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First Trial with DRMS Using a Suspended Sphere as Calibration Target

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First Trial with DRMS Using a Suspended Sphere as Calibration Target (U)

G. Farley
Defence Research Establishment Ottawa

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
DREO TM 1999-062
February 1999

National Defence Défense nationale

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Electronic Countermeasures Section

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ABSTRACT

This report documents a trial conducted with the DREO Radar Cross Section (RCS) Measurement System (DRMS). The purpose of the trial was to test the functionality of DRMS using a sphere as a calibration target. A detailed description of the trial and the processing of the data is given along with suggestions for future work.

RÉSUMÉ

Ce rapport documente un essai effectué avec le Système de Mesures RCS du Centre de Recherche pour la Défense à Ottawa (SMRC). L'objet de cet essai était de vérifier la fonctionnalité du SMRC lorsqu'une sphère est utilisé comme cible de calibration. Une description détaillée de l'essai et du traitement des données est donnée avec des suggestions pour les travaux futurs

EXECUTIVE SUMMARY

The Radar Cross Section (RCS) of a platform is a measure of how detectable it is to radar. The effectiveness of Electronic Countermeasures (ECM) to protect a given platform is highly dependent on the RCS of that platform. It is for that reason that the ECM section of the Defence Research Establishment Ottawa (DREO) has undertaken the development of DRMS (DREO RCS Measurement System).

DRMS was used to make RCS measurements of various platforms. It made absolute RCS measurements by using known calibration targets. Previously, trihedrals were used as calibration targets. However, to reduce the multipath of the calibration measurements, it is proposed to henceforth use spheres as calibration targets. To test the functionality of DRMS with spheres as calibration targets, a trial was conducted by DREO at Area 5, which is an area along the Ottawa River that belongs to the Department of National Defence (DND).

This report gives a detailed description of the trial conducted and the analysis of the collected signals. This analysis revealed that there was a great difference between the measurements and what was to be expected. For that reason, a number of suggestions are given for future work to resolve that discrepancy.

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1.0 INTRODUCTION

The DREO RCS Measurement System (DRMS) has been used to measure the absolute Radar Cross Section (RCS) of various military targets [1]. In the past, trihedral corner reflectors were used as calibration targets. Since the RCS of those corner reflectors were known because they had been measured in a laboratory, absolute RCS measurements could be obtained. In an effort to reduce the multipath in the calibration measurements, DREO now wishes to use spheres instead of corner reflectors. These spheres can be suspended with helium balloons such that they only have the sky as background during the calibration collections.

In order to test the functionality of DRMS with this new method of calibration, a trial was conducted at Area 5. This area is along the Ottawa River and belongs to DND. This trial was conducted on 28 July 1998. A sphere measuring approximately 30 centimetres was used to calibrate. The sphere was elevated using helium balloons such that its background was the sky. This ensured that minimum background clutter was included in the calibration measurements. The measurement target used was a trihedral that was previously measured in the David Florida Laboratory (DFL) [2]. All data collections followed the same pattern: two calibrations were collected, followed by two RCS measurements, and finally two more calibrations were again collected.

This report documents the trial that was conducted and gives suggestions for future work. Section 2.0 gives details of the data collections performed. Section 3.0 outlines the processing that was done on the collections: the System Configuration parameters that were used and why, the results of the data processing performed, and an analysis of those results. Finally, section 4.0 gives suggestions for future work as a result of this trial.

2.0 COLLECTION

Forty-two sets of measurements were performed and the trial matrix that gives the details of those measurements is shown in Table 1. The calibration target used was a 30-cm sphere suspended by helium balloons. The measured target was a trihedral that is commonly called the *DREO large corner reflector*. This trihedral was measured in the David Florida Laboratory (DFL) anechoic chamber [2] and is one of the calibration targets used in the DREO RCS Data Processing Software (as part of the System Configuration definition). It should be noted that all the measurements performed used a pulse width of 600 ns and a pulse repetition frequency (PRF) of 10 kHz. A manual sampling mode was used and the distance to the measured object was manually recorded and is shown in Table 1. A 20-dB attenuator was used to prevent the saturation of the A/D converter as is indicated in the trial matrix. It should be noted that HH refers to the fact that the polarisation of the transmit and receive antennas was horizontal. The video camera that is aligned with the antennas allowed observations during the measurements and those are noted in Table 1. For the RCS measurements, the duration of data collection was noted and has been inserted in the OBSERVATIONS column of Table 1. A column has been inserted to this table to indicate the number of bursts contained in each file, and each one of those bursts contains 100 pulses.

