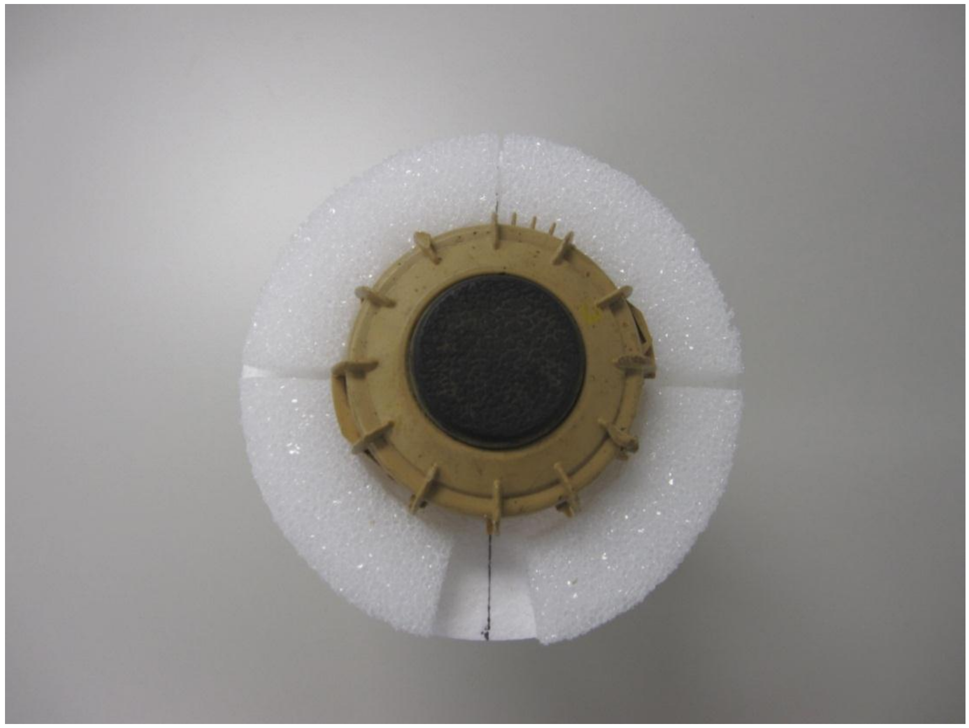
RADAR CROSS SECTION MEASUREMENTS OF A TEST TARGET IN SUPPORT OF THE MAV6 CIEDETS PROGRAM



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Timothy Tanigawa, Robert Kozma, Orges Furxhi,

Sergi Consul

Advanced Radar Imaging and Sensor Integration Laboratory

Center for Large-Scale Integrated Optimization and Networks

University of Memphis

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FINAL REPORT

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1. INTRODUCTION

This report summarizes work accomplished under contract with MAV6 by the Advanced Radar Imaging and Sensor Integration Laboratory's (ARSIL) anechoic chamber facility at the University of Memphis. ARSIL is a newly established laboratory, part of the Center for Large-Scale Integrated Optimization and Networks (CLION) and was established in the past year with significant support from the Air Force Research Laboratory (AFRL) sensors directorate.

In this work effort The University of Memphis provided Mav6 with measurement data for the purpose of determining the accuracy of the mathematical models used in the Common Improvised Explosive Device Exploitation Target Set (CIEDETS) program. The objective of the test is to obtain Radar Cross Section (RCS) data from a test target provided by Mav6.

The period of performance for this effort was from June 18, 2012 until July 31, 2012, with a no-cost extension until August 30, 2012. It is understood that the present experiment is Phase I of the collaboration project between MAV6 and The University of Memphis. Upon successful completion of Phase I it is anticipated that additional project Phase II and III will be outlined in August 2012, and executed in the coming period.

2. OVERVIEW

Several major tasks were outlined in the statement of work (SOW) for the contract and are summarized in Table 1.

Task	Description	W1 Jun 18-Jun 22	W2 Jun 25-Jun 29	W3 Jul 2-Jul 6	W4 Jul 9-Jul 13	W5 Jul 16-Jul 20	W6 Jul 23-Jul 27	W7 Jul 30-Aug 3	W8 Aug 6-Aug10
1	Requirements gathering	▲▲							
2	Chamber reconfiguration	▲▲		▲▲	▲				
3	RCS measurements				▲	▲▲	▲▲	▲▲	
4	Deliverable and reporting						▲▲	▲▲	▲

Table 1 Project Tasks

During the contract period we have achieved the stated goals and the deliverables are provided to MAV6 as specified in the contract. Specifically, we have achieved the following:

- The chamber was reconfigured to operate at X-band. This included replacing the antennas. Fabricating a new antenna mount and integrating into the chamber. Reconfiguration was completed and functionality tests completed.
- Several calibration targets were measured. A calibration standard from an 8 inch diameter sphere was measured and chosen to be applied to measurement data.
- Background and target mount measurements were collected to determine the noise levels and contribution of the target mount to RCS. In general noise levels were negligible and effects of the mount were low.

