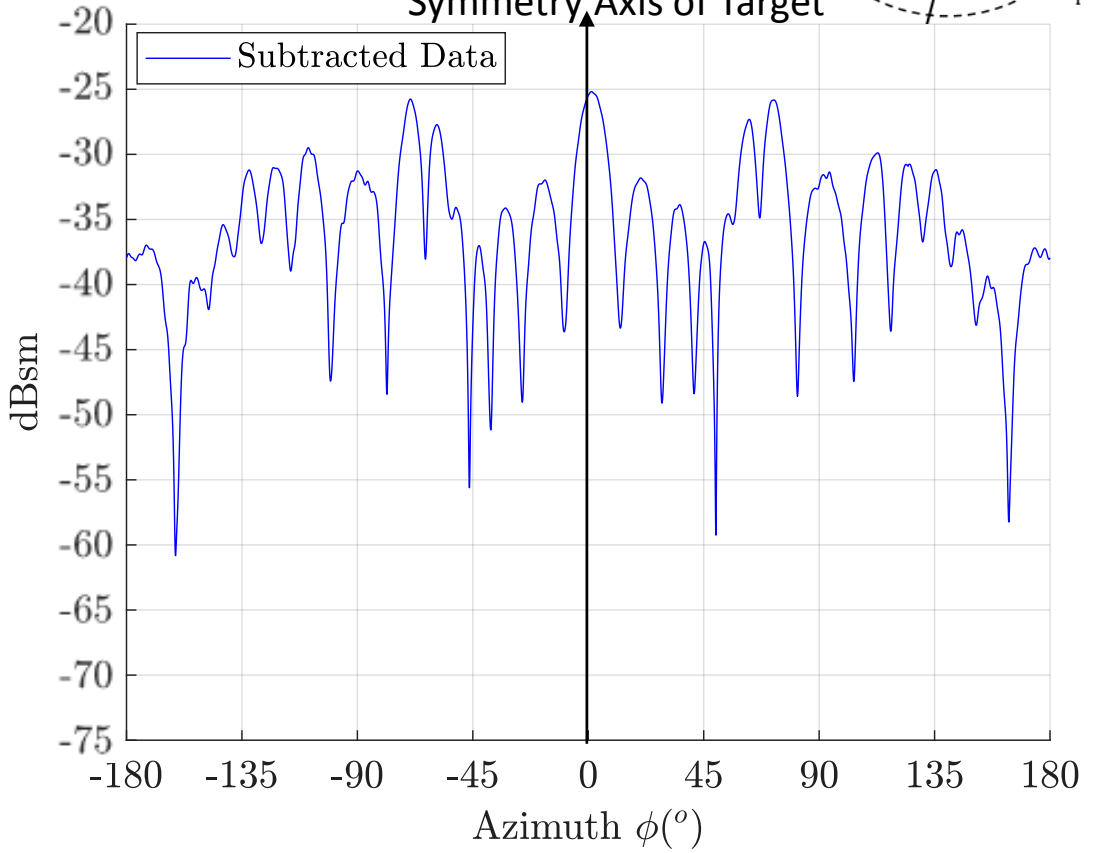
Measurement Post-Processing

- Measurement Post-Processing
  1. Background Subtraction
  2. Symmetry Alignment: Can use the symmetry of the target to reduce measurement uncertainty





Symmetry Axis of Target



Use target symmetry to acquire two theoretically identical RCS measurements ranging from $\phi \in [-180°, 0°]$ and $\phi \in [0°, 180°]$ from the 420° of data acquisition

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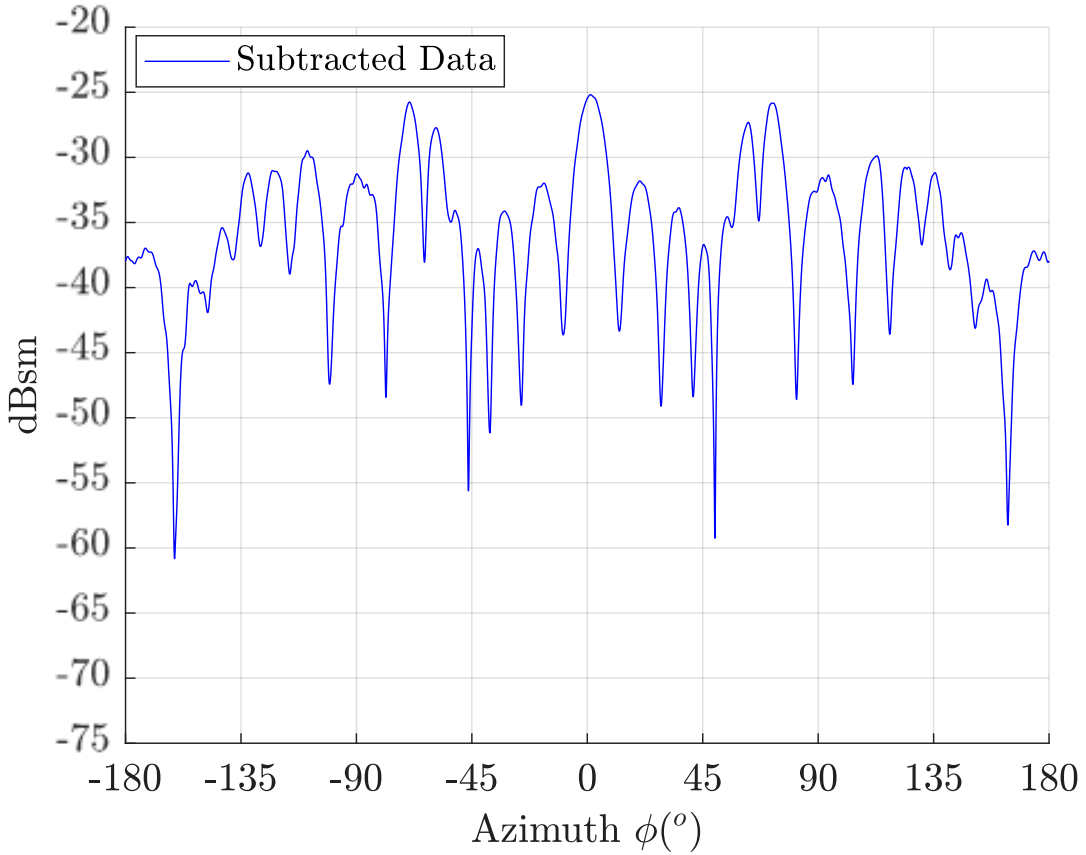

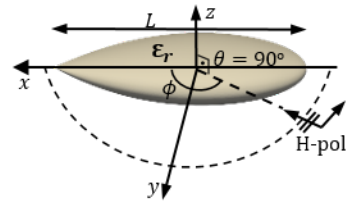

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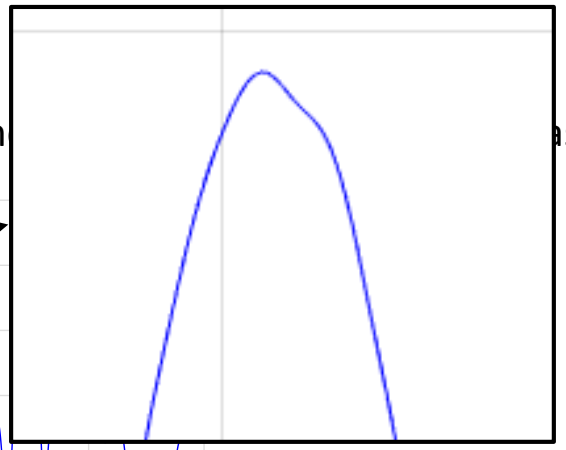