Table 1: Trial Matrix for Measurements of DREO Large Corner Reflector (28 July 98)

FILE #	TYPE	BURSTS	FREQUENCY	OBSERVATIONS
1	Calibration	5	9.0 GHz	HH, 20 dB Attenuation used, 247 meters,
2	Calibration	6	9.0 GHz	HH, 20 dB Attenuation used, 247 meters,
3	RCS MEASUREMENT	201	9.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes, not a square pulse on the A-Scope display
4	RCS MEASUREMENT	205	9.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes, the antenna moved above the target during measurements
5	Calibration	5	9.0 GHz	HH, 20 dB Attenuation used, 247 meters,
6	Calibration	4	9.0 GHz	HH, 20 dB Attenuation used, 247 meters,
7	Calibration	4	11.0 GHz	HH, 20 dB Attenuation used, 247 meters,
8	Calibration	5	11.0 GHz	HH, 20 dB Attenuation used, 247 meters,
9	RCS MEASUREMENT	201	11.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes
10	RCS MEASUREMENT	201	11.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes
11	Calibration	4	11.0 GHz	HH, 20 dB Attenuation used, 247 meters,
12	Calibration	4	11.0 GHz	HH, 20 dB Attenuation used, 247 meters,
13	Calibration	4	13.0 GHz	HH, 20 dB Attenuation used, 247 meters,
14	Calibration	5	13.0 GHz	HH, 20 dB Attenuation used, 247 meters,
15	RCS MEASUREMENT	202	13.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes
16	RCS MEASUREMENT	204	13.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes
17	Calibration	5	13.0 GHz	HH, 20 dB Attenuation used, 247 meters,
18	Calibration	5	13.0 GHz	HH, 20 dB Attenuation used, 247 meters,
19	Calibration	5	15.0 GHz	HH, 20 dB Attenuation used, 247 meters,
20	Calibration	5	15.0 GHz	HH, 20 dB Attenuation used, 247 meters,
21	RCS MEASUREMENT	203	15.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes
22	RCS MEASUREMENT	204	15.0 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes

23	Calibration	4	15.0 GHz	HH, 20 dB Attenuation used, 247 meters,
24	Calibration	4	15.0 GHz	HH, 20 dB Attenuation used, 247 meters,
25	Calibration	5	9 & 15 GHz	HH, 20 dB Attenuation used, 247 meters,
26	Calibration	5	9 & 15 GHz	HH, 20 dB Attenuation used, 247 meters,
27	RCS MEASUREMENT	203	9 & 15 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes, the antenna moved during measurements
28	RCS MEASUREMENT	203	9 & 15 GHz	HH, 20 dB Attenuation used, 247 meters,
29	Calibration	4	9 & 15 GHz	HH, 20 dB Attenuation used, 247 meters,
30	Calibration	5	9 & 15 GHz	HH, 20 dB Attenuation used, 247 meters, the antenna moved to the right during the measurements.
31	Calibration	5	9,12,15 GHz	HH, 20 dB Attenuation used, 247 meters,
32	Calibration	5	9,12,15 GHz	HH, 20 dB Attenuation used, 247 meters,
33	RCS MEASUREMENT	204	9,12,15 GHz	HH, 20 dB Attenuation used, 247 meters, 2 minutes
34	RCS MEASUREMENT	304	9,12,15 GHz	HH, 20 dB Attenuation used, 247 meters, 3 minutes
35	Calibration	5	9,12,15 GHz	HH, 20 dB Attenuation used, 247 meters,
36	Calibration	5	9,12,15 GHz	HH, 20 dB Attenuation used, 247 meters,
37	Calibration	5	9.0 GHz	HH, 20 dB Attenuation used, 256 meters,
38	Calibration	4	9.0 GHz	HH, 20 dB Attenuation used, 256 meters,
39	RCS MEASUREMENT	501	9.0 GHz	HH, 20 dB Attenuation used, 256 meters, 5 minutes
40	RCS MEASUREMENT	602	9.0 GHz	HH, 20 dB Attenuation used, 256 meters, 6 minutes
41	Calibration	5	9.0 GHz	HH, 20 dB Attenuation used, 256 meters,
42	Calibration	5	9.0 GHz	HH, 20 dB Attenuation used, 256 meters,