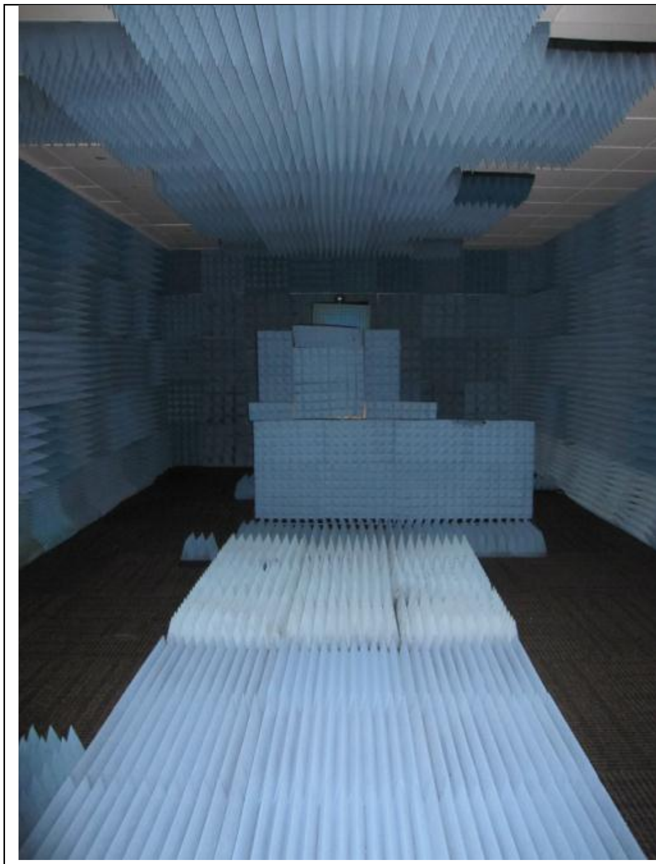
- RCS measurements were made of a six inch plate and were compared to theoretical values. The plate was chosen because the RCS can be easily calculated and varies predictably over incident angle. Measurements were made over 22 degrees in azimuth with a .2 degree resolution. Measured values were in good agreement with the theoretical values for a six inch plate.
- Target measurements were then made over 40 degrees in azimuth and in 0.4 degree increments. Measurements were made at 10 degree increments from 0 to 80 degrees in elevation for both polarizations (VV and HH).

3. ARSIL ANECHOIC CHAMBER

The ARSIL anechoic chamber is a newly established core research facility used for high-resolution radar imaging, RCS measurements, device and algorithm development and test. For the current project the system was configured for RCS measurements.

The measurement system uses a HP 8510 network analyzer which includes a synthesized sweeper and frequency converter which acts as the radar. The system also uses four positioners to position the target. The azimuth and elevation positioners provide incident angles for the target and the X-Y positioners are used for background cancelation. Figure 1 show the chamber components.

The system was converted to X-band which was necessary to make the desired measurements. A new coupler and antenna cables were purchased. A new antenna mount was fabricated and the X-band antennas were installed. A new chamber antenna integration assembly was constructed. The new components were installed and the system was tested for function.



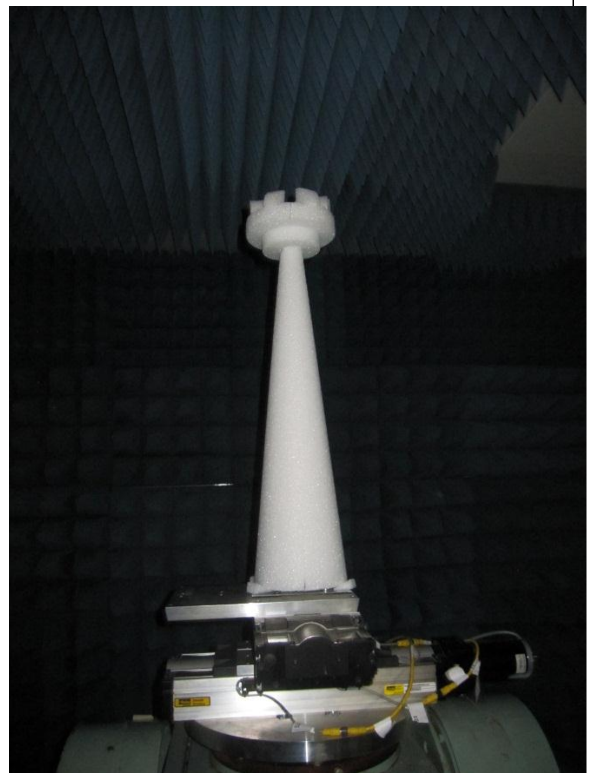


Figure 1ARSIL Anechoic Chamber Photos

4. MEASUREMENT SETUP

The RCS measurement uses a 10GHz frequency modulated continuous wave (FMCW) waveform with a 1GHz bandwidth (9.5GHz-10.5GHz). This translated into a 15cm range resolution. The system also uses a 4ns time-gate corresponding to a 60cm window.

The azimuth and elevation positioner are used to move the target to the desired position. The X- Y linear stages are used to move the target ¼λ toward the radar and used for background subtraction to isolate the target signal.

Two measurements are taken for each RCS position: target and target ¼λ. When these two measurements are subtracted, the background is subtracted and the target is added constructively. The results are then compared to the reference signal. This yields the target RCS for the measurement system. The calibration factor is a scalar factor which is multiplied with the complex RCS measurements. The result is the calibrated RCS in dBsm. Figure 2 is a functional diagram of the chamber measurements.

