

A Study on Bistatic RCS Simulations, Measurements and Calibration



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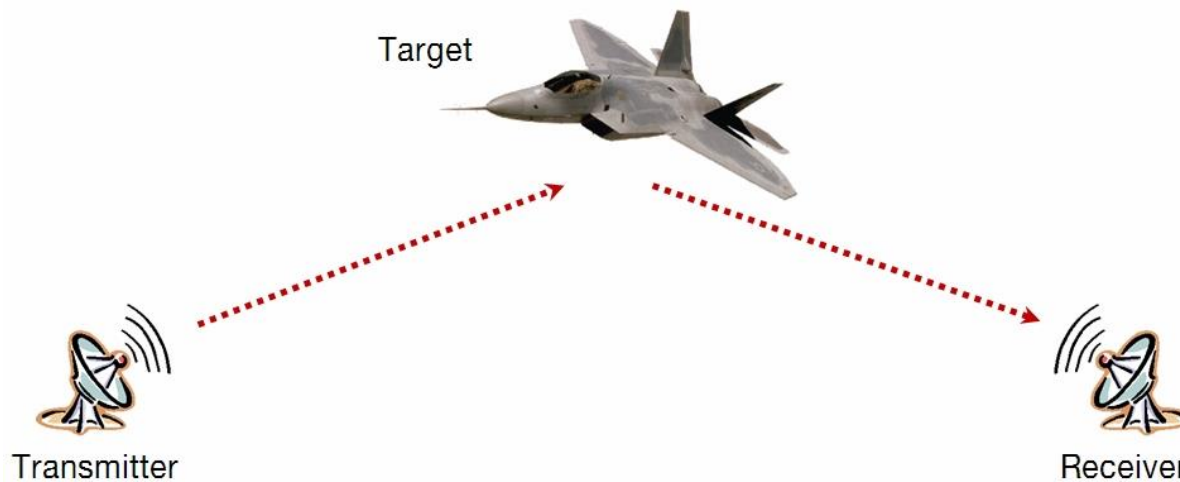


A Study on Bistatic RCS Simulations, Measurements and Calibration

- University of Pretoria – Department of Electromagnetism
 - Supervisor: Prof J.W. Odendaal
 - Co-supervisor: Prof J. Joubert

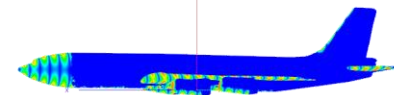
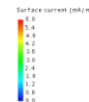
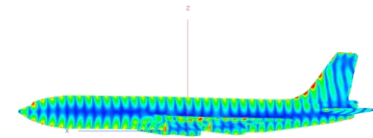
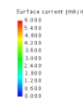
Introduction

- Bistatic RCS
 - Improve detection, characterisation and identification
 - Enhance target information
 - Stealthy targets
 - Low monostatic return
 - » Shaping
 - Larger bistatic scattering



Introduction

- Characterisation measurements can be impractical:
 - High cost
 - Logistics
 - Time constrains
- Simulations are convenient to calculate RCS of targets (CEM)
 - Accurate
 - Efficient



Scope

Bistatic RCS Simulations

- **Asymptotic methods**
 - Geometrical Optics (GO)
 - Physical Optics (PO)
- **Accuracy & efficiency**
 - Complex electrically large targets

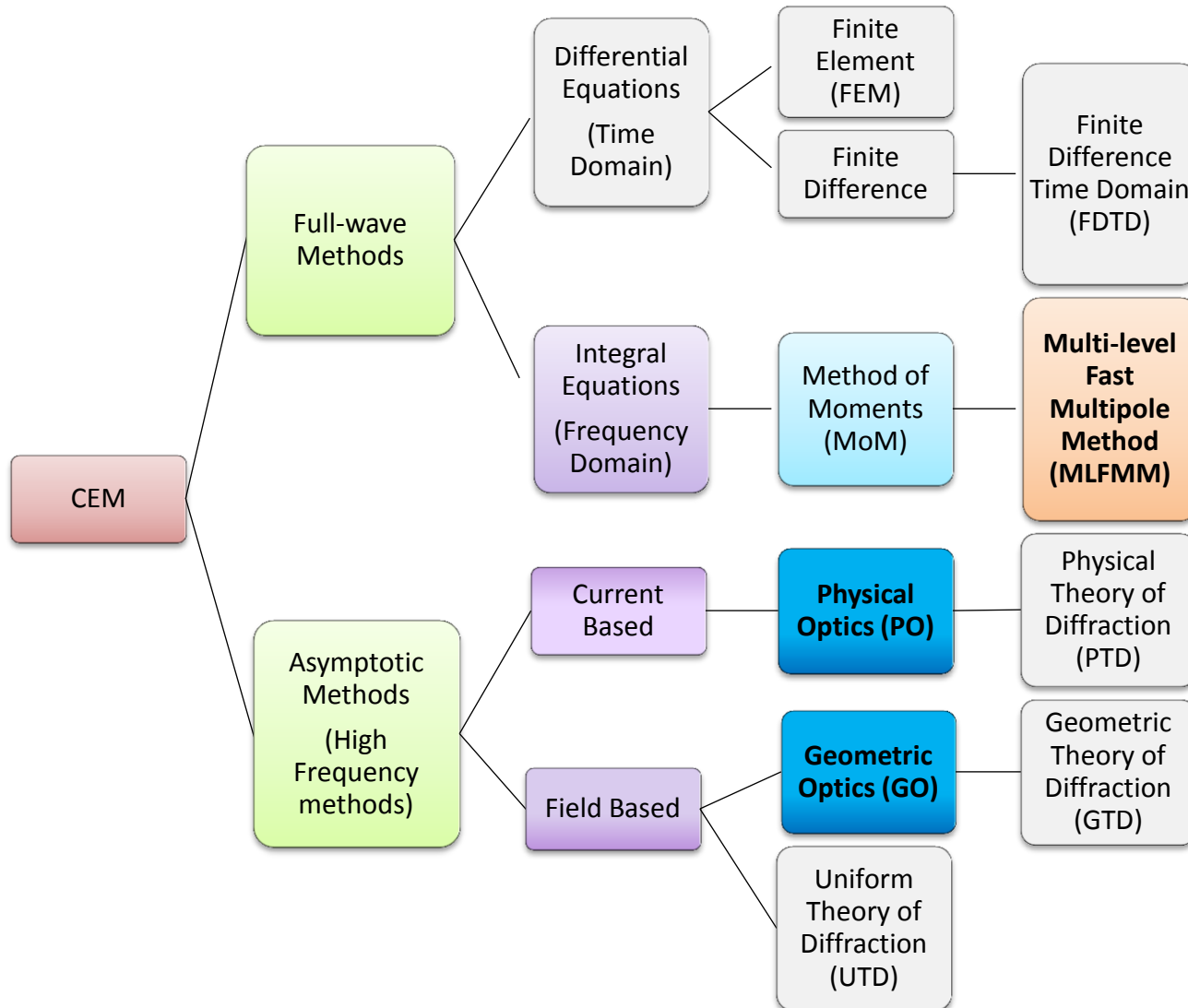
Bistatic RCS Measurements

- Used for validation of CEM methods
- Compact Range at University of Pretoria was configured for bistatic RCS measurements