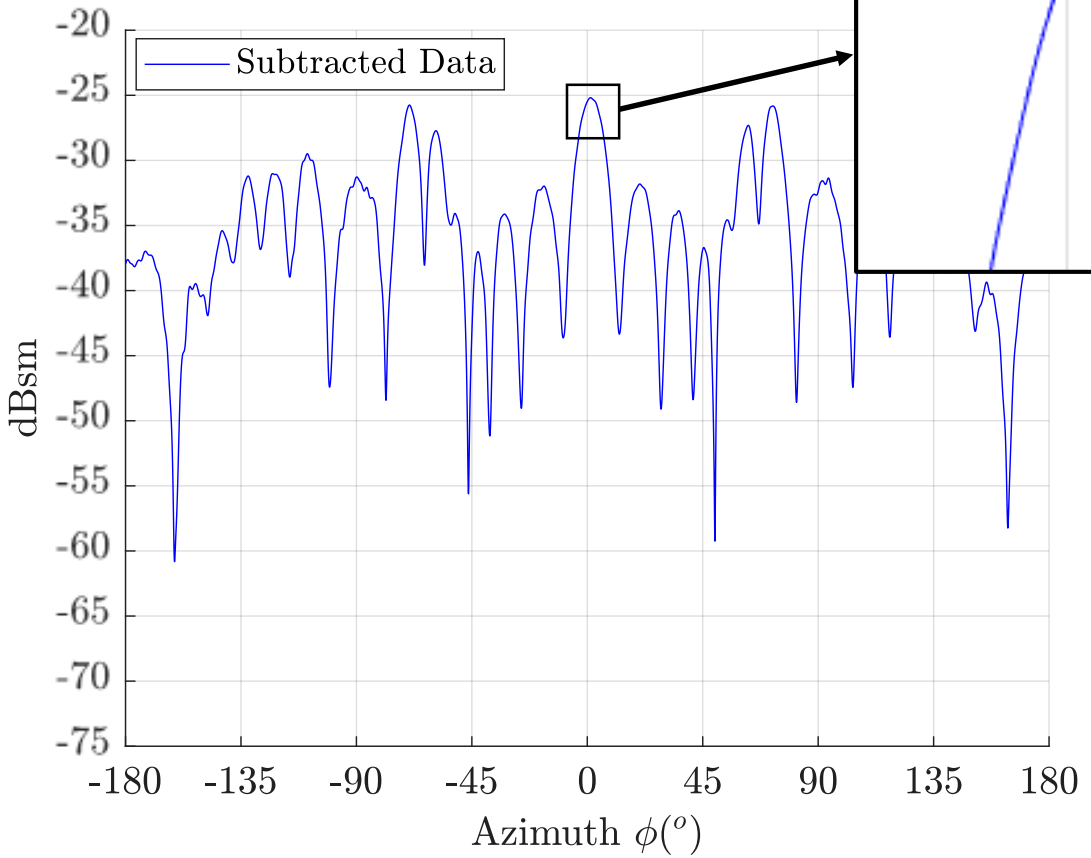

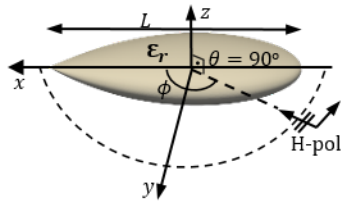

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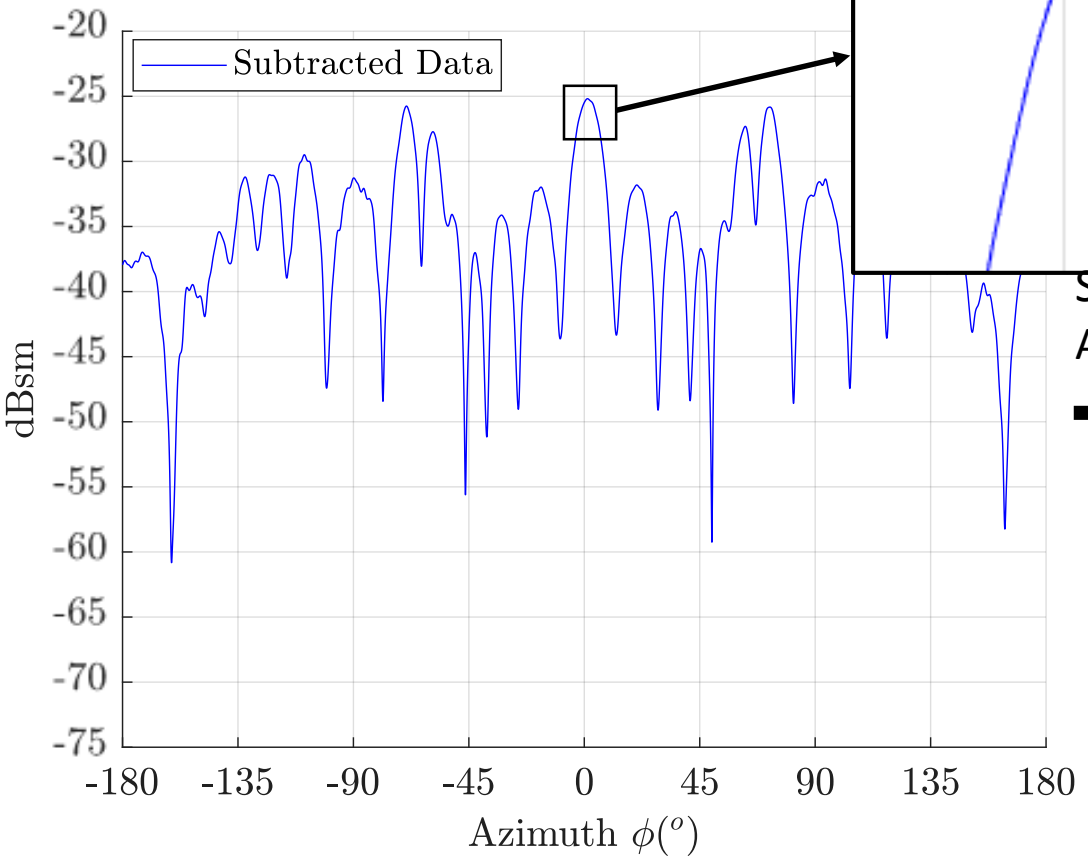
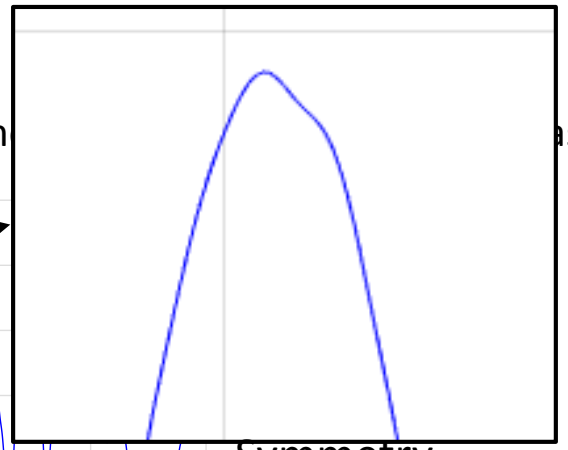
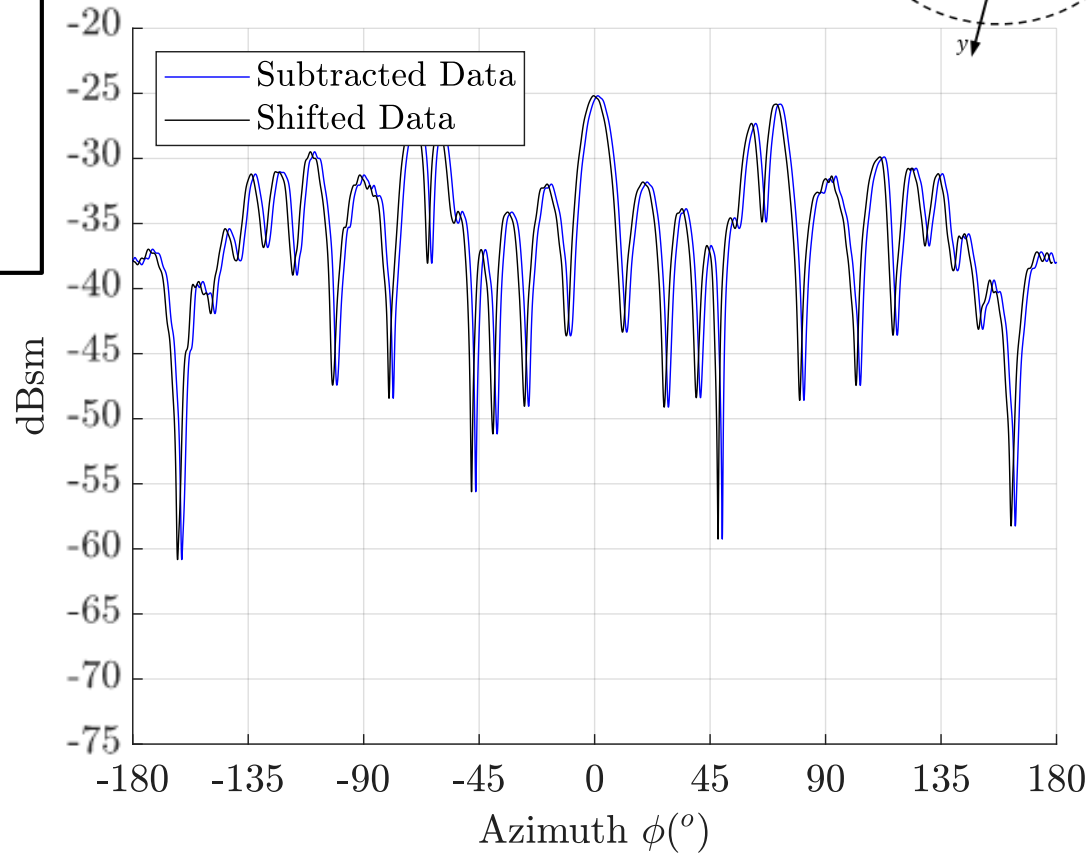
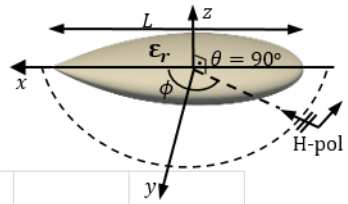