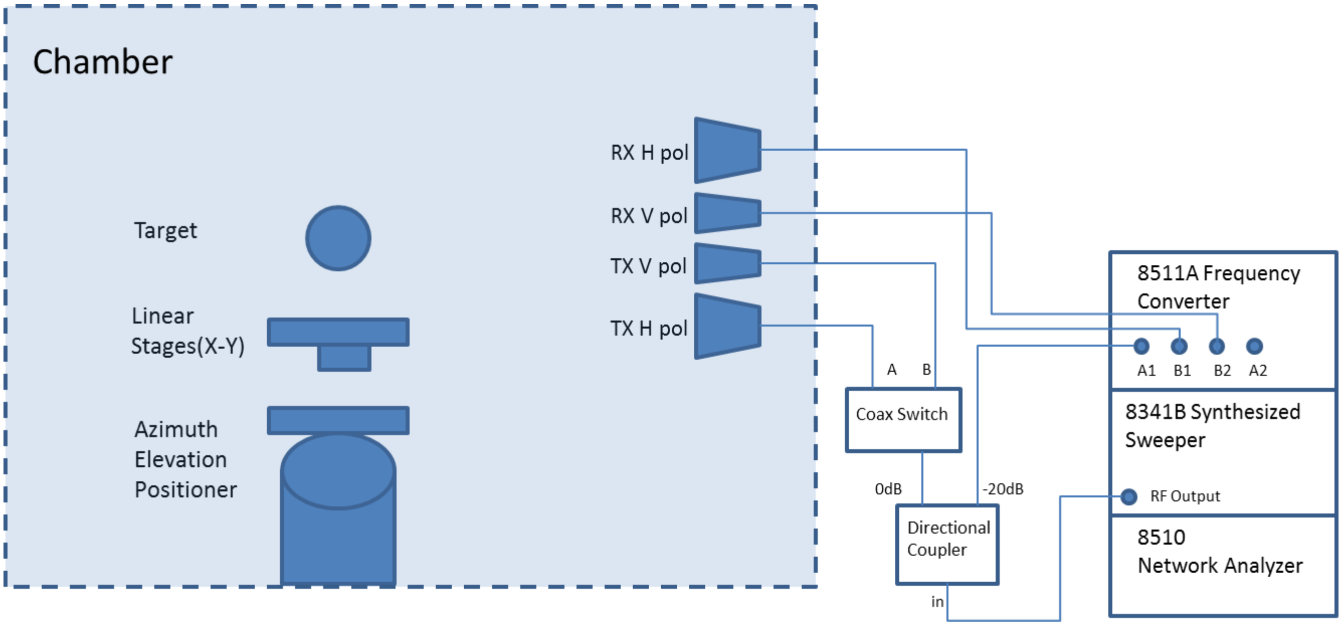


Figure 2 Chamber Functional Diagram

5. CALIBRATION

Calibration is necessary to get an absolute measurement. A target of known RCS can be used as a reference for the network analyzer measurements. ARSIL has several reference targets that can be used for calibration. Two spheres (4inch and 8inch diameter) and a 5.5inch trihedral were measured. The sphere makes a good reference target because it has a fairly constant RCS in elevation and azimuth. The drawback is a low RCS. The RCS is also fairly constant over frequency when the wavelength is large with respect to the circumference. The trihedral has a large fairly broad RCS that is easy to measure. Calibration is a scaling factor applied to the measurement to yield measurement in dBsm. Figure 3 shows the reference targets.

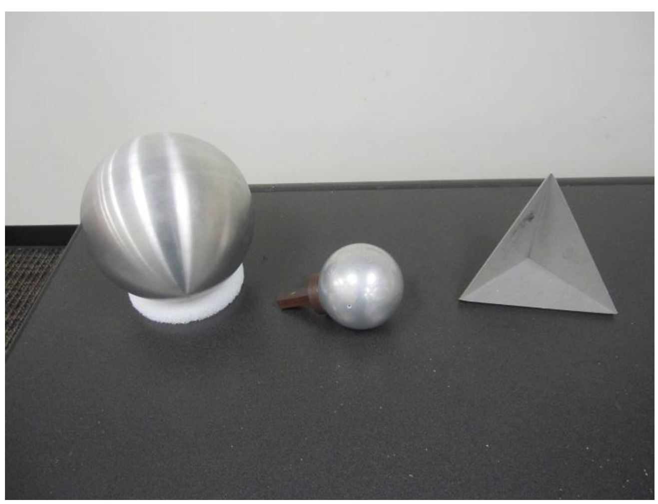


Figure 3 Reference Targets

The three targets were measured by the system and the results were compared with the theoretical values. The difference represents the calibration factor applied to the data. The large 8 inch diameter sphere yielded the best results and was used to calibrate the data. The results are summarized in Table 2. The calibration factors in Table 2 are shown in dB but were applied as a scaling factor (not dB) to the complex measurement data. Only the calibration factors for the large sphere were used.

Target	Theoretical (10GHz)	Measured (dB)		Calibration Factor (dB)	
		HH	VV	HH	VV
Small Sphere (4in)	-20.5	-51.65	-53.71	31.15	33.21
Large Sphere (8in)	-14.97	-50.8409	-50.6568	35.8709	35.6868
Trihedral (5.5in)	2.49	-33.9113	-34.8901	36.4013	37.7901

Table 2 Calibration Factors for Various Targets

The large sphere and trihedral calibration factors are within two dB and the agreement is fairly good. The small sphere was less accurate. This may be because of the dielectric post attached to the sphere or the variation in RCS over the 1GHz bandwidth at 10GHz. The Trihedral has some variation in incident angle and must be aligned and was only used as comparison.

An estimate was made for the smallest target the system could measure. An estimate of the noise was made by measurement of the empty chamber. The data was collected at an empty range and processed normally. The data indicates that the noise level is about -60dBsm, which is well below the target return. This is shown in figure 4.