Bistatic RCS Calibration

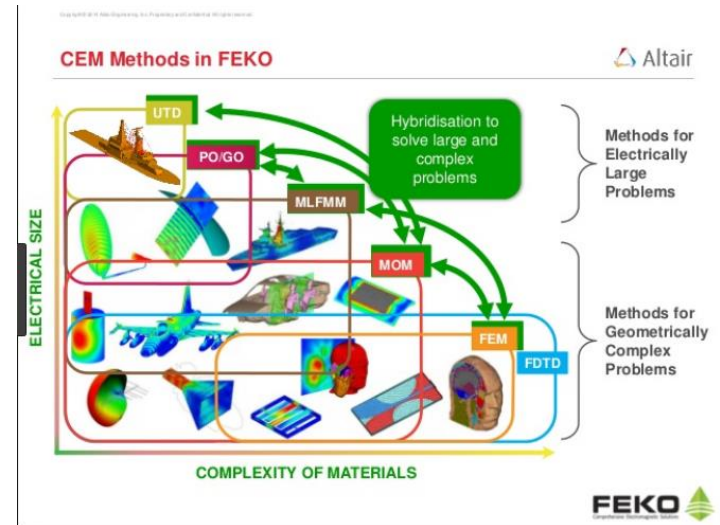
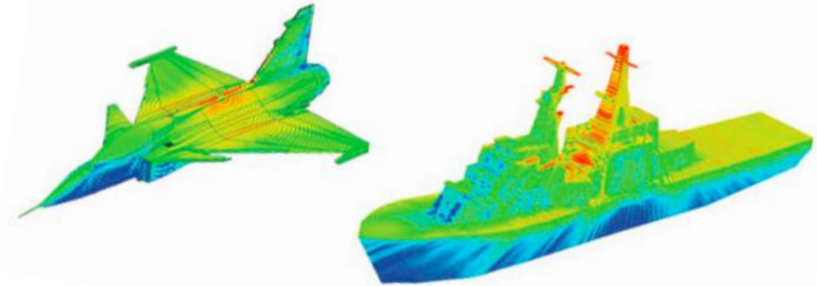
- Compact range measurements
- Traditional: Passive calibration targets
- Active calibration target

BISTATIC RCS SIMULATIONS



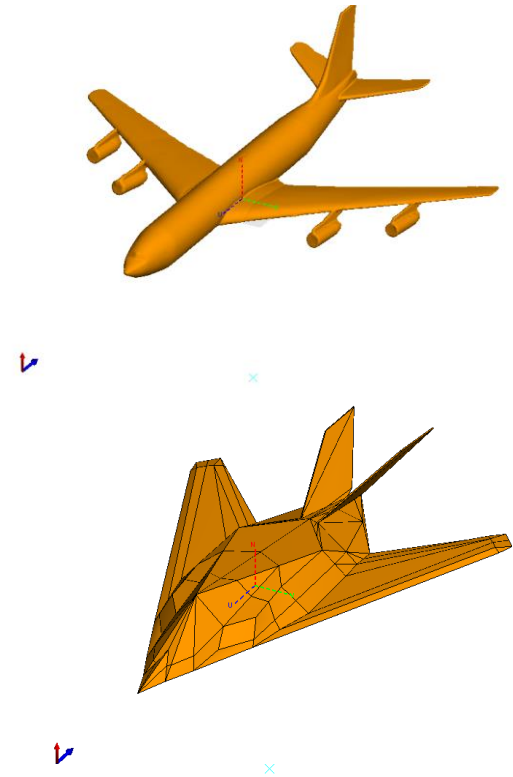
Bistatic RCS Simulations

- Asymptotic vs Full-wave
 - More efficient
 - Runtime
 - Computational resources
 - Less accurate
 - Ideal for electrically large problems
- Accuracy & efficiency investigated
 - Full ray-tracing PO &
 - Ray-launching GO
 - Complex targets
 - Large bistatic angles



Bistatic RCS Simulations

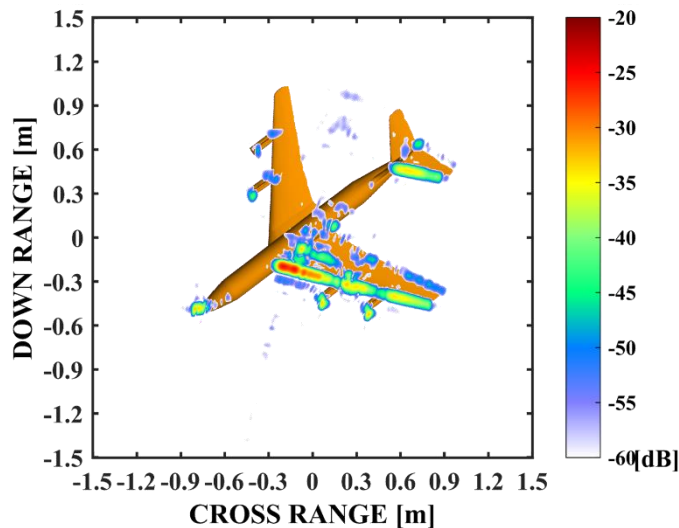
- Canonical targets
 - Flat metal plate
 - Dihedral corner reflector
- Complex targets
 - Canonical missile shape
 - 1:25 Boeing 707 scale model
 - 1:34 F117 scale model



