Radar Cross Section Models for AFCAP Dashboard: Quo Vadis?

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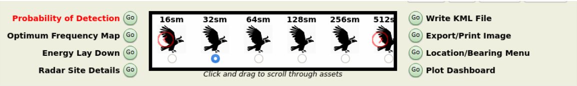
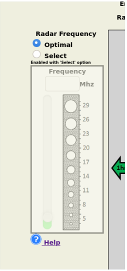
Scope: A Snapshot of Progress

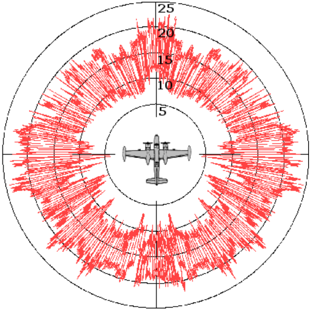
1. The Process
2. Fourier Decomposition Results
3. Polynomial Decomposition Results

Dashboard Controls





Current Dashboard Control



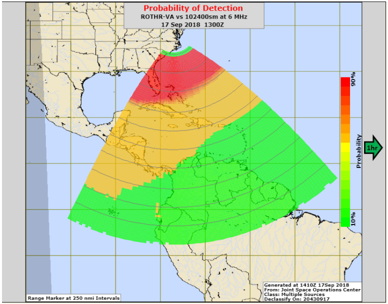


Table: Capture RCS Variability in the Dashboard

Nominative Dashboard Control

	current		enhanced
1.	select target type	1.	select asset (A, B, . . .)
2.	select RCS (2^k, $k \in \mathbb{Z}^+$)	2.	pick radar frequency in MHz $3 \leq \nu \leq 30$
		3.	pick yaw angle $\alpha \in [-\pi, \pi]$
		4.	pitch angle is fixed at $\beta = \pi/12$

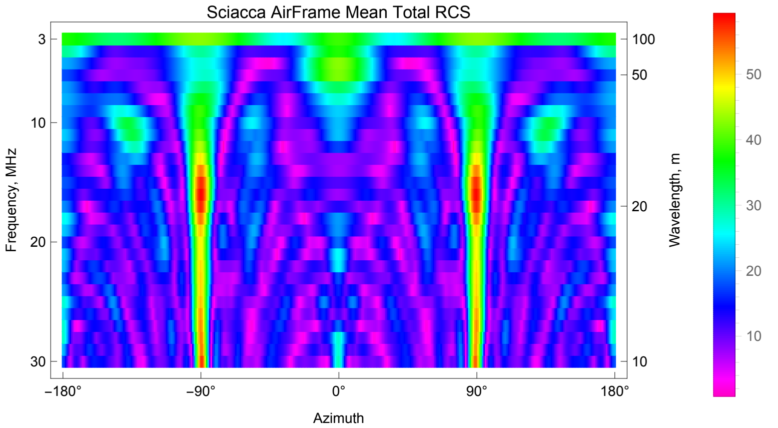
Table: AFCAP Dashboard capability for RCS.

Config.xml


```xml
<Asset>
  <Label>16sm</Label>
  <ICONImage>Bald Eagle-sm.png</ICONImage>
  <crossSection>16</crossSection>
  <description>Aircraft</description>
  <nominalSpeed>400</nominalSpeed>
  <CIT>2.0</CIT>
</Asset>
```

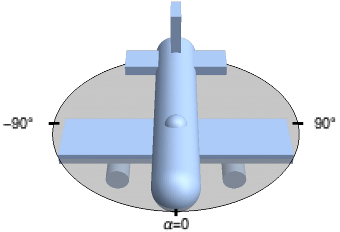
Probability of Detection

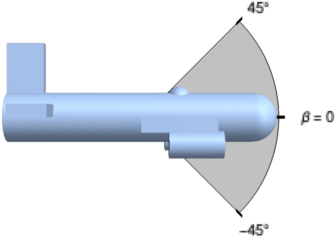
```
from frOPCclass.js
function plotProbability (ctx, jsonObj, jsonCoord, \
 xSection, assetCIT, nomSpeed) {
 ...
 var xSecRadius = Math.sqrt(xSection/Math.PI)
 var sphereArea = Math.PI * xSecRadius * xSecRadius;
 ...
 }
```


Sciacca AirFrame Mean Total RCS
Frequency, MHz
3
10
20
30
Wavelength, m
100
50
20
10
−180°
−90°
0°
90°
180°
Azimuth
50
40
30
20
10

Defining Angles

Yaw α	Pitch β
$-180 \leq \alpha < 180$	$\beta_0 = 30°$





Best Way To Update Dashboard?

1. Compression
   - Fourier decomposition
   - Taylor decomposition
   - wavelets
2. Reduction
   - Average neighbors
   - Sampling

Best Way To Update Dashboard?