Symmetry Alignment





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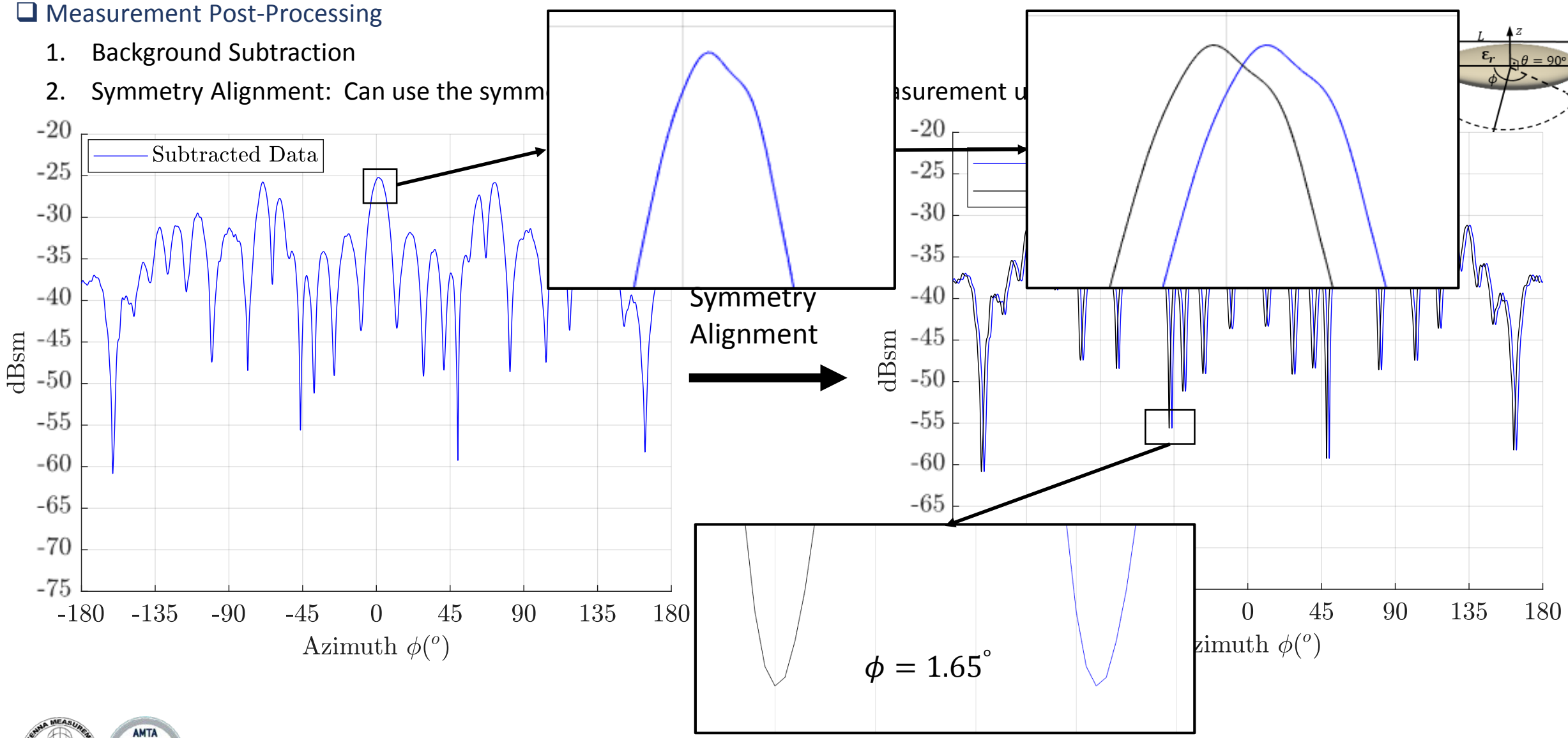

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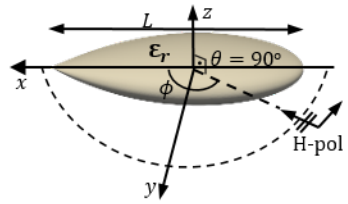
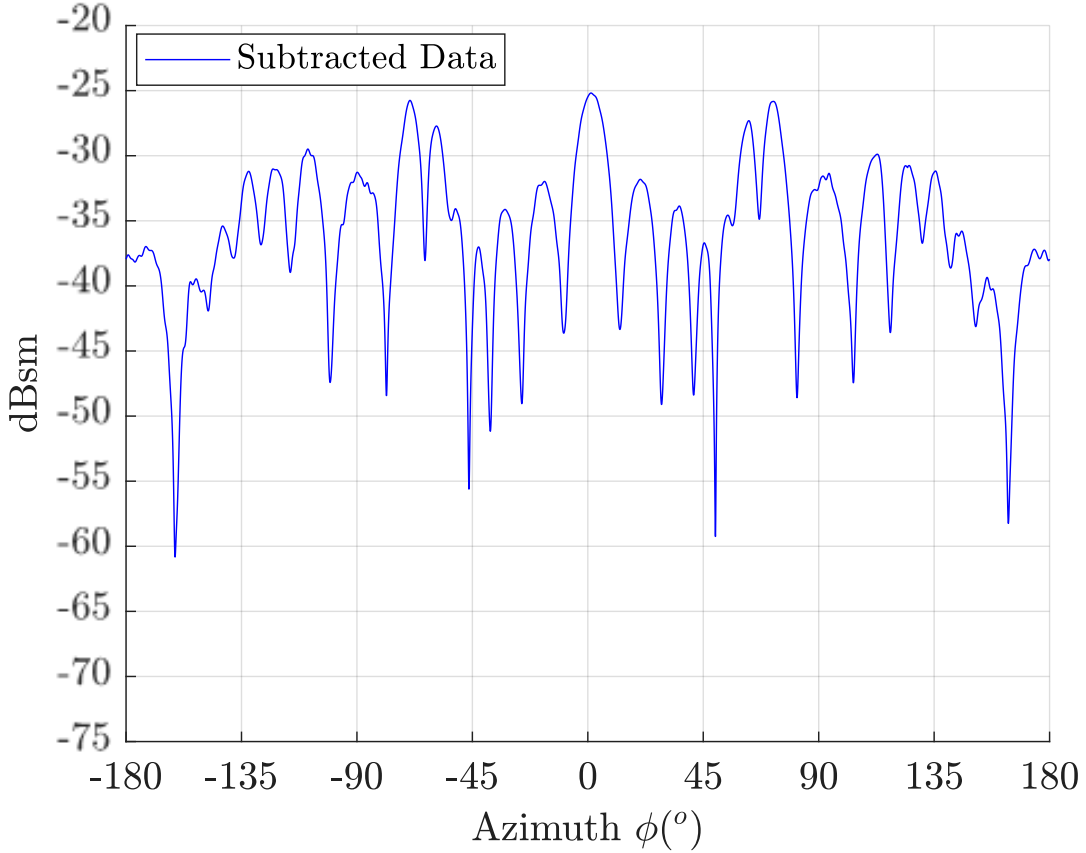
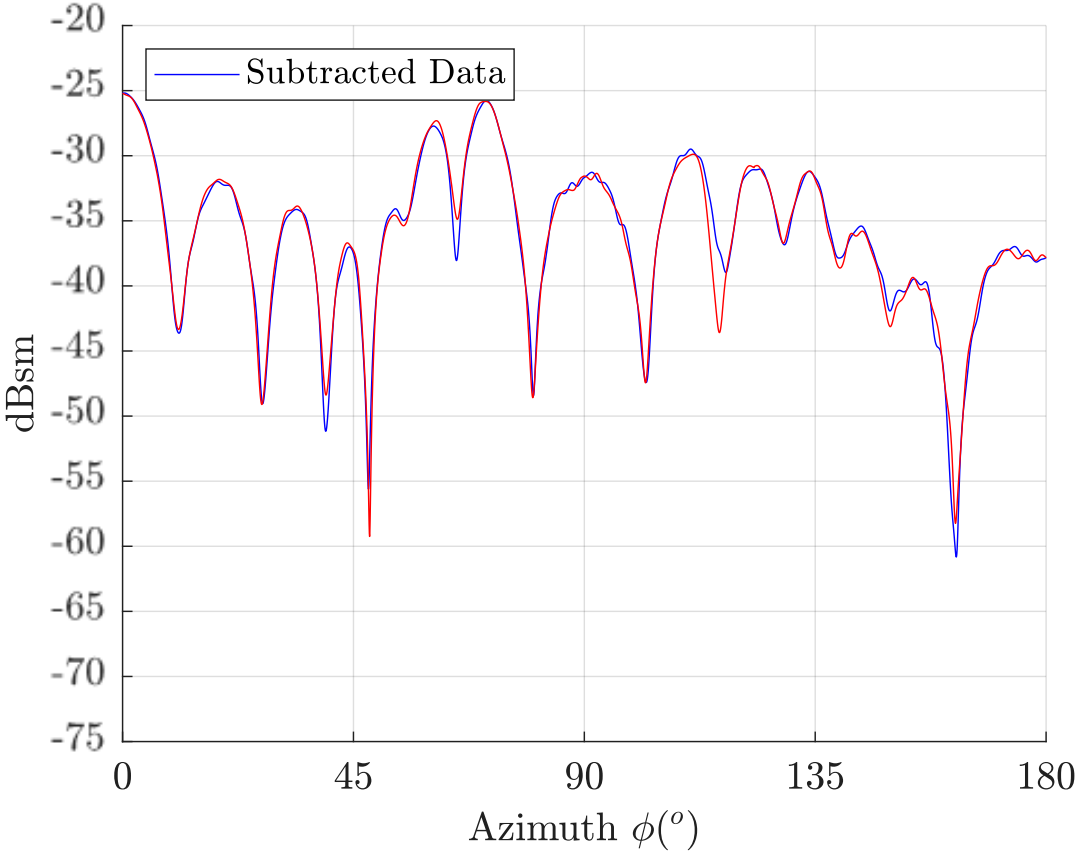
  3. Data Averaging