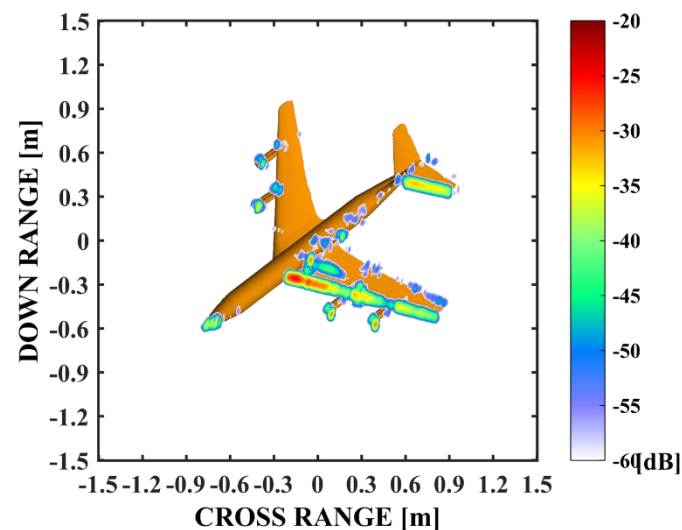
Bistatic RCS Simulations

1:25 Boeing 707 scale model
 $\beta = 30.8^\circ$

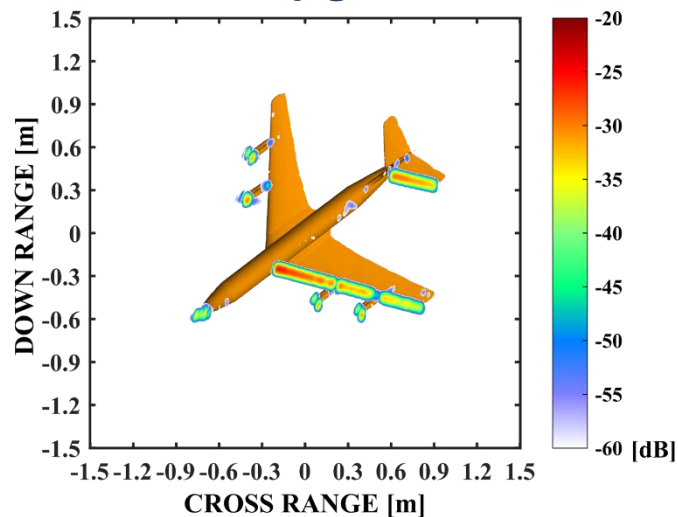
Measured



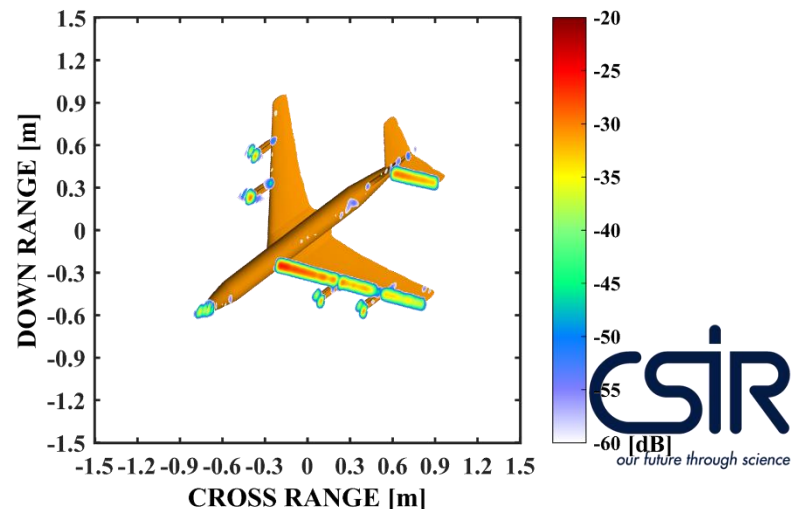
MLFMM



PO

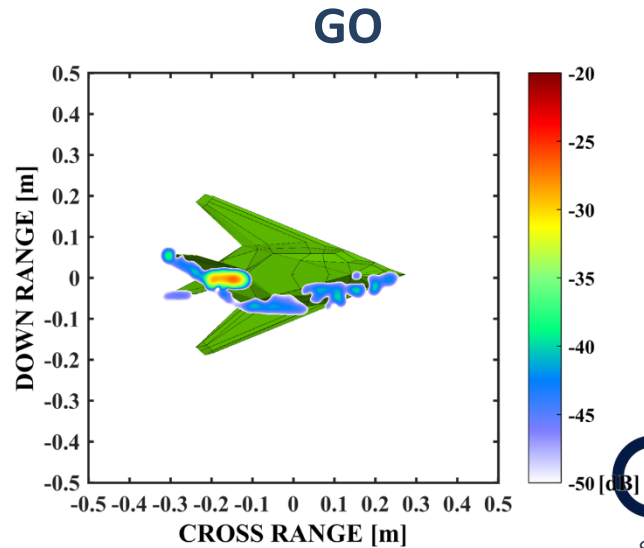
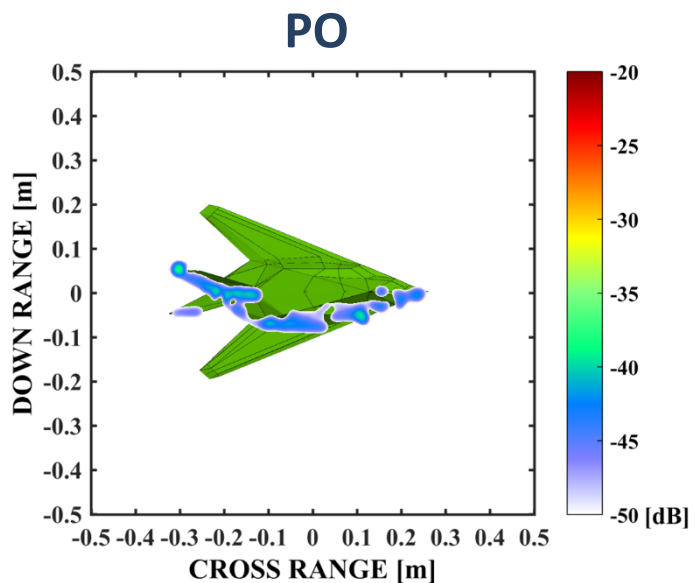
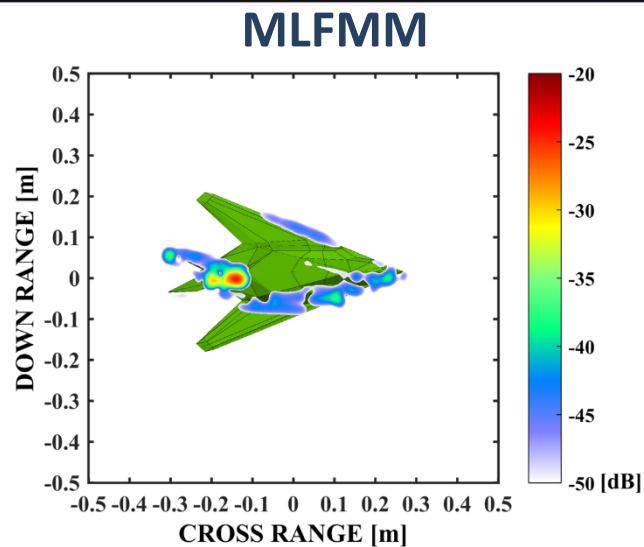
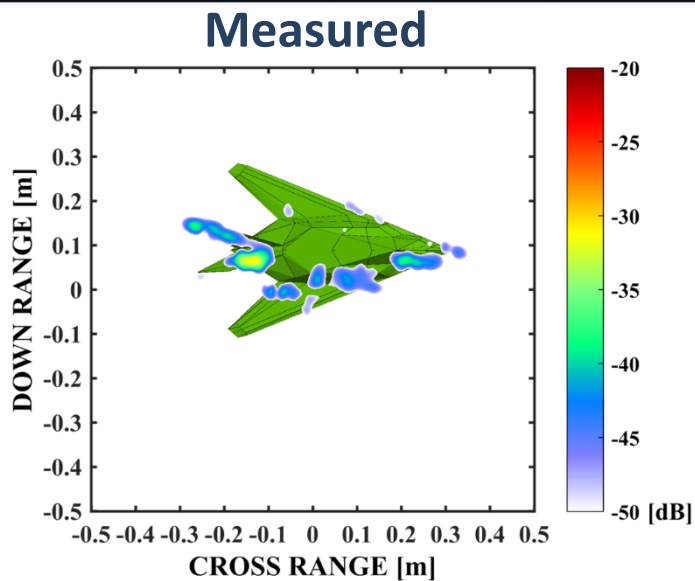