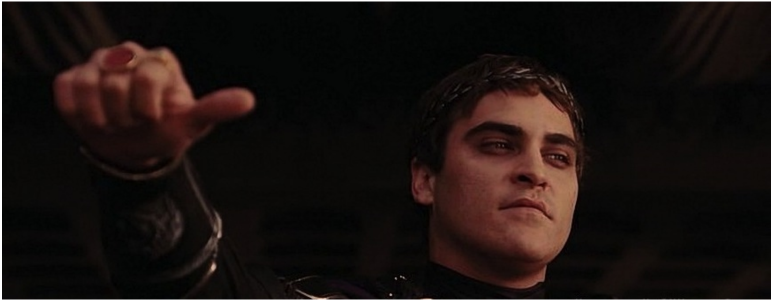


Figure: Criterion: Bonito Thumb Test

Big Picture

1. ✓Create a model in FreeCAD
2. ✓Use Mercury MoM to create HF RCS data
3. ✓Experiment with Compression and Reduction Techniques

Sciacca Process

1. Create a model in FreeCAD – `*.obj`
2. Use MATLAB/ALPINE to create `*.facet`
3. Use `MMViz` to "seal the mesh"
4. Generate RCS profile with Mercury MoM
5. Use MATLAB/ALPINE to plot RCS data

A great first generation process, but uses proprietary software.

Streamlined Process

1. Create a model in FreeCAD, fix mesh – `*.obj`
2. Use Python to create `*.facet`
3. Generate RCS profile with Mercury MoM
4. Use Python to plot RCS data

Features better mesh tools, open source software.

Along the Way

1. Discovered a sophisticated toolkit for mesh repair
2. Quantified the limits of Mercury MoM mesh analysis
3. Replaced MATLAB/ALPINE scripts with Python
4. Developed a reduced instruction set for Mercury MoM
5. Streamlined and updated the process

These matters were detailed in previous briefings.

Radar as a Tool

1. Radar interrogation is a powerful tool
2. Reveal target details
3. Reveals environment details
4. Description of the complex electromagnetic field
    4.1 A: amplitude (strength)
    4.2 : i: complex unit modulus
    4.3 k: wavenumber (wavelength)
    4.4 r: position vector
    4.5 f: frequency
    4.6 t: time
    4.7 ϕ: phase

$$Ae^{i(k\cdot r-ft)} = Ae^{i\phi}$$

Extracting Information

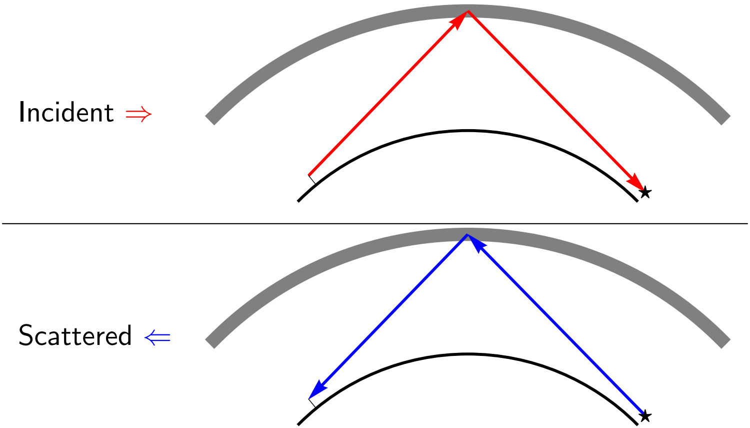
Phase		Amplitude	
$\frac{\partial \phi}{\partial x}$	angle	$\frac{\partial A}{\partial x}$	shape
$\frac{\partial \phi}{\partial t}$	relative velocity	$\frac{\partial A}{\partial t}$	rotation
$\frac{\partial \phi}{\partial f}$	range	$\frac{\partial A}{\partial f}$	size

Table: *Intro. to Radar Systems*, M. I. Skolnik, §10.2

Exploit Radar Cross Section

Exploit radar cross section to demonstrate how probability of detection varies with asset perspective.

Radar Cross Section: A Measure of Energy Difference



Radar Cross Section: Discussion

- Rayleigh scattering
- Radar cross section is a far field phenomenon
- Assumes single polarization to and from target
- Target is completely metallic:
  E field results from surface currents
- Shape is quasi-dimensional
  - Dimensions in two known directions
  - Fuselage, wings
- Resonant scattering:
  Ratio of typical dimension to wavelength ≈ 1
- See Kolosov, §4.6

Effective Radar Cross Section: Definition

$$\sigma_\star = \frac{\text{power scattered per unit solid angle}}{\text{incident power density per } 4\pi} \tag{3.1}$$

Effective Radar Cross Section: Definition

$$\sigma_\star = 4\pi \lim_{r\to\infty} r^2 \left| \frac{E_{incident}}{E_{scattered}} \right|^2 \tag{3.2}$$

Modal Methods

1. Fourier
2. Taylor

1. Sampling
2. Averaging

References

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  1993 ISBN 9780890066188

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