3.0 PROCESSING

3.1 SYSTEM CONFIGURATION

The collected data was processed using the DRMS Data Processing Software. The system configuration parameters used to process the data are shown in Figure 1.

Calibration Target:	
SPHERE TARGET	
COHERENCY TIMES:	
Calibration Target:	2 ms.
Measurement Target:	10 ms.
Coherency Value:	3 dB
Range Correction:	85 m
DSP OFFSET VALUES:	
I Zero:	32755
Q Zero:	32745

Figure 1: System Configuration settings used.

We have obtained the calibration target coherency time by examining the raw calibration files. The criterion that we have used is to set the coherency time as the time during which the phase does not change by more than $\pi/8$ radians (i.e. 0.39 radians). We call this "$\pi/8$ criterion". Figure 2 is an example of the Raw Data View of the Signal Processing Software of DRMS. This figure represents information on burst 4 of file #1 that is obtained from the *View Raw Data* option of the Signal Processing Software of DRMS. It should be noted that the PRF used is 10 kHz such that the total burst of 100 pulses represents a time span of 10 ms.. We can see that the phase changes by more than $\pi/8$ radians during one burst. This means that the sphere is not stationary and this is understandable. From the phase plot in Figure 2 we can see that selecting a coherency time of 2 ms. will not violate the above "$\pi/8$ criterion". Having considered the other bursts and calibration files, we conclude that a *Calibration Target Coherency Time* of 2 ms. (c.f. Figure 1) is adequate for many bursts. However, there are bursts that should use a shorter coherency time. For example, Figure 3 shows burst 3 of file 7 and we can see that the "$\pi/8$ criterion" would require that a calibration target coherency time smaller than 0.7 ms. be selected. In addition, we have observed that the "$\pi/8$ criterion" would even give different values depending on which bursts are considered *within the same file* because the phase does not change at the same rate for different burst collection within the same file. This can be confirmed by considering Figure 4, which shows burst 4 of file 7, where a calibration target coherency time of 2 ms. would be adequate. We have not done an exhaustive analysis, but we noted that the following bursts had a large phase change: file 7 bursts 2 and 3; file 14 bursts 3 and 4; file 18 bursts 1,2,3,and 4; file 20 bursts 2 and 3; file 23 bursts 1, 3, and 4.