GO



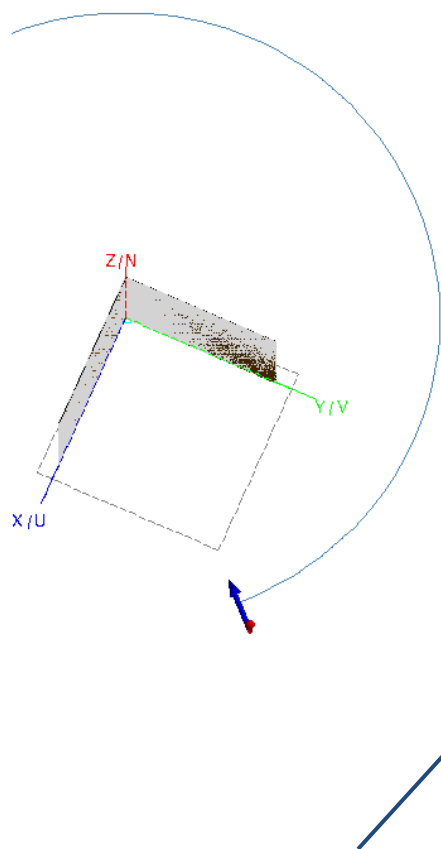
Bistatic RCS Simulations

1:34 F17 scale model
 $\beta = 30.8^\circ$

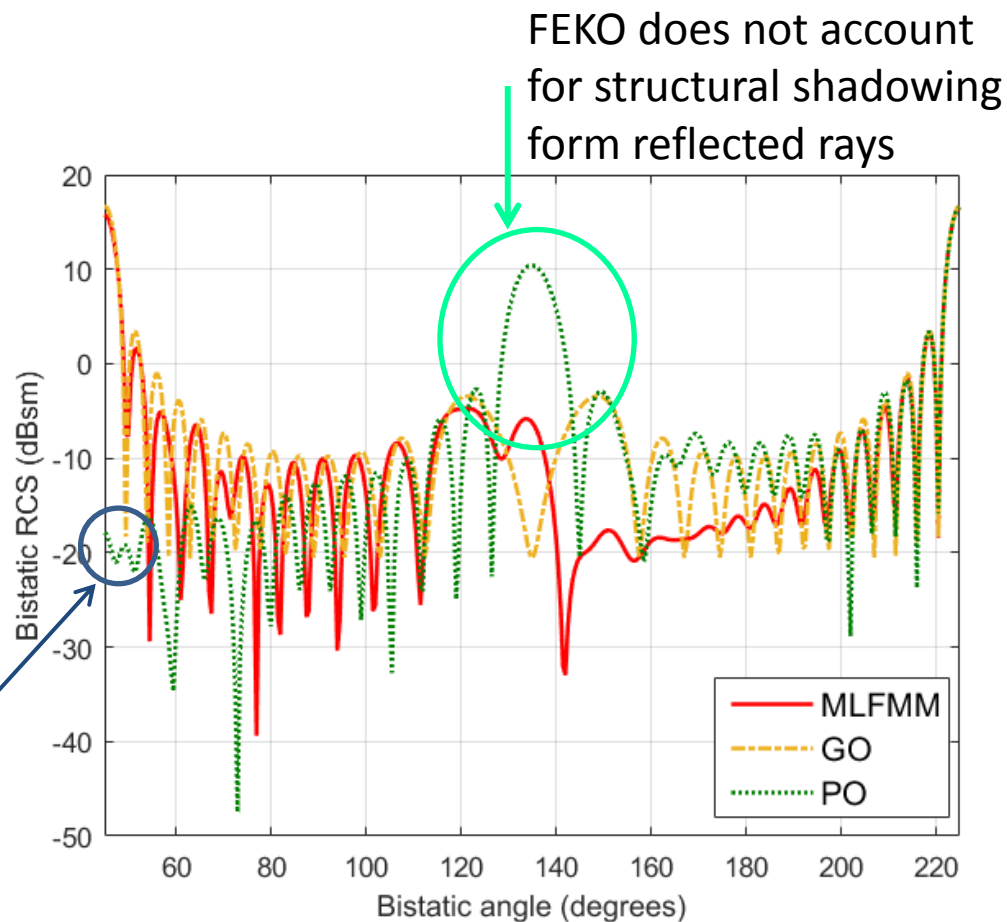


Bistatic RCS Simulations

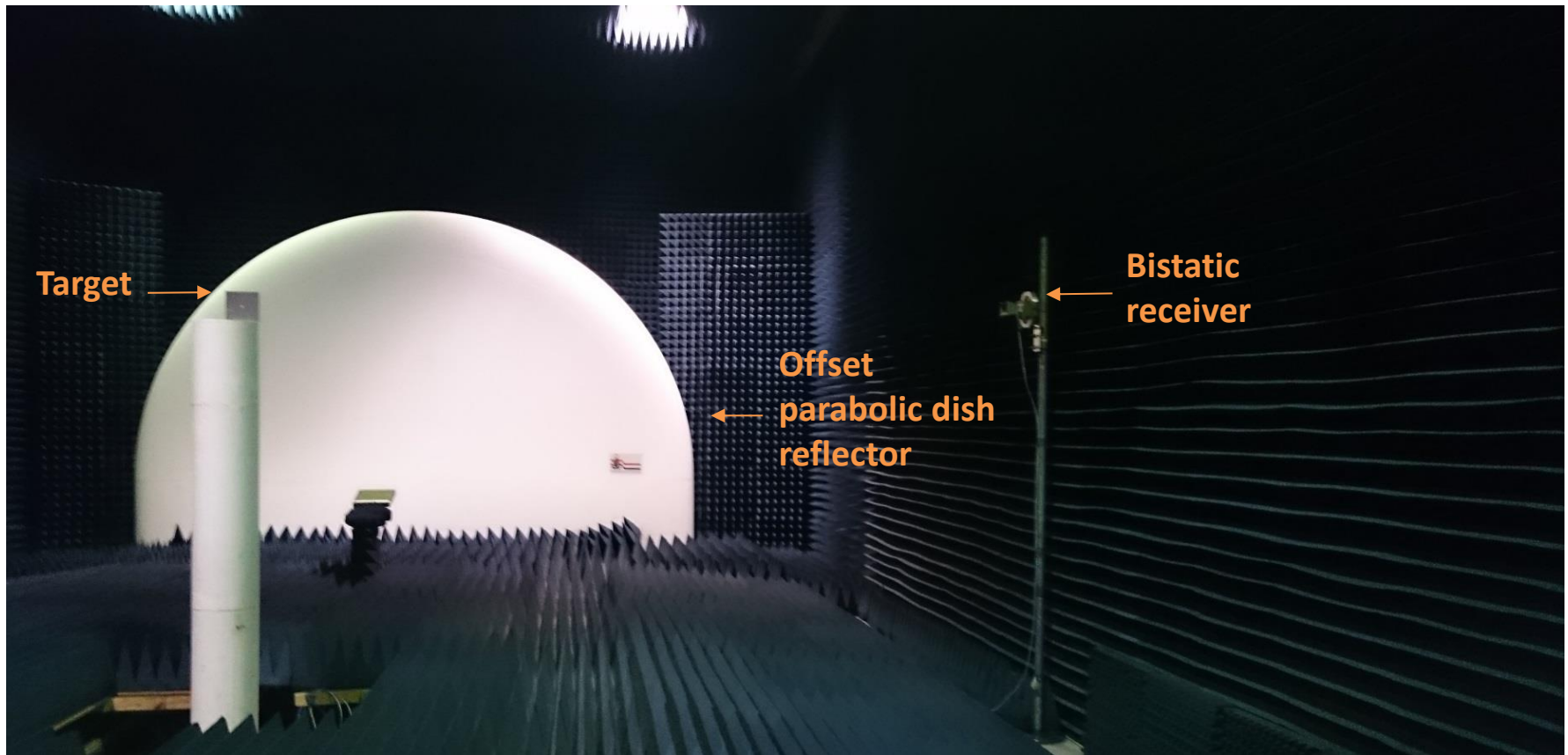
Dihedral corner reflector
 $\beta = 90^\circ$