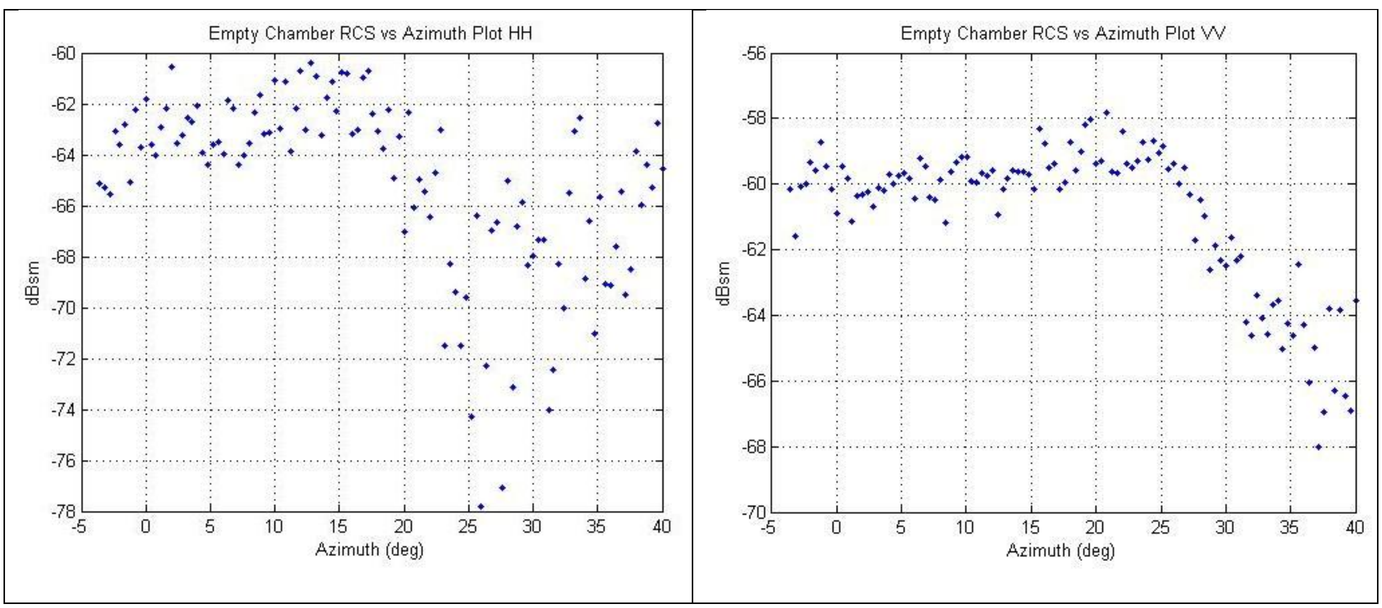


Figure 4 Empty Chamber Measurement HH,VV

A second measurement was made with the target mount only, without a target. A representative angle of 40 degrees was chosen to make the measurement which is midway in elevation. Full characterization was not possible due to project constraints. The second mount was chosen because the RCS was likely larger. The plot was compared to the target result and gives an indication of the contribution of the mount to the RCS. Figures 5 is a plot of the target and mount without the target at 40 degrees elevation. The black line is target data and the blue line is the mount without the target data. Most of the time the mount return is small compared to the target. There were a few angles where the mount return approached the target return.

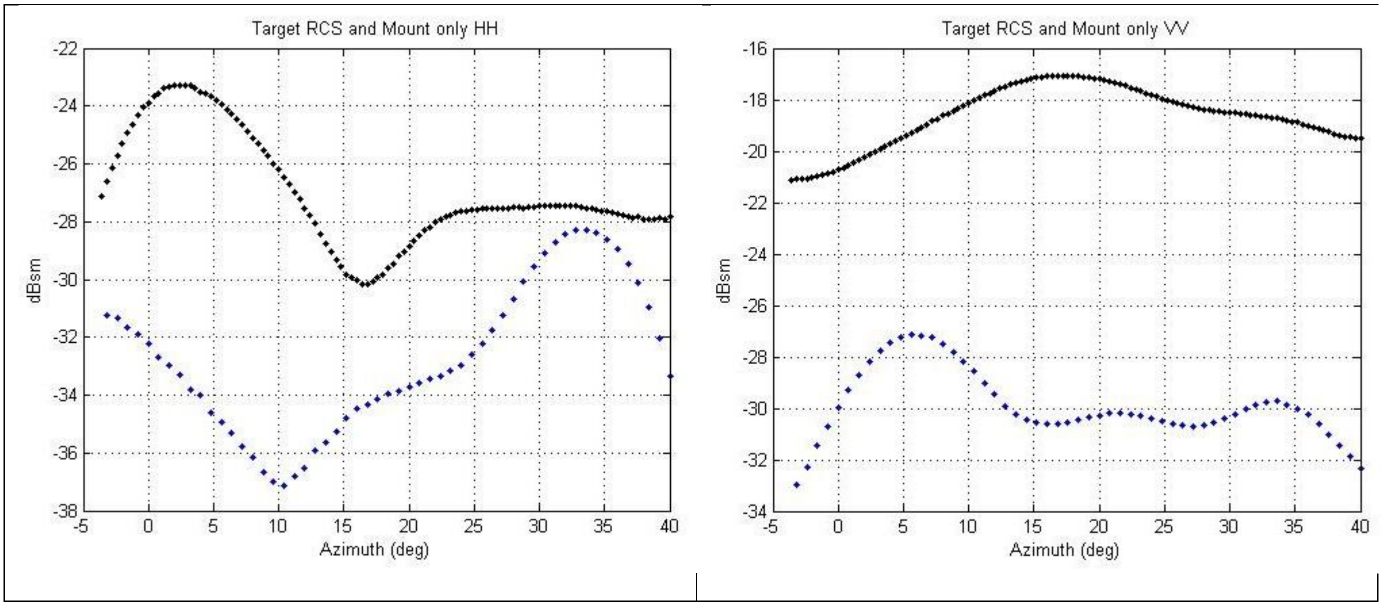


Figure 5 Target and Mount Only Measurements

6. TARGET ALIGNMENT

Two mounts were used to make measurements. The first mount was used for the 0-20 degree elevation angles. The mount used a single Styrofoam disk and smaller supports for the target. The mount was not stable for measurements greater than 20degrees. A second custom mount was constructed to make the higher elevation measurements. This second sturdier mount was necessary for added stability and held the target more securely, which is required for the higher elevation angles. The mounts are made of Styrofoam because of its low RCS characteristics. A 5 7/8 inch disk was used as a support base for the target. 90 degree lines were drawn in for a reference. For the second mount the disk was reinforced with a smaller disk and mounted to a large Styrofoam cone. The mount is shown in figure 6. The figure also shows the mount with six inch plate and target. The mount was installed on the positioner and the target platform leveled to ensure the target is parallel to the azimuth platter.