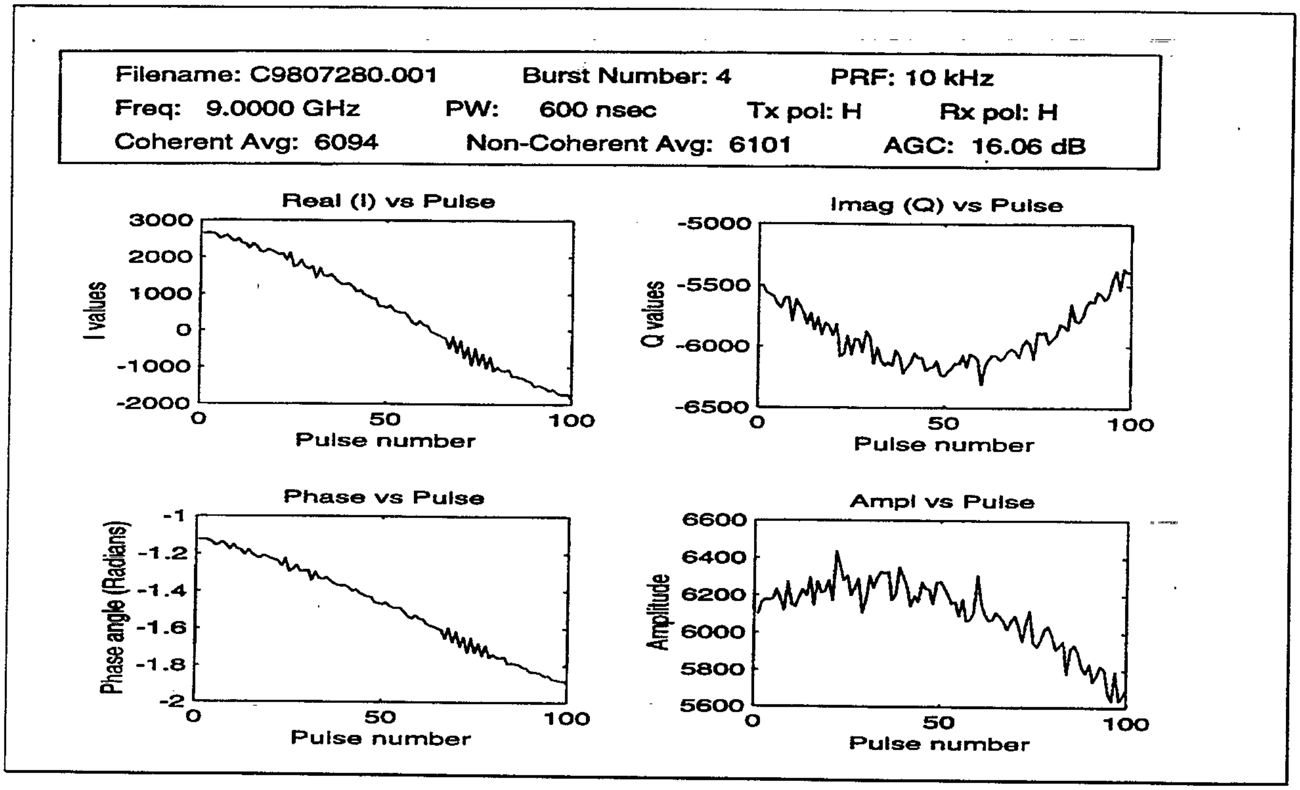

Figure 2: File 1 Burst 4 (Raw Data view of Signal Processing software of DRMS).