PO does not account
for multi-bounce



BISTATIC RCS MEASUREMENTS



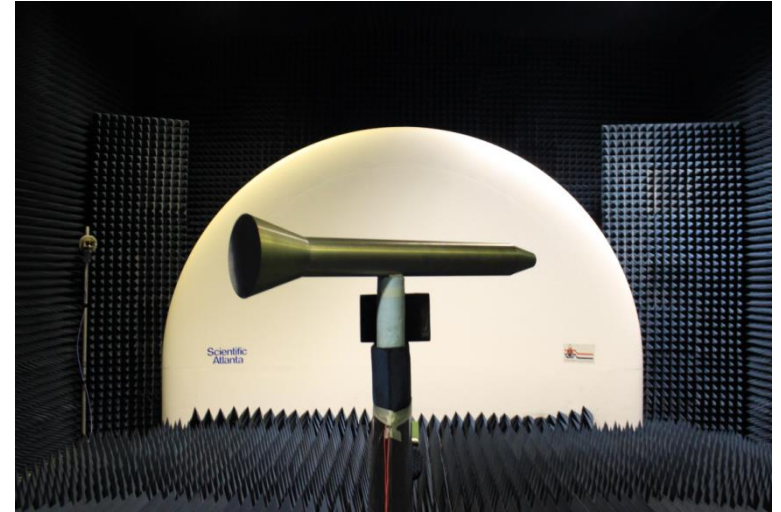
$\beta = 30.8^\circ$

$\beta = 45^\circ$

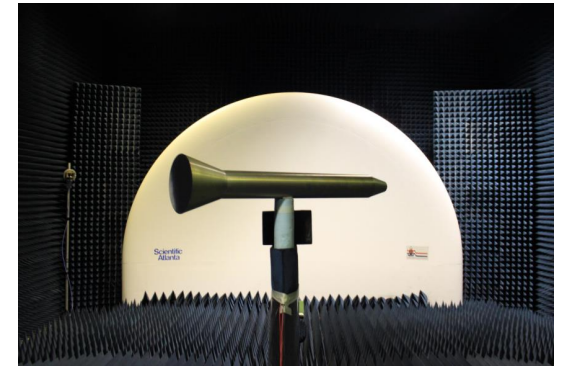
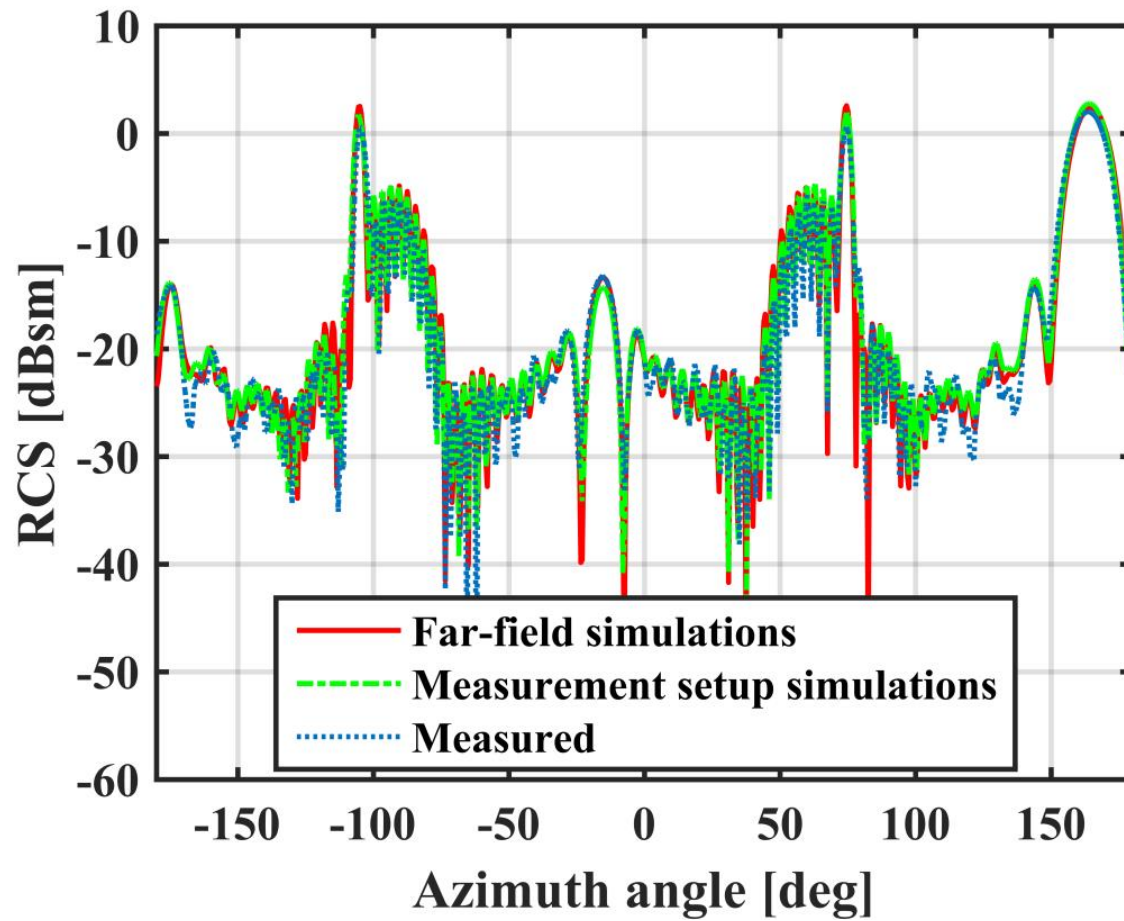
$\beta = 90^\circ$

Bistatic RCS Measurements

- Canonical targets
 - Flat metal plate
 - Dihedral corner reflector
- Complex targets
 - Canonical missile shape
 - 1:25 Boeing 707 scale model
 - 1:34 F117 scale model