Both mounts used the plate to align the mount to the radar. The plate was mounted and moved manually in elevation and azimuth to find the maximum return. The peak measurement in elevation and azimuth angle represents the zero positions for the mount. The plate is removed and the target is mounted with the fins aligned to the 90 degree reference and is shown in figure 7.

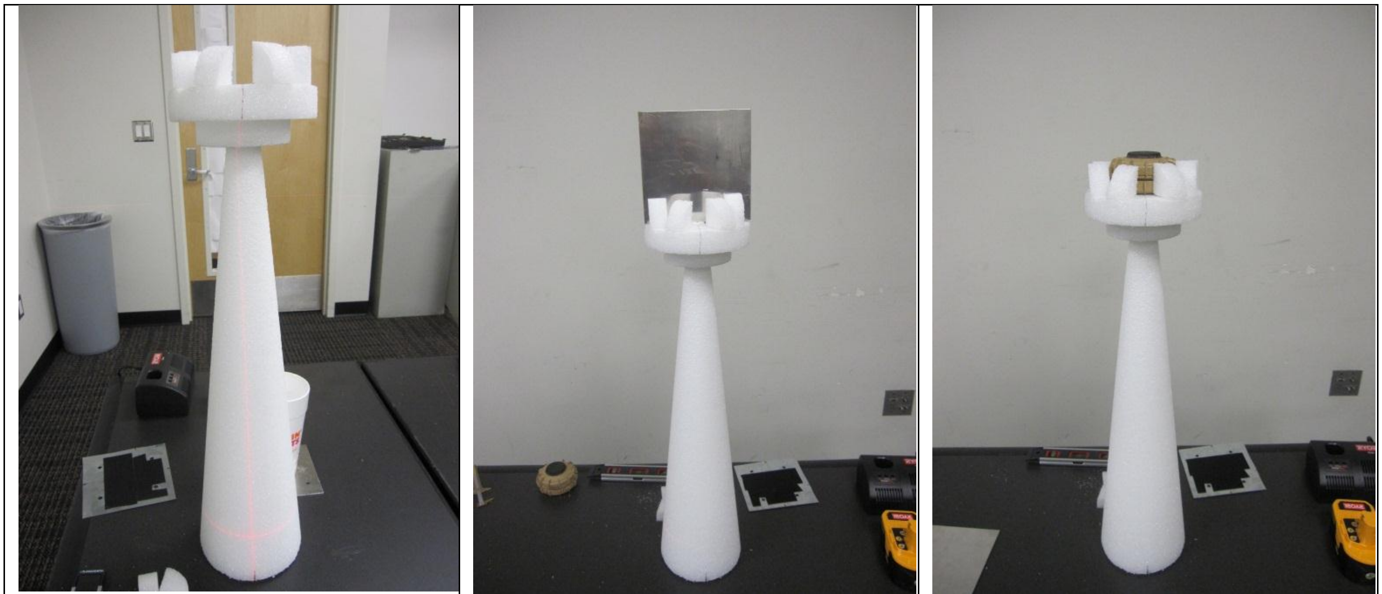


Figure 6 Target Mount With Plate and Target

Figure 7 Target and Plate Alignment

Figure 8 shows the geometry of the measurement. A is the height of the target mount, B is the distance from the antenna to the target mount, D is the height of the target above the antenna when θ is 0 degrees, θ is the elevation stage angle and α is the elevation angle target to antenna. It can be shown that the relation between α and θ is:

$$\sin(\alpha) = \frac{B1\sin(180-\theta)}{Y}$$

For the new mount A = 37”, D = 344” And D = 26” for HH and 32.5” for VV. The document elevation.docx has the elevation information for the measurement runs and is included with the data.