Two Theoretically Identical Data Sets



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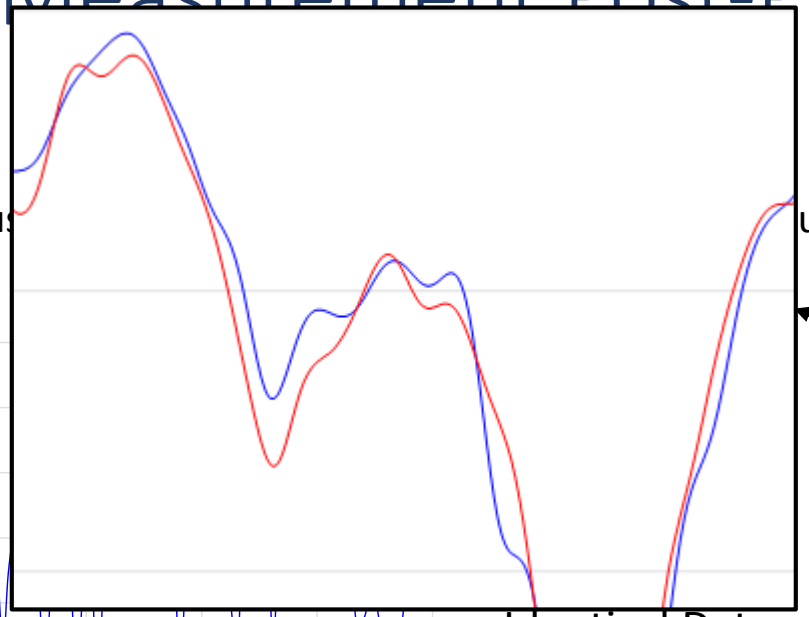
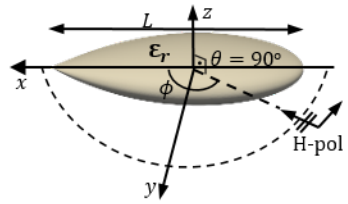
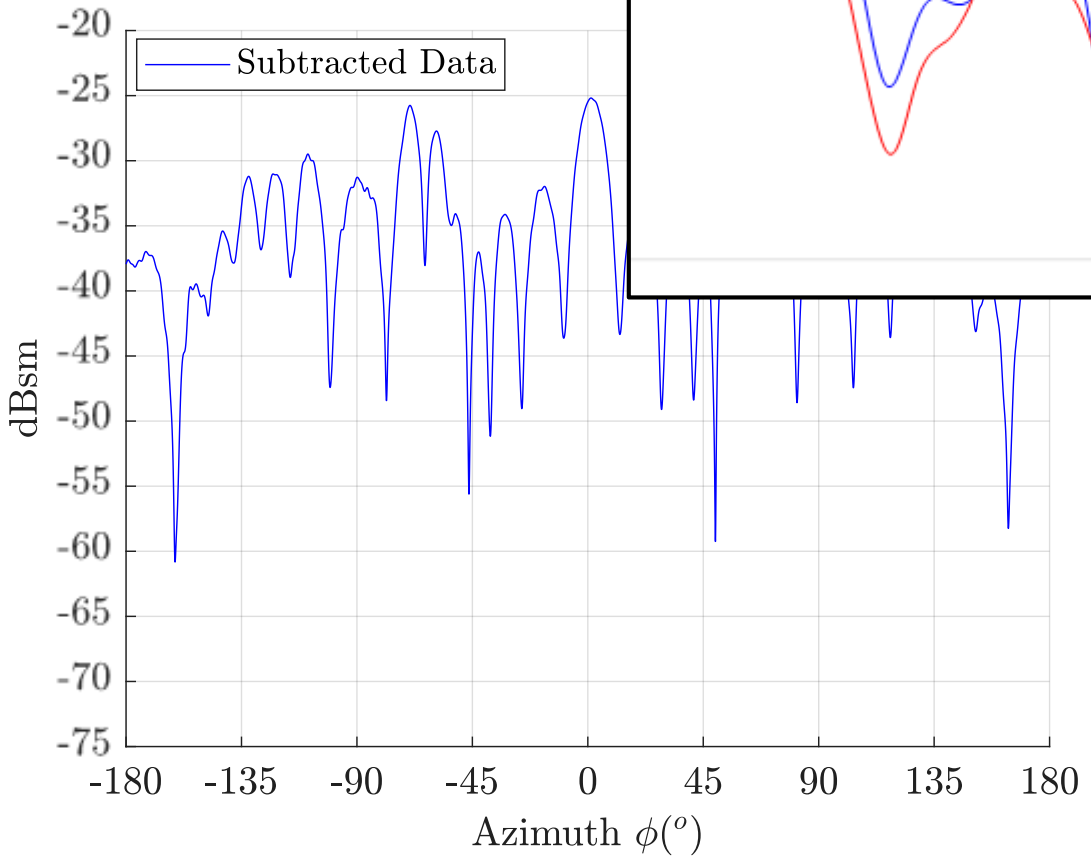
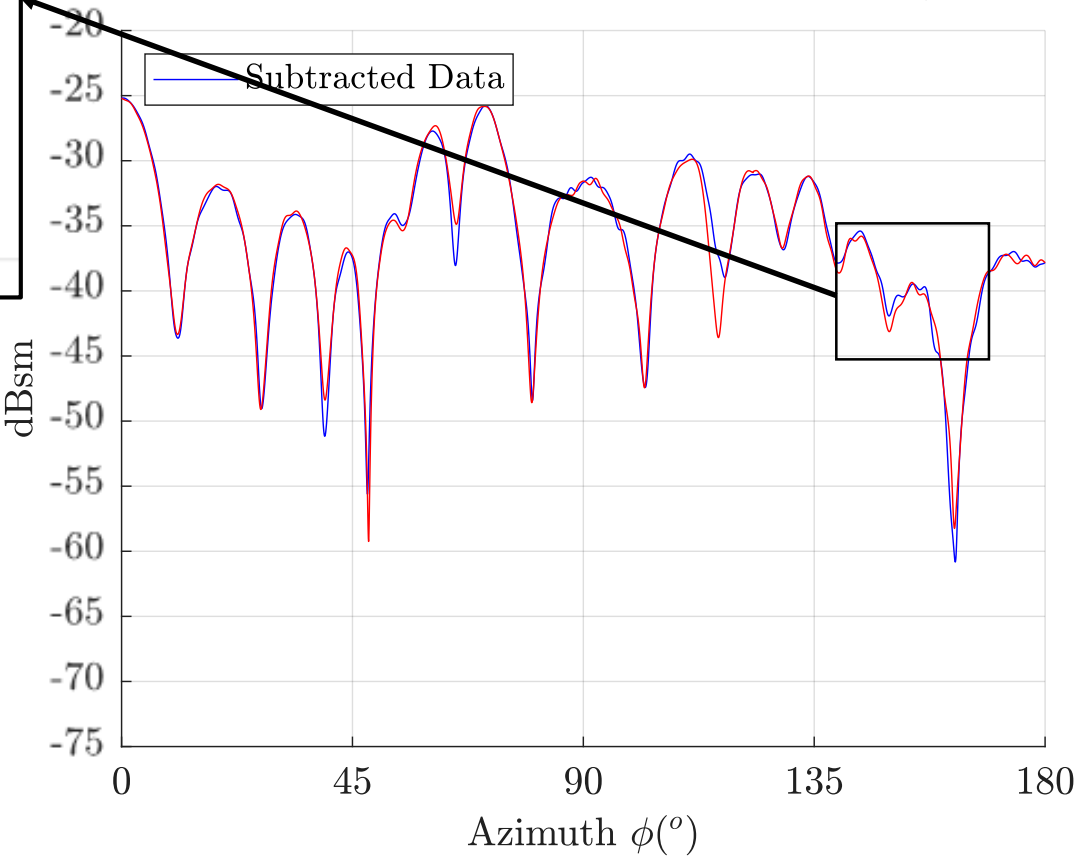