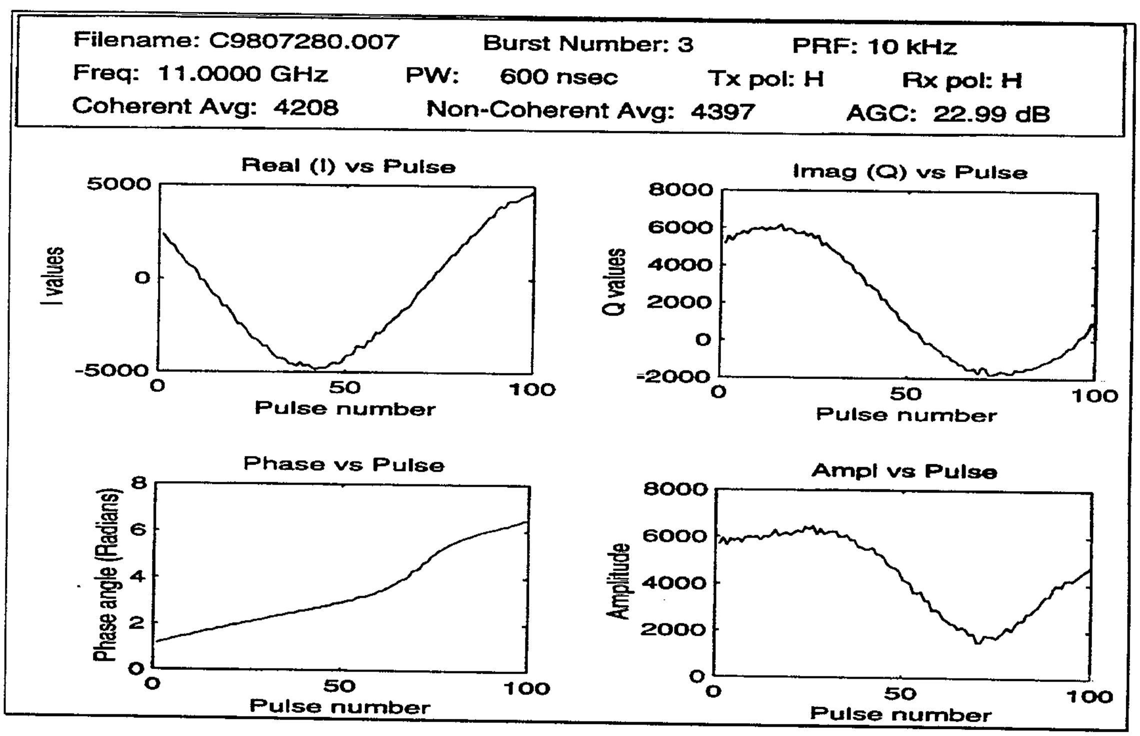

Figure 3: File 7 Burst 3 (Raw Data view of Signal Processing software of DRMS).

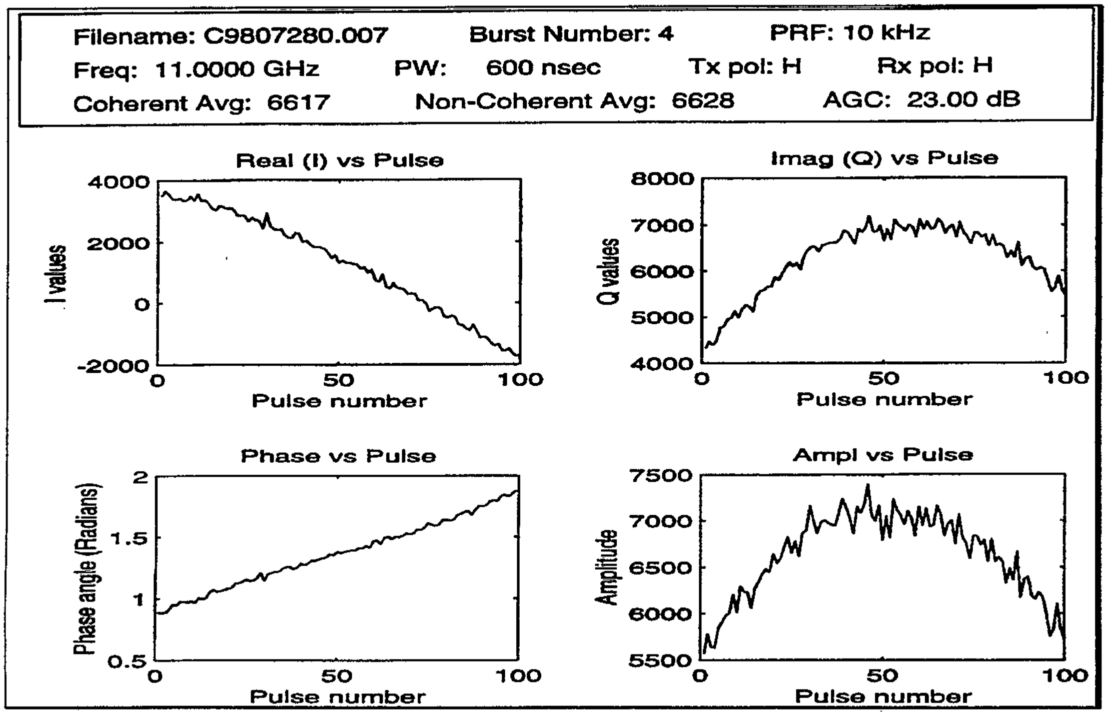

Figure 4: File 7 Burst 4 (Raw Data view of Signal Processing software of DRMS).

Similarly, we have obtained the Measurement Target coherency time by examining the raw measurement files. Figure 5 represents information on burst 100 of file 3. We can see that the phase does not change by $\pi/8$ radians for the duration of a burst. Hence, a *Measurement Target Coherency Time* of 10 ms. (c.f. Figure 1) is acceptable. We have also verified other bursts and measurement files and have seen that this value is adequate.