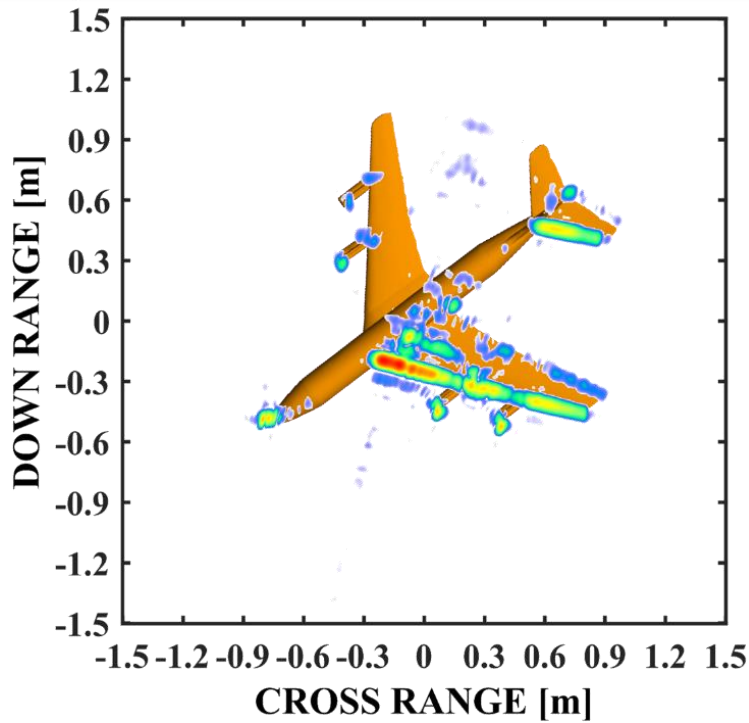


Bistatic RCS Measurements

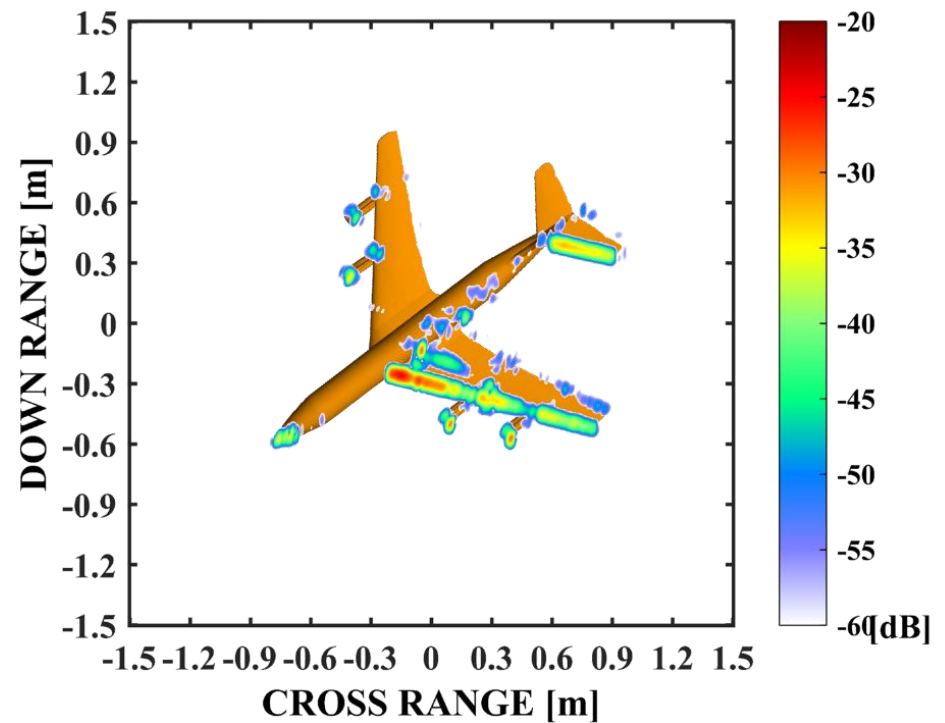


Bistatic RCS Measurements

Measured

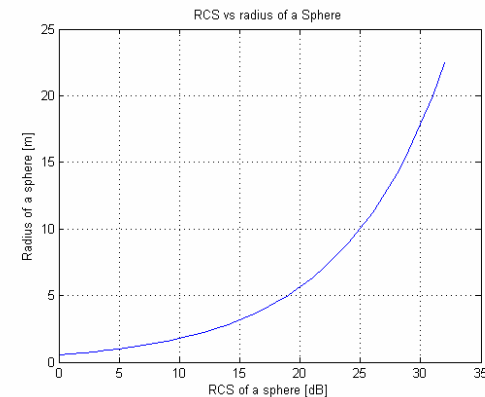
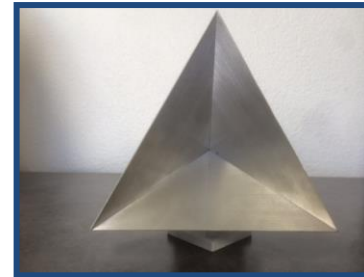


MLFMM



BISTATIC RCS CALIBRATION

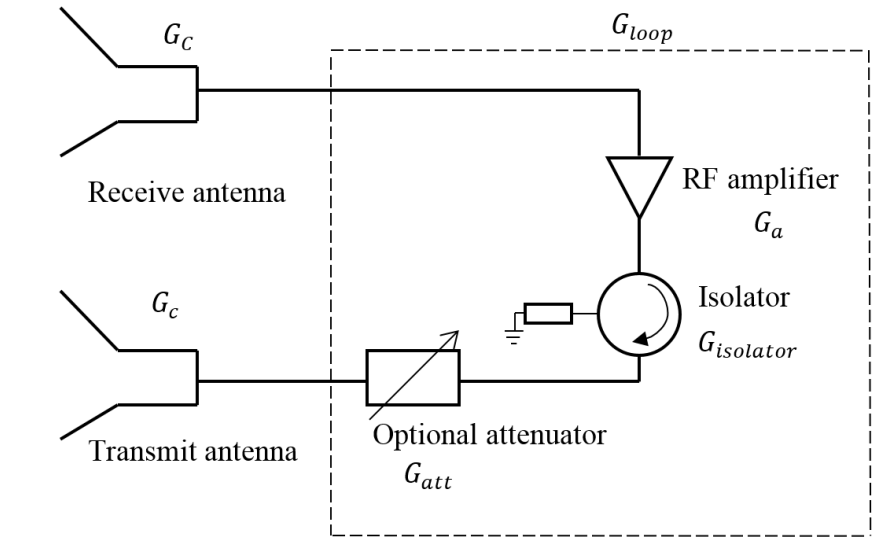
- Passive Calibration Targets
 - Spheres, Corner reflectors
 - Physically large for High RCS
 - Decreased beamwidth
 - Co-polarization
 - Monostatic calibration
- Active Calibration Targets



Calibration Target	Dimensions	Value (RCS = 10dBsm)
Sphere	Diameter	3.6 m
Active Target	LxWxH	0.25x0.15x0.1 m

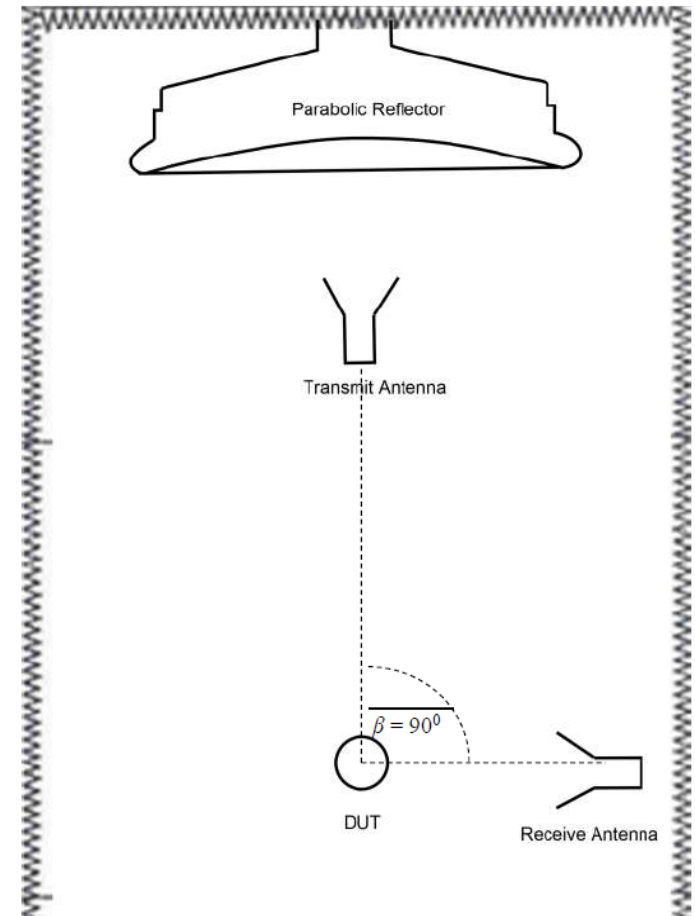
Bistatic RCS Calibration: Active Calibration Target

- A small lightweight active calibration target was designed and used for monostatic and bistatic RCS calibration
- Benefits active calibration target
 - ✓ High dynamic range in all four polarization configurations
 - ✓ Large beamwidth
 - ✓ Large bistatic angle