Identical Data Sets



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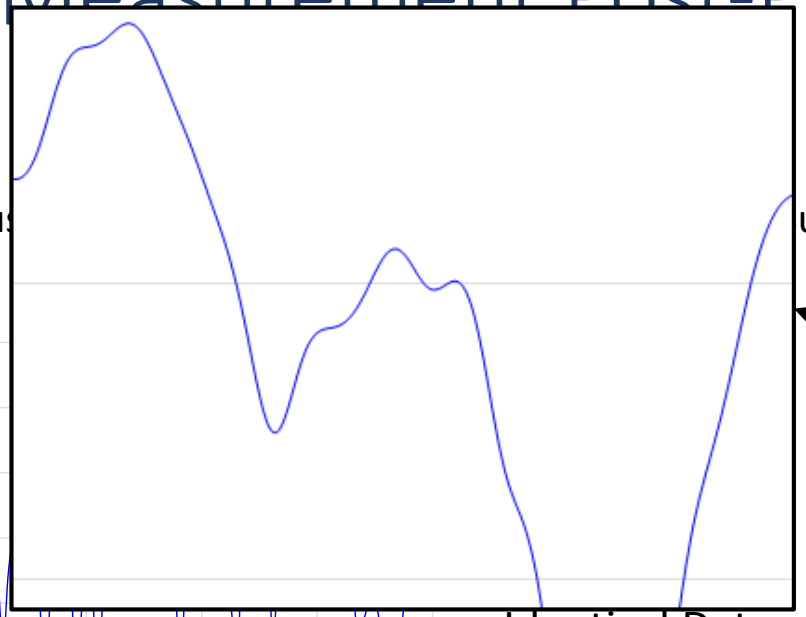
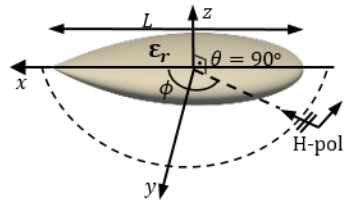
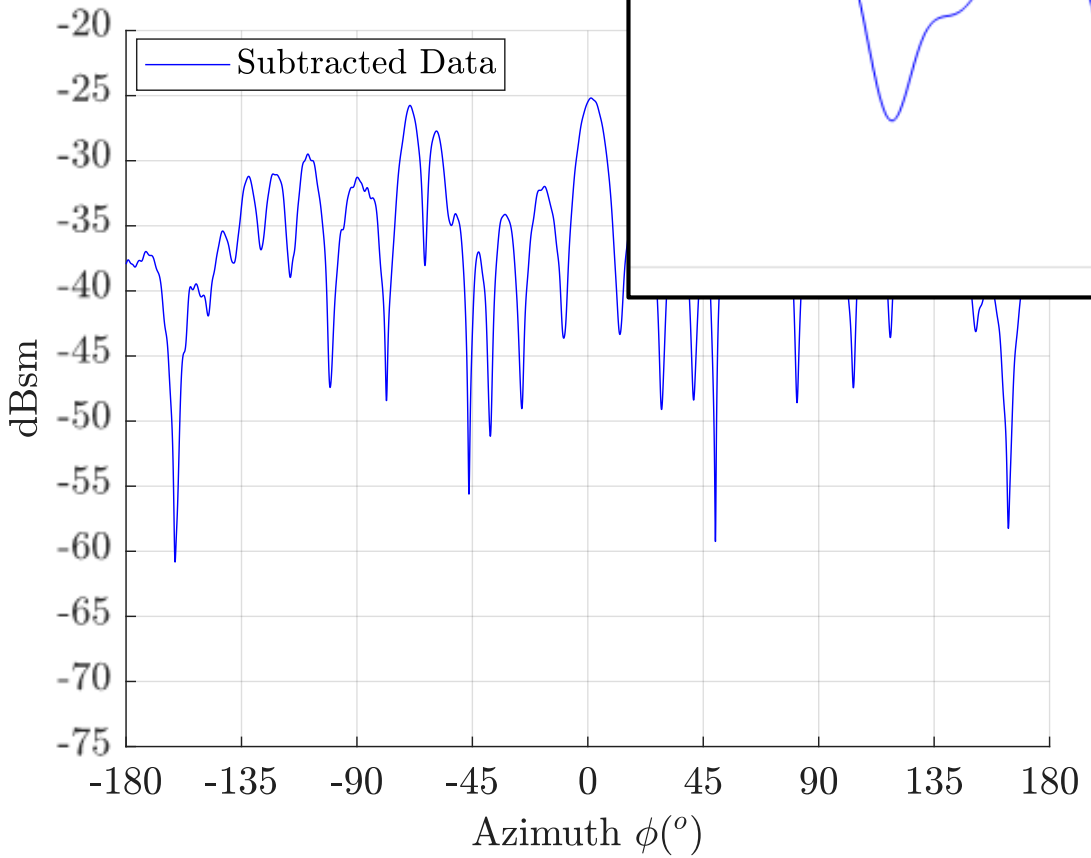
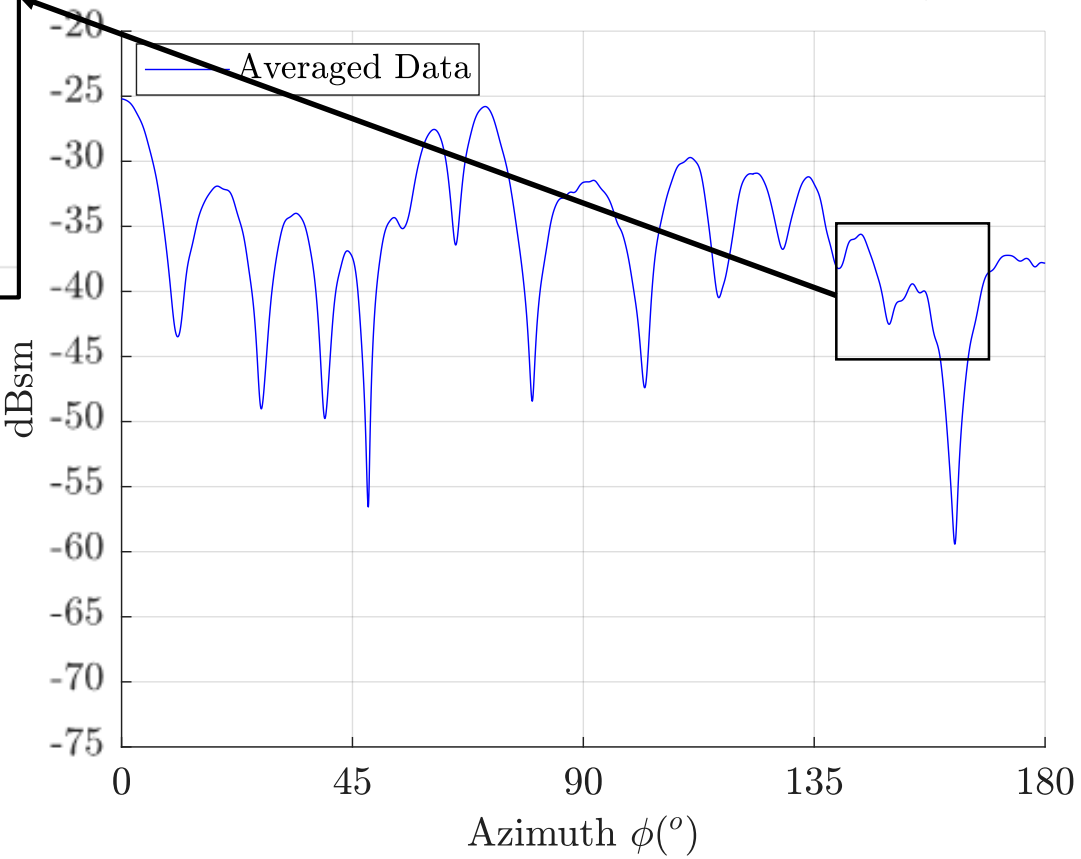