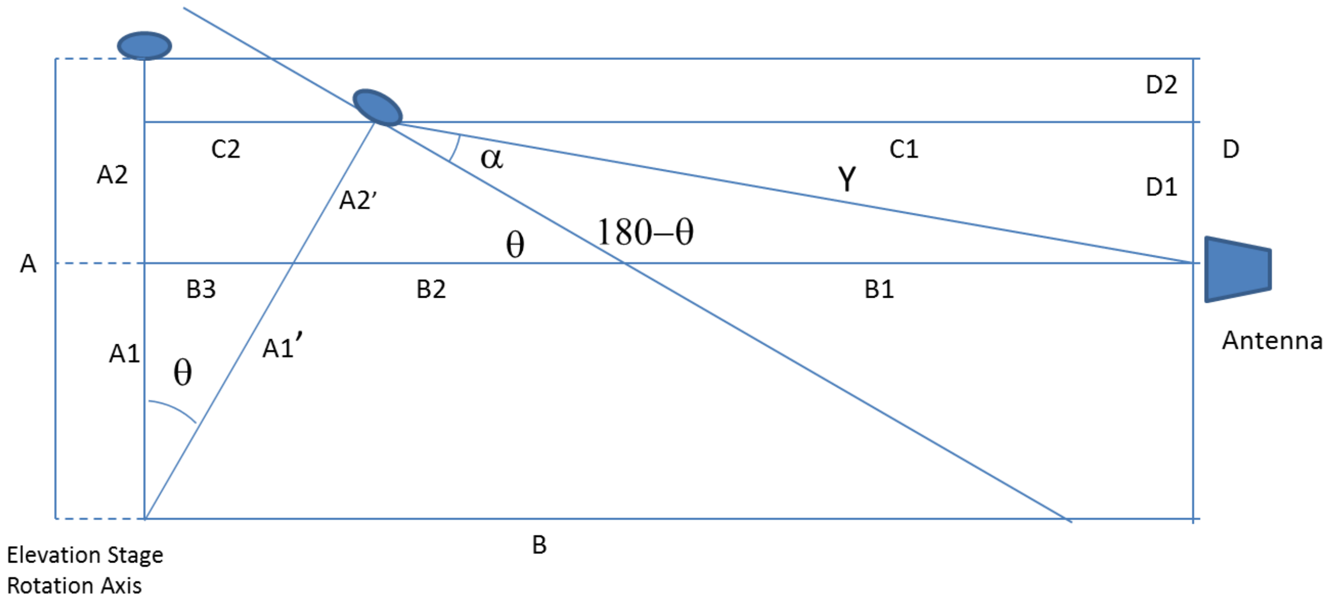


Figure 8 Measurement Geometry

7. RCS MEASUREMENTS

Data were collected in July and early August. The first sets of measurements were made on a 6 inch plate. The plate was first aligned by finding the peak in azimuth and elevation. The RCS measurements of the plate are shown in Figures 9, and 10. The black line is the theoretical values and the blue trace is the calibrated measured values. The measured values have good agreement especially the HH polarization. This may be due to the alignment was done with the HH antennas.

Next the target was measured. The DD mount was used for the 0-20 degree elevations. The mount has a low cross-section and smaller target supports. The rest of the measurements used the styro cone mount which was more stable and could support the target at the higher elevation angles.

The measurements were taken starting at 40 degree azimuth at .4 degree increments. 110 samples were taken, making the total range -4 through 40 degrees. Figures 11,12 and 13 show representative cuts at 20,40 and 60 degrees elevation angle.