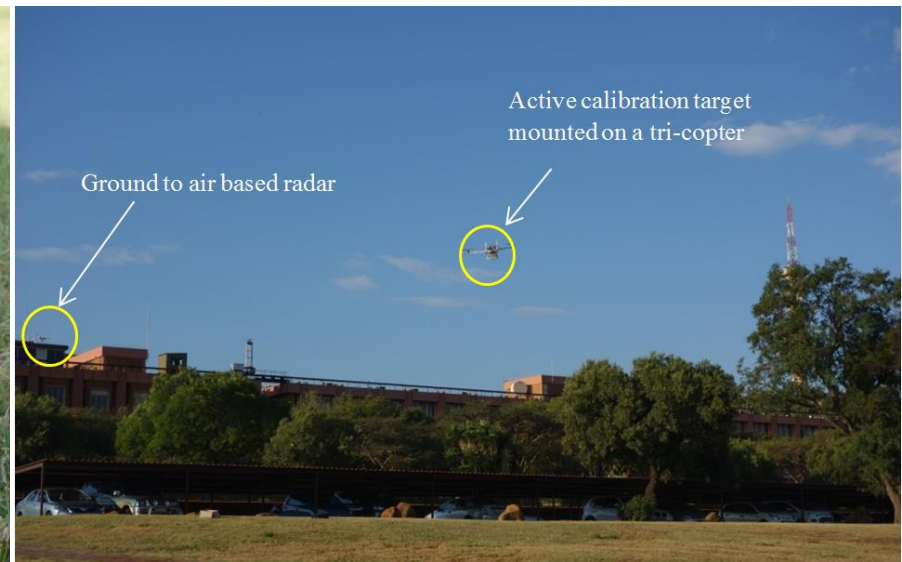
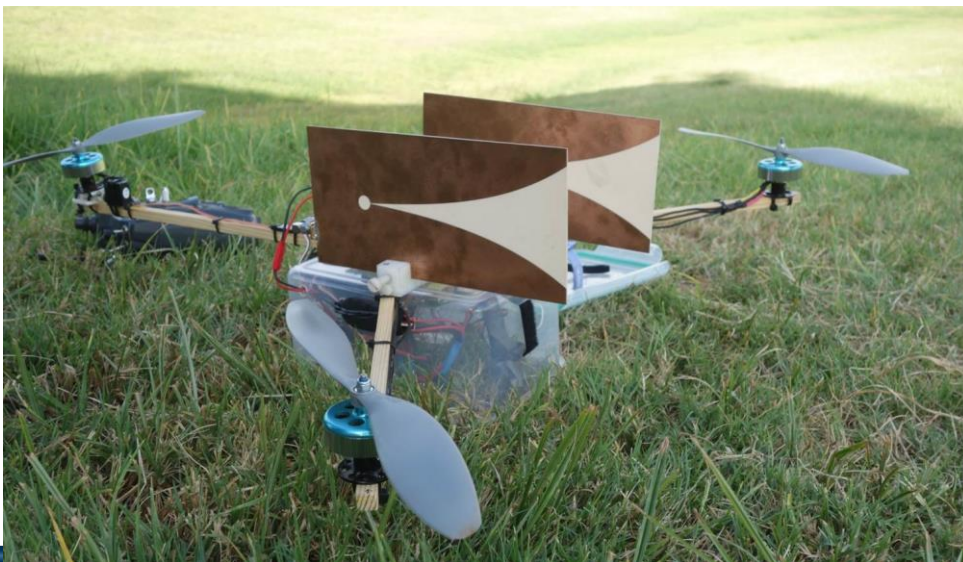
Active Calibration Target

- Characterised and tested
 - Compact range
 - Sphere
 - Outdoor measurements



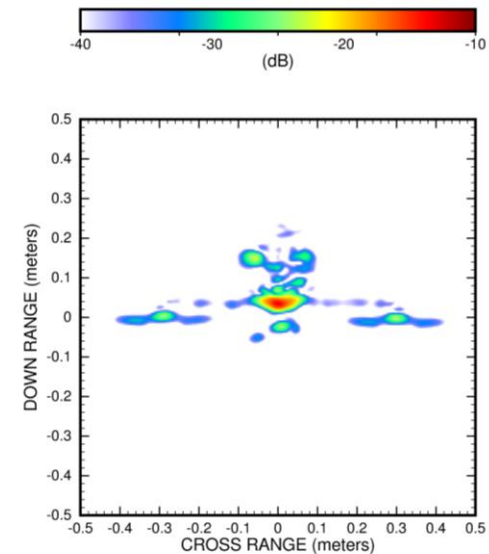
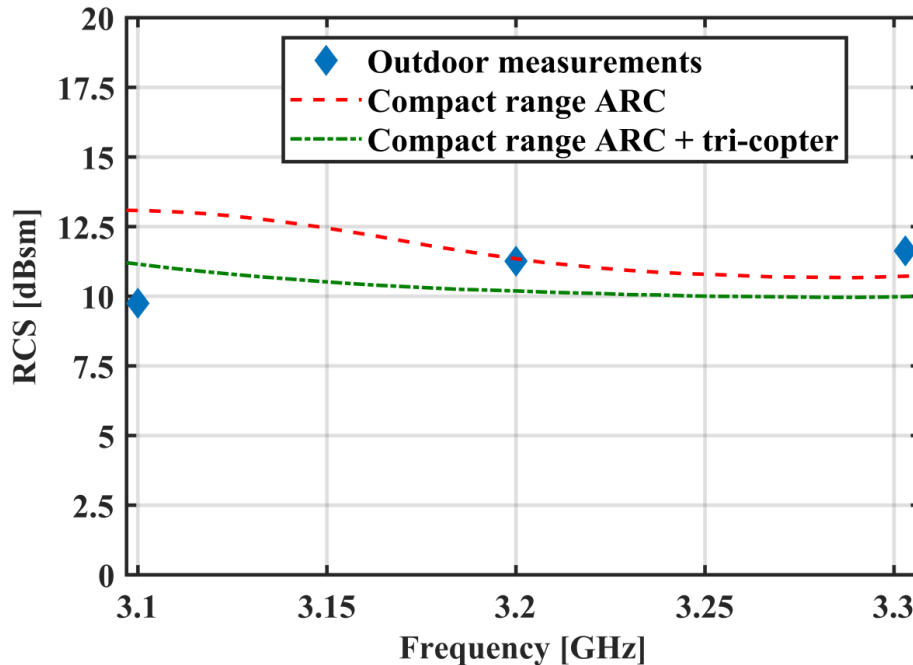
Monostatic RCS Measurements

- Outdoor measurements
 - Verify ability of the calibration target to calibrate a ground to air radar in a dynamic environment
 - S-band single polarization Doppler radar
 - 3.1 GHz – 3.3 GHz
 - Calibration target mounted on a tri-copter



Monostatic RCS Measurements

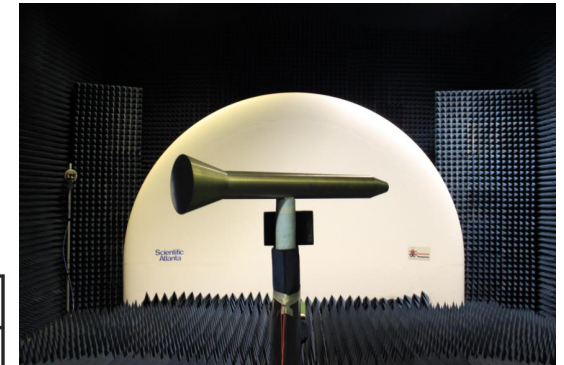
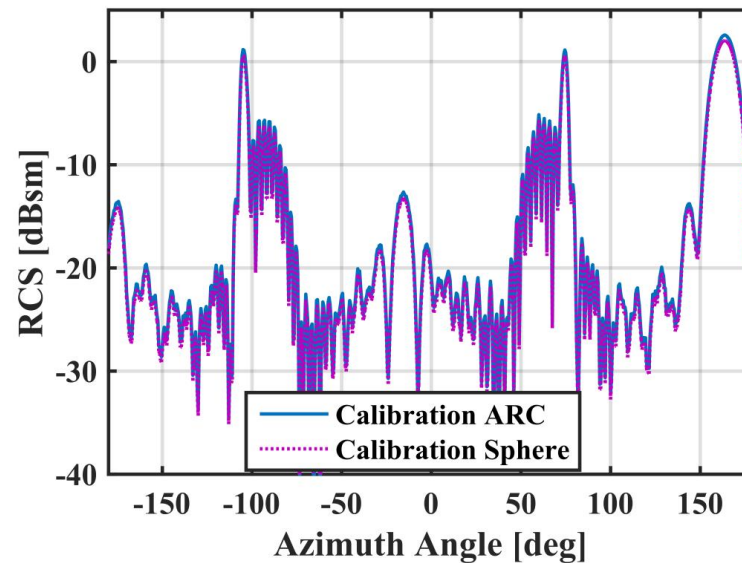
- Azimuth and elevation angle of approximately 0° towards the radar