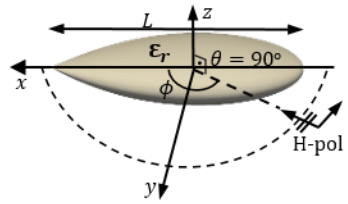


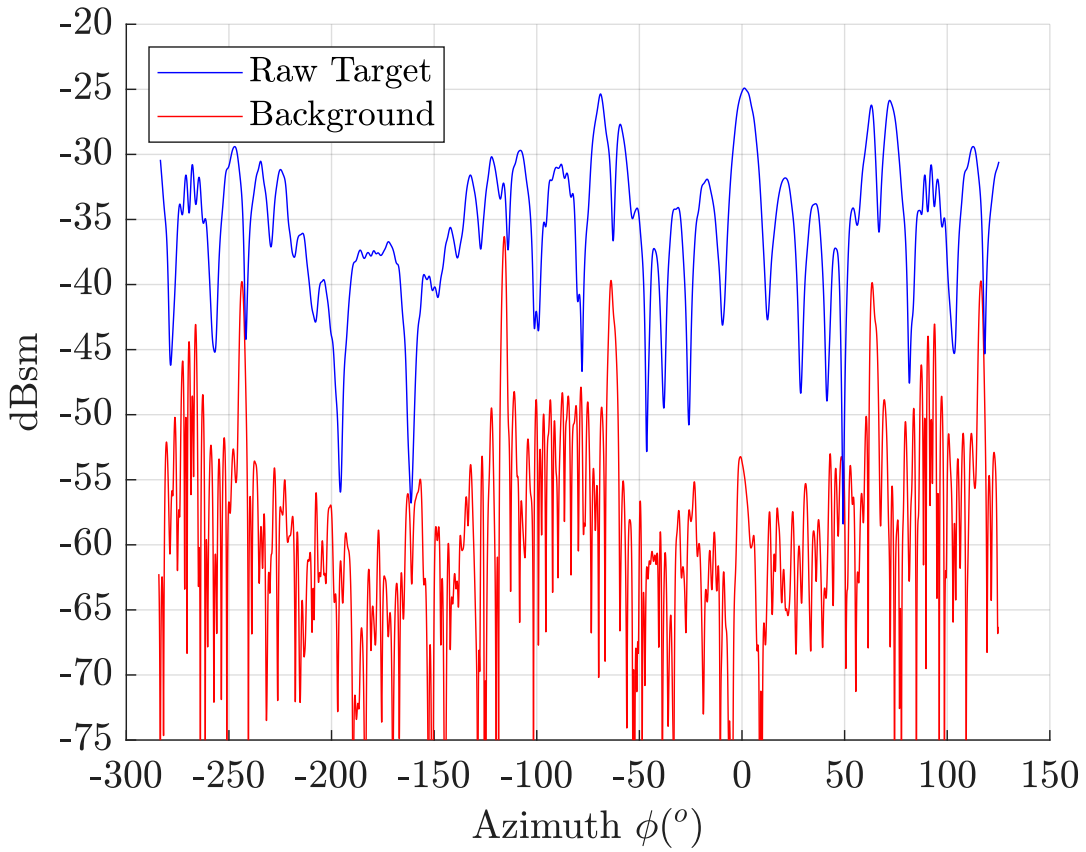
Identical Data Sets



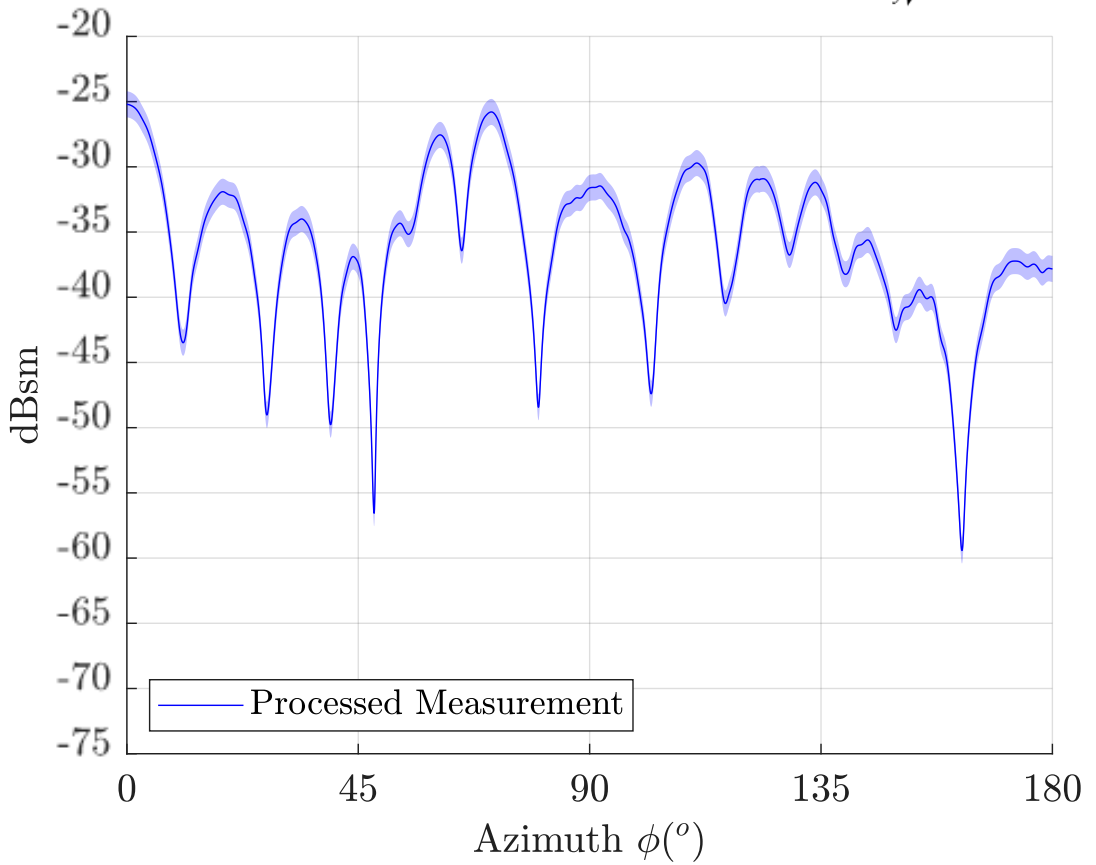
Measurement Post-Processing

- Measurement Post-Processing
  1. Background Subtraction
  2. Symmetry Alignment: Can use the symmetry of the target to reduce measurement uncertainty
  3. Data Averaging