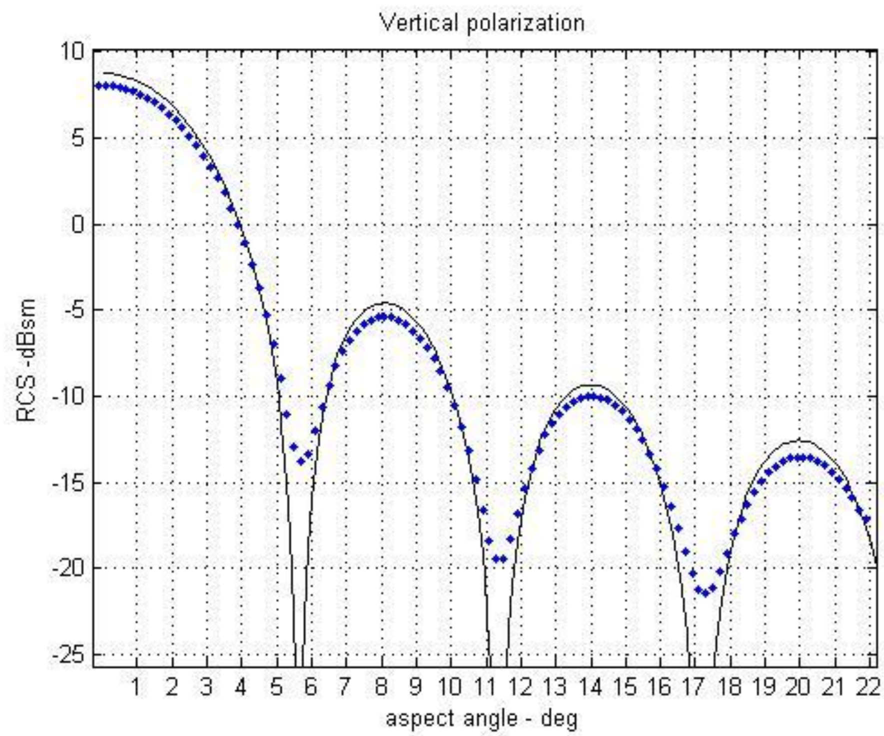


Figure 9 RCS 6" Plate vs Theoretical VV

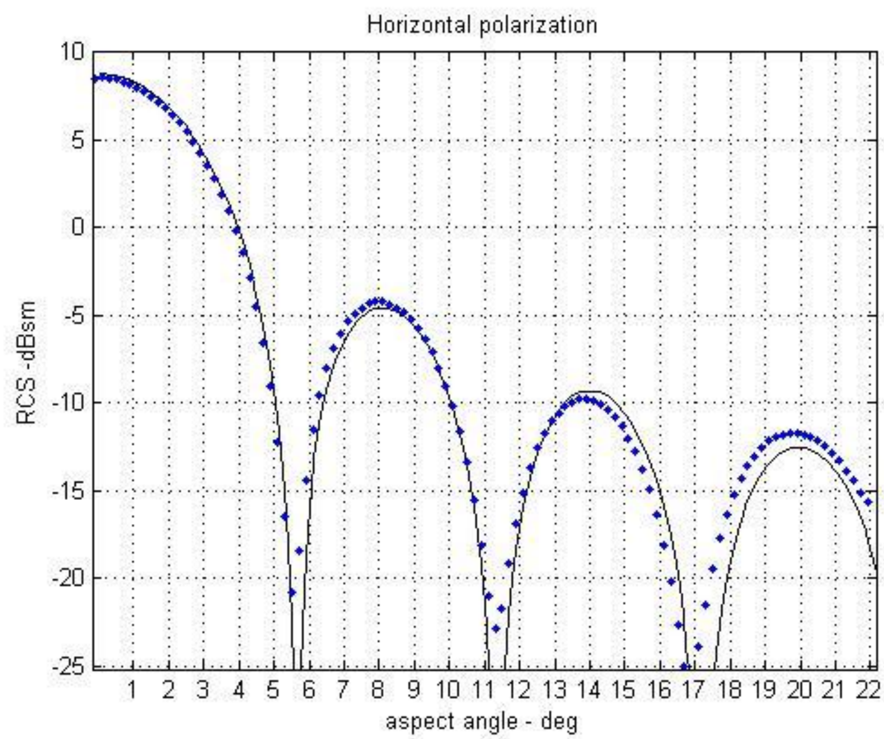


Figure 10 RCS 6" Plate vs Theoretical HH

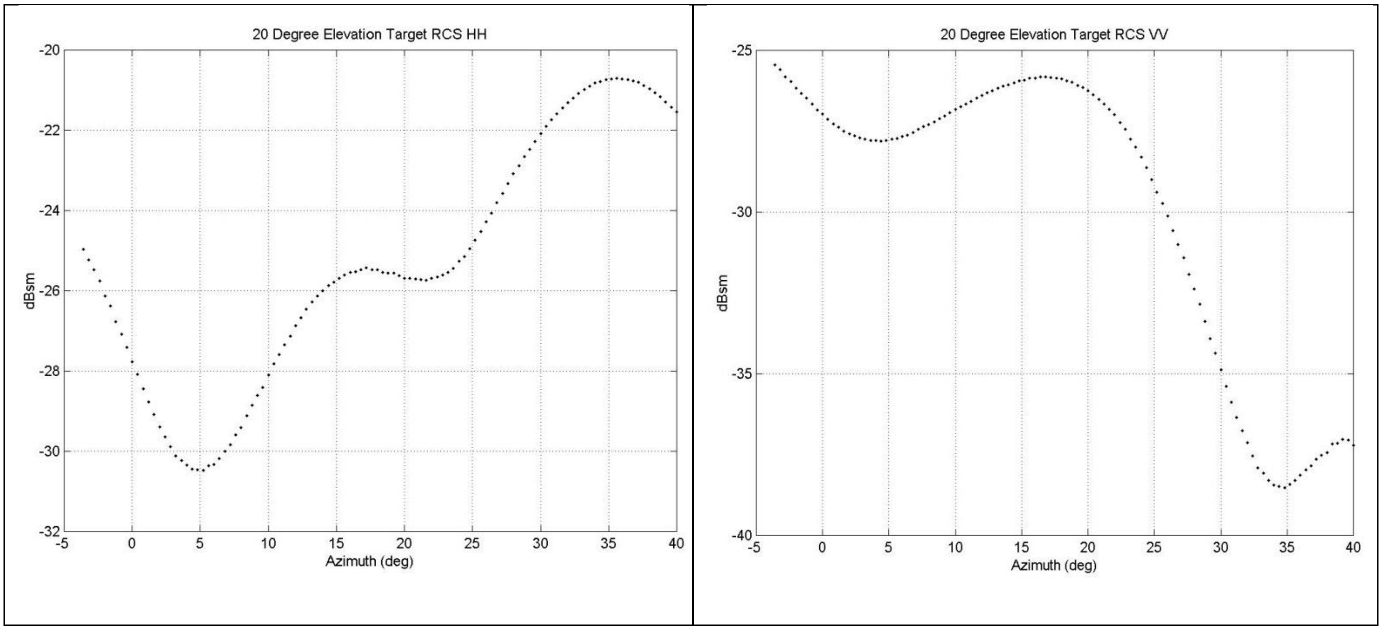


Figure 11 Target RCS 20 Degree Elevation

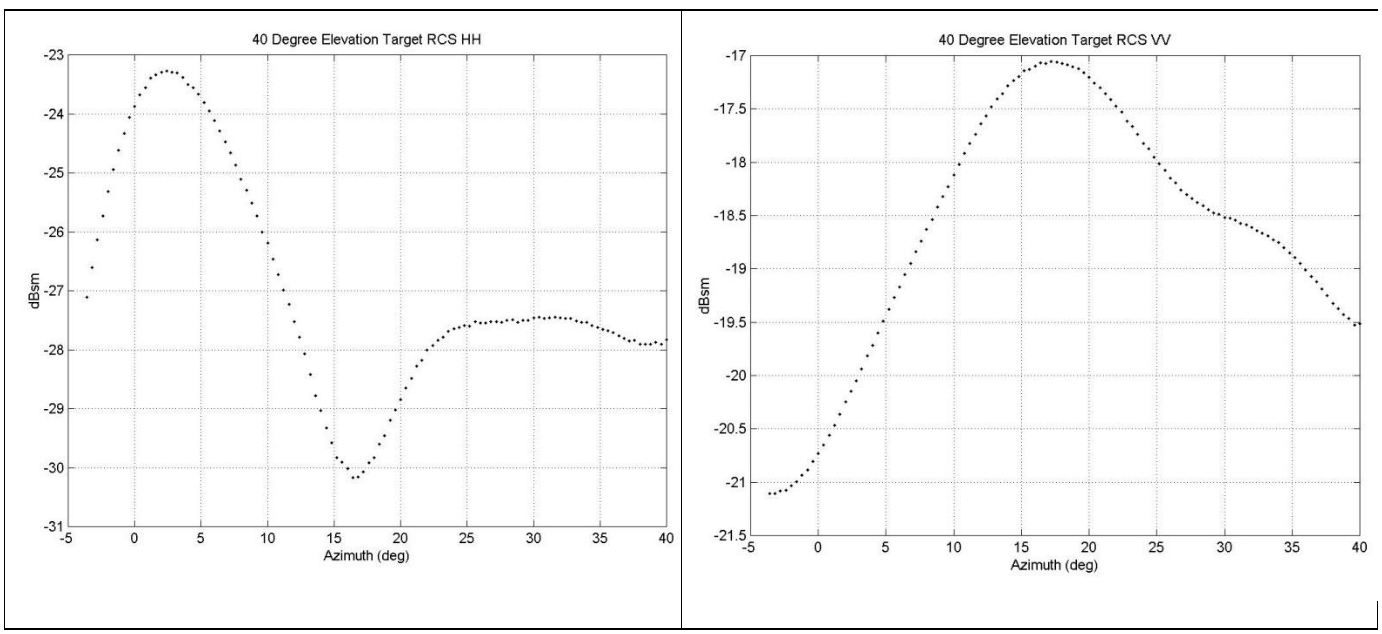


Figure 12 Target RCS 40 Degree Elevation

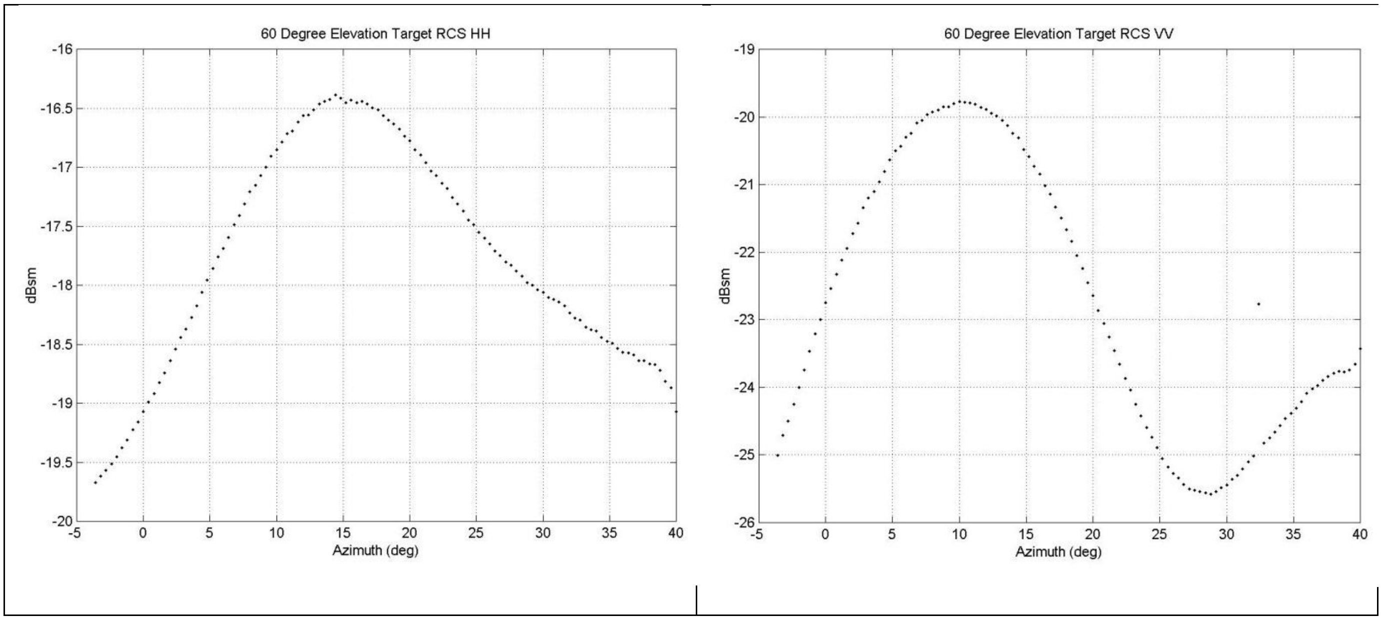


Figure 13 Target RCS 60 Degree Elevation

8. DATA PRODUCTS/DELIVERABLES

The following products are deliverable to MAV6 at the end of the contract.

- Matlab target.mat file with complex calibrated data .
- "elevation.docx" file with additional documentation on measurement data.
- Final report (this document) with experiment procedures and descriptions.

The "target.mat" file contains the complex calibrated RCS data. The variables have the format:

TgtRCS	HH	10	a
Prefix	HH or VV depending on polarization	Elevation angle set 10,20 etc.	a,b,c etc.

It is setup as a 2 element array. For example: TgtRCSHH10a(1) is the azimuth values in degrees and TgtRCSHH10a(2) is the complex calibrated data. The Matlab command to get dBsm values is:

20*log10(abs(TgtRCSHH10a(2)).

The command to plot the RCS versus azimuth would be:

plot(TgtRCSHH10a(1), 20*log10(abs(TgtRCSHH10a(2))))

Elevation.docx gives additional elevation information calculated from the measurement geometry described in section 5 on the variables contained in target.mat.

9. CONCLUSIONS

- The ARSIL chamber was successfully converted to make measurements at X-band.
- Several calibration targets were measured and compared to each other and to theoretical values. The large sphere yielded the best results and agreed with the 5.5 inch trihedral.
- RCS measurements of the six inch plate compared favorably to theoretical values, especially the horizontal elevation.
- Noise and empty target mount measurements indicated low contribution to RCS measurements.
- Target cut measurements were made at 10 degree increments from 0 to 80 degrees in elevation. Each cut consisted of 110 measurements from -4 degrees to 40 degrees at 0.4 degree increments.

The measurements were successful although there may have been a few points where the target mount may have affected the measurement. Further investigation could be made should full characterization of the target be desired.

With the target RCS being so small more consideration could be given to reducing the RCS of the mount particularly the HH polarization. Additional shaping and reduction of material could reduce RCS. Full characterization of the mount would also improve the measurement.

10. REFERENCES

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