- Improve
 - Stabilizing gimbal
 - More advanced tri-copter
 - Batteries

Bistatic RCS Calibration

- Bistatic RCS calibration performance of the active calibration target
 - Compared
 - Full-wave MLFMM simulations
 - Sphere calibration



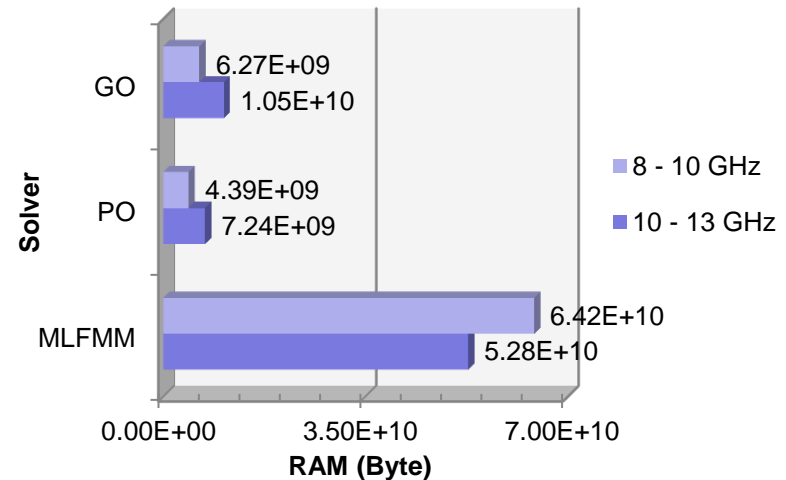
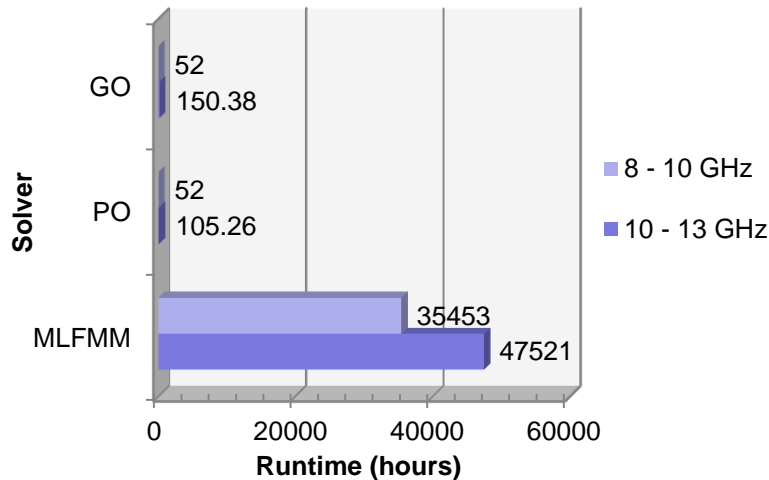
Bistatic RCS of the canonical missile, $\theta = 30.8^\circ$, VV polarisation at 3.6 GHz.

Conclusion

- **Bistatic RCS Simulations**

- Canonical & complex electrically large targets

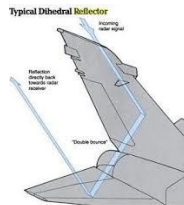
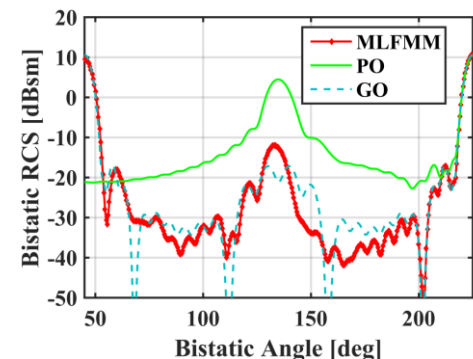
- RAM & Runtime – 1:25 Boeing 707 scale model



- Complex electrically large targets

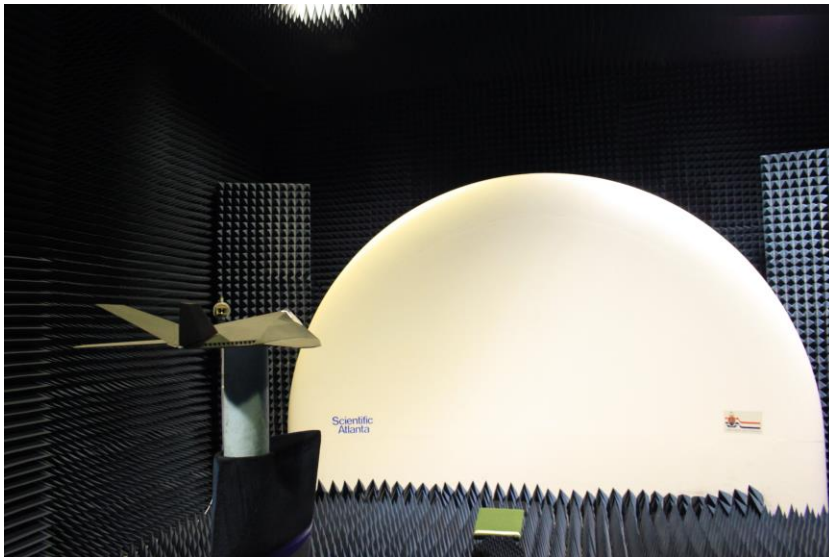
- Multiple scattering

- GO optimal



Conclusion

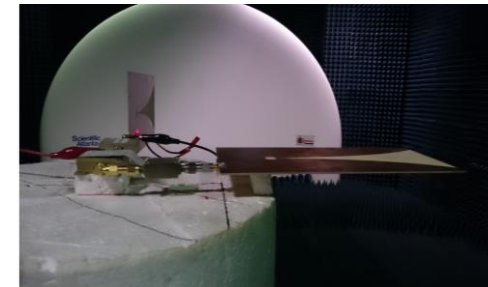
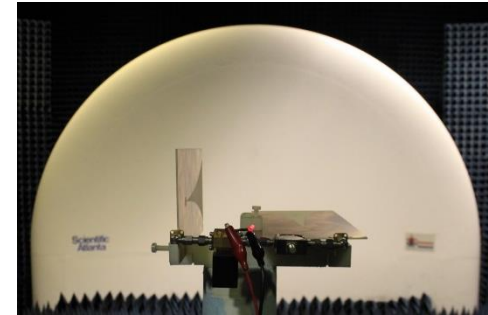
- **Bistatic RCS Measurements**
 - Compact range
 - Limit: target-receiver far-field distance
 - Good results
 - Complex targets – various sized scatterers



Conclusion

- **Bistatic RCS Calibration**
 - Compact Range measurements
 - Bistatic full-polarimetric calibration target
 - Small, lightweight & cost effective
 - Large bistatic angles

$$\sigma_{cal DUT} = \left(\frac{\mathbf{E}_{DUT} - \mathbf{E}_{DUT,back}}{\mathbf{E}_{Ref} - \mathbf{E}_{Ref,back}} \right) \sigma_{Calib}$$



Thank you

[1] "Active calibration target for bistatic radar cross-section measurements."

[2] "Bistatic RCS measurements in a compact range."

[3] "An active wideband reference target for the calibration of ground to air radar systems."

[4] "Dynamic radar calibration using an airborne active calibration target."

[5] "RCS Measurements and Simulations" CEM Workgroup



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