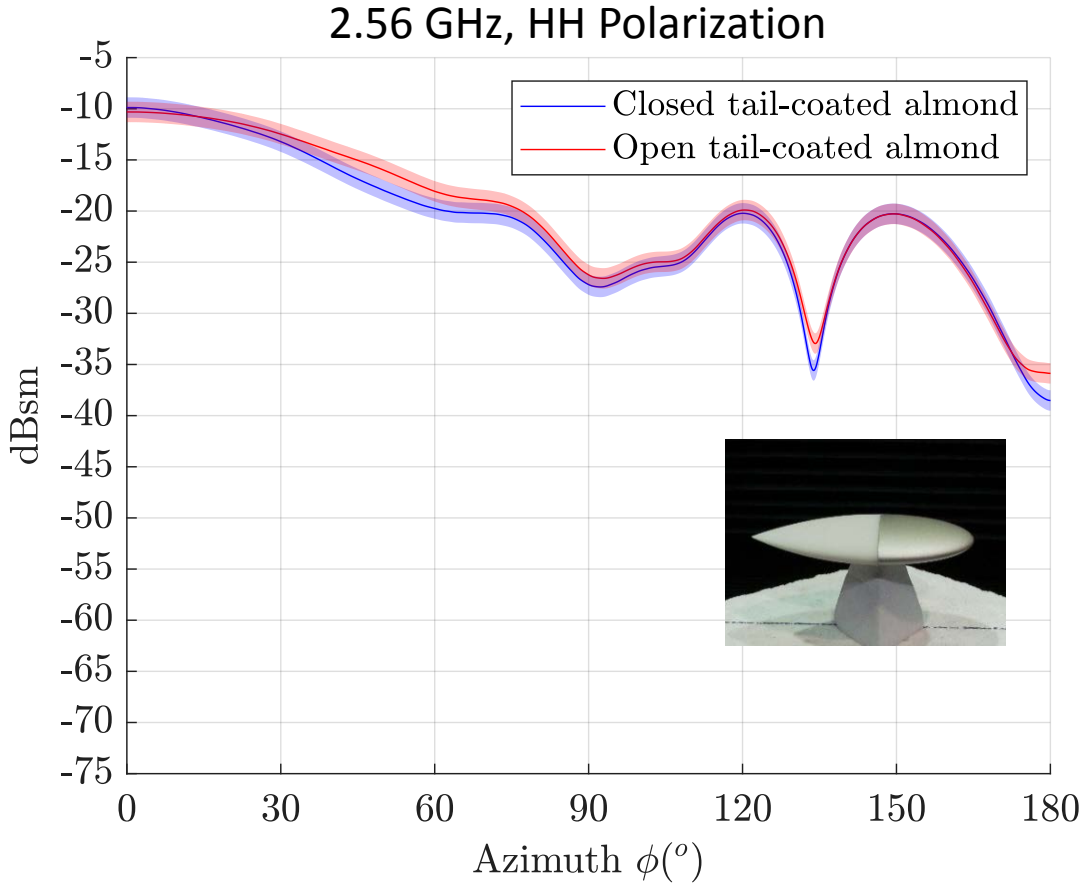
Post-Processing

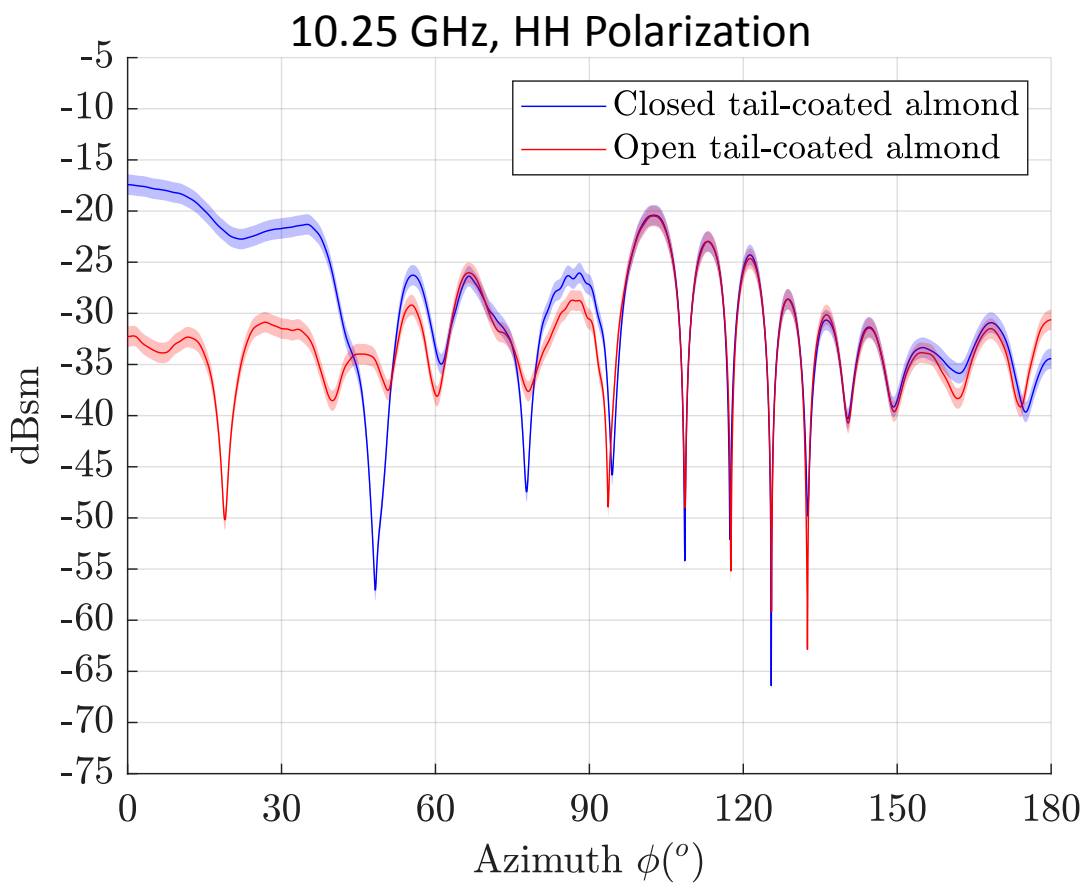


Measurement Post-Processing

❑ Measurement Post-Processing

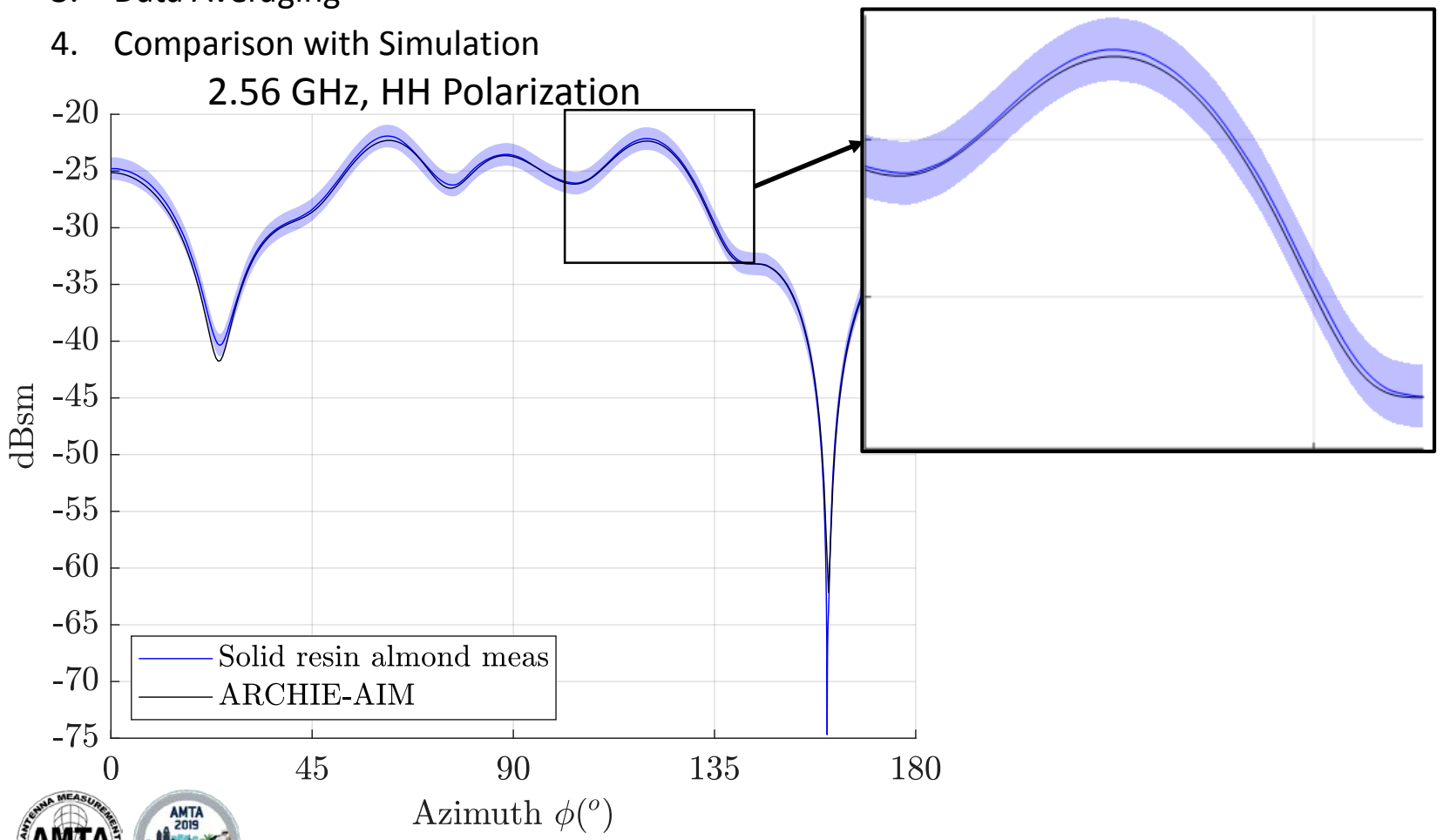
- Applied same post-processing scheme to the other targets

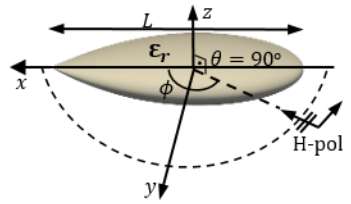




Measurement Post-Processing

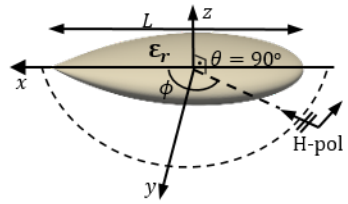
- Measurement Post-Processing
  1. Background Subtraction
  2. Symmetry Alignment: Can use the symmetry of the target to reduce measurement uncertainty
  3. Data Averaging
  4. Comparison with Simulation

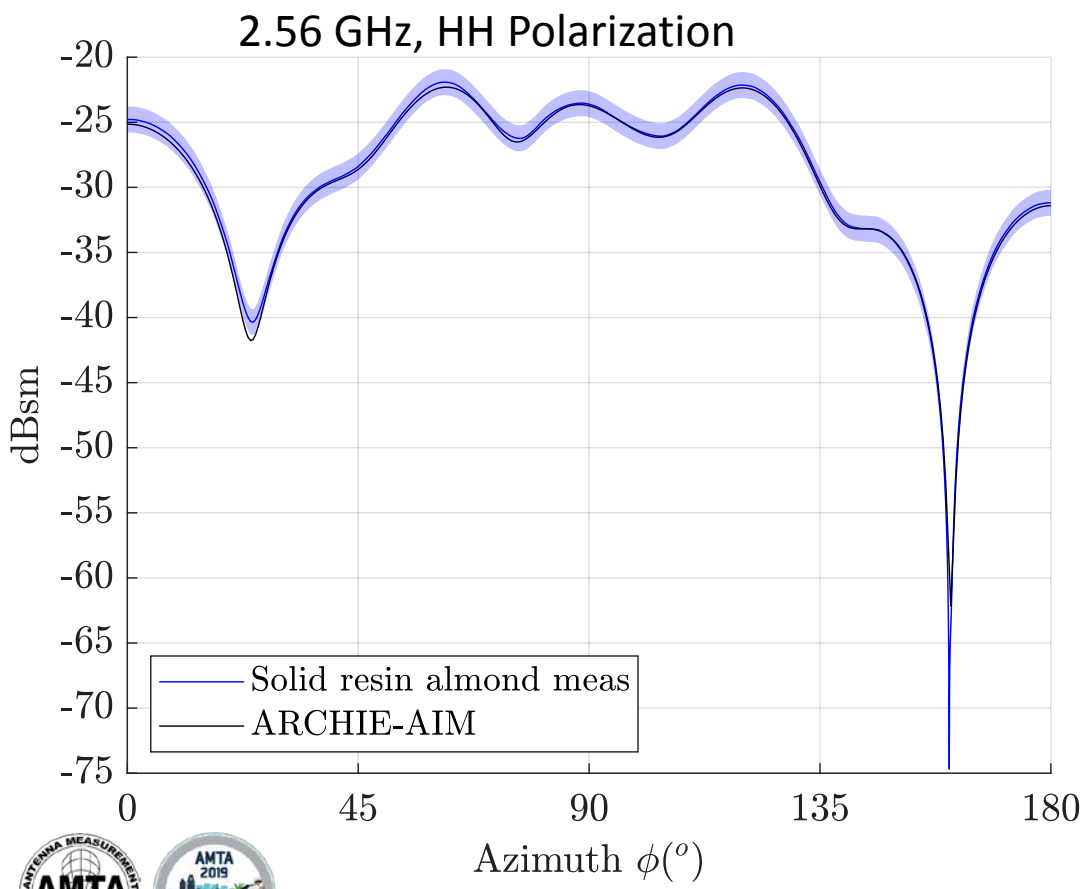


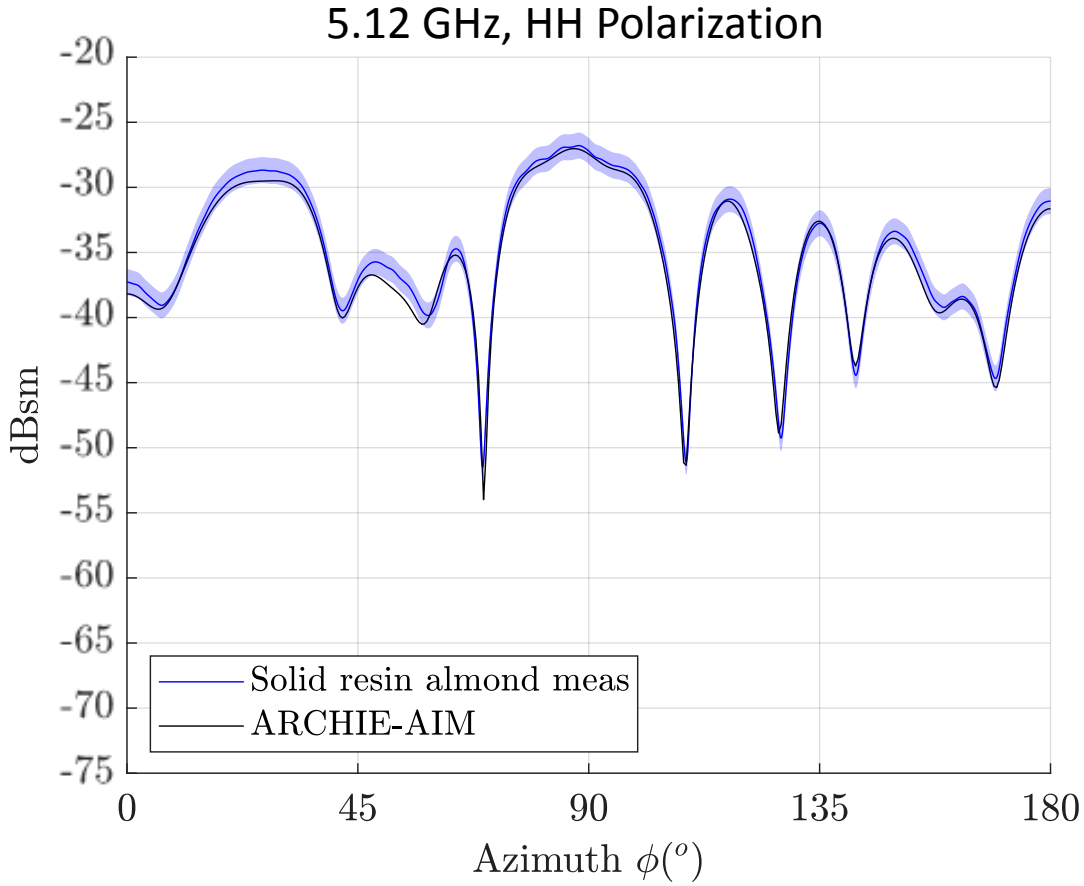


Measurement Post-Processing

- Measurement Post-Processing
  1. Background Subtraction
  2. Symmetry Alignment: Can use the symmetry of the target to reduce measurement uncertainty
  3. Data Averaging
  4. Comparison with Simulation

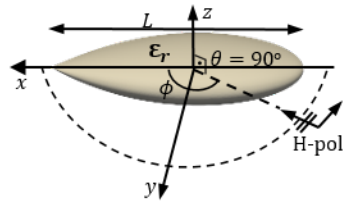


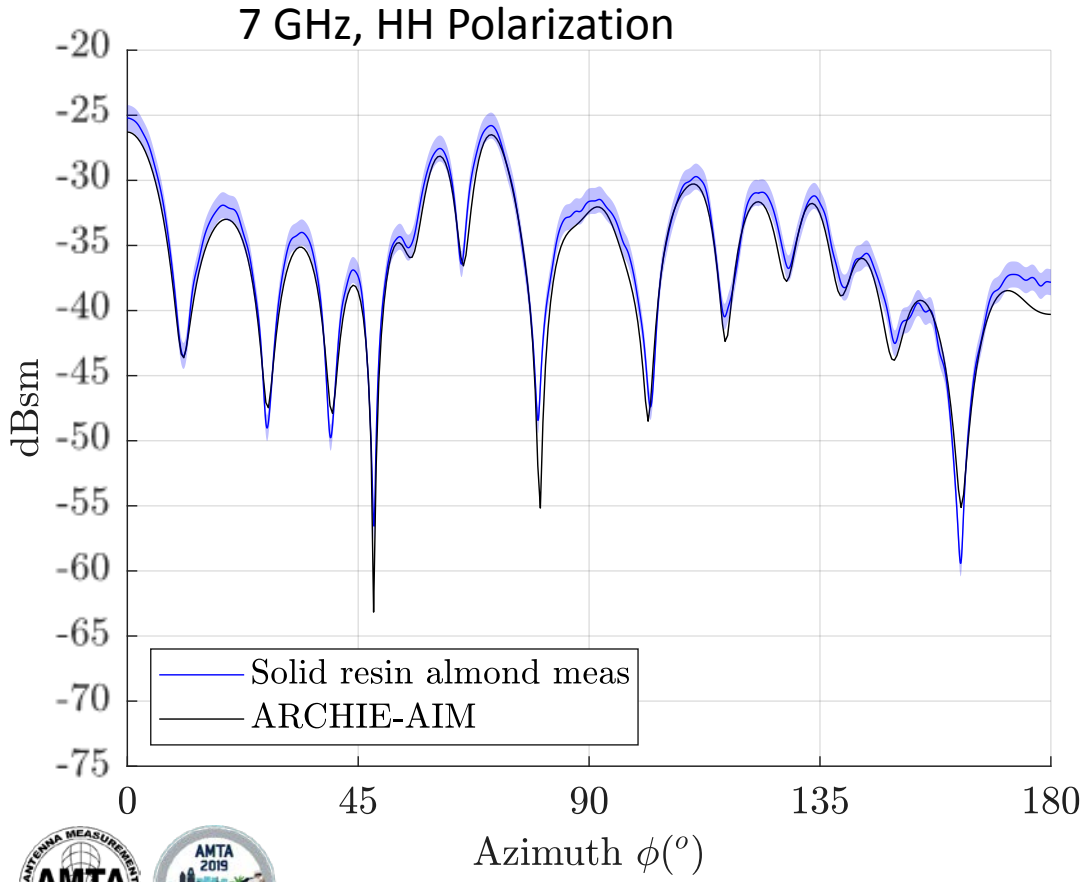


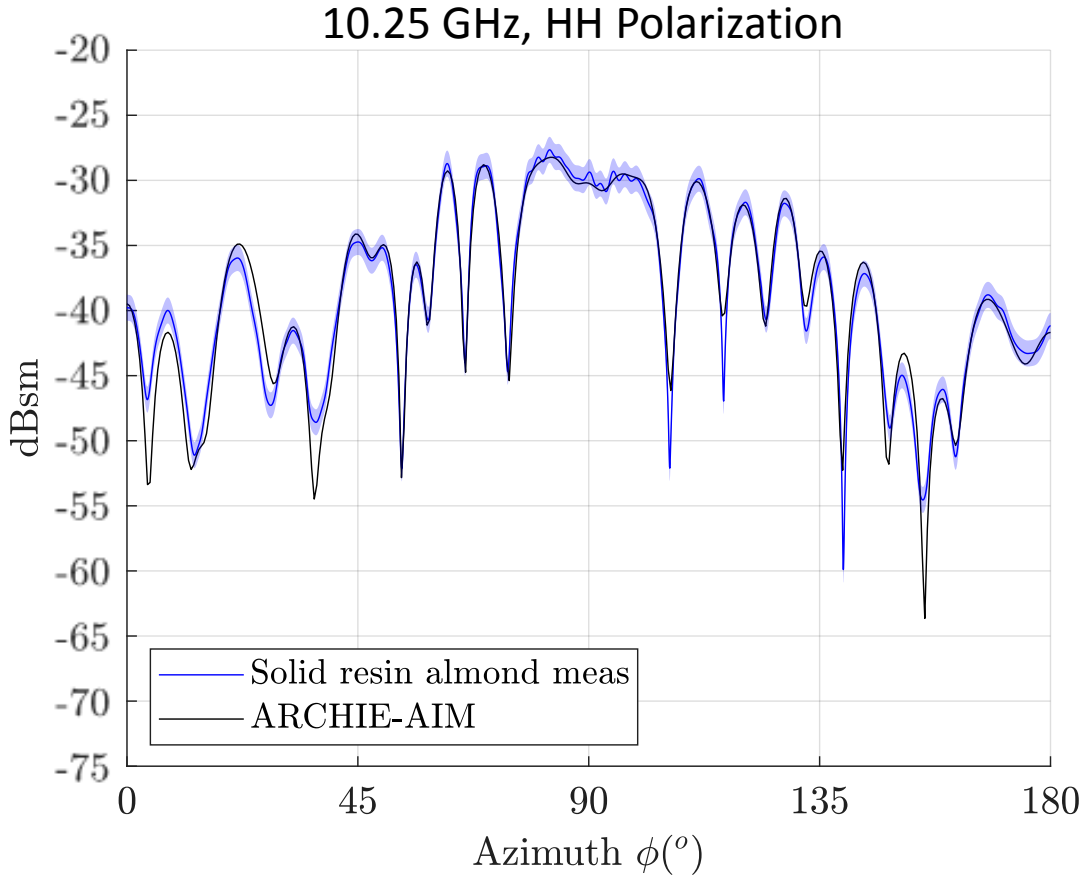


Measurement Post-Processing

- Measurement Post-Processing
  1. Background Subtraction
  2. Symmetry Alignment: Can use the symmetry of the target to reduce measurement uncertainty
  3. Data Averaging
  4. Comparison with Simulation







Conclusion

- CEM R&D needs modern benchmarks and benchmarking
  - Empirical results make theoretical science better
  - Benchmark suites encourage and support R & D
- Austin RCS Benchmark Suite
  - Publicly available
  - Being populated with problems spanning difficulty levels
  - Contains reference solutions—including new measurement data
- Next generation benchmarking requires next generation measurement precision
- Acknowledgments:

Branch: master ▾ AustinCEMBenchmarks / Austin-RCS-Benchmarks / Create new file Upload files Find file History

UTAustinCEMGroup Updated reference data Latest commit 7d6667d 6 days ago

Problem I-Spheres	Updated reference data	6 days ago
Problem II-Plates	Updated reference data	6 days ago
Problem III-Almonds	Updated reference data	6 days ago
HowToParticipate.md	Populating placeholder messages	last year
LICENSE.txt	no message	last year
PerformanceMeasures.md	Populating placeholder messages	last year
QuantitiesofInterest.md	Populating placeholder messages	last year
README.md	Update README.md	last year
References.md	Populating placeholder messages	last year
Simulator1Description.md	Populating placeholder messages	last year
URSI2018presentation.pdf	Add files via upload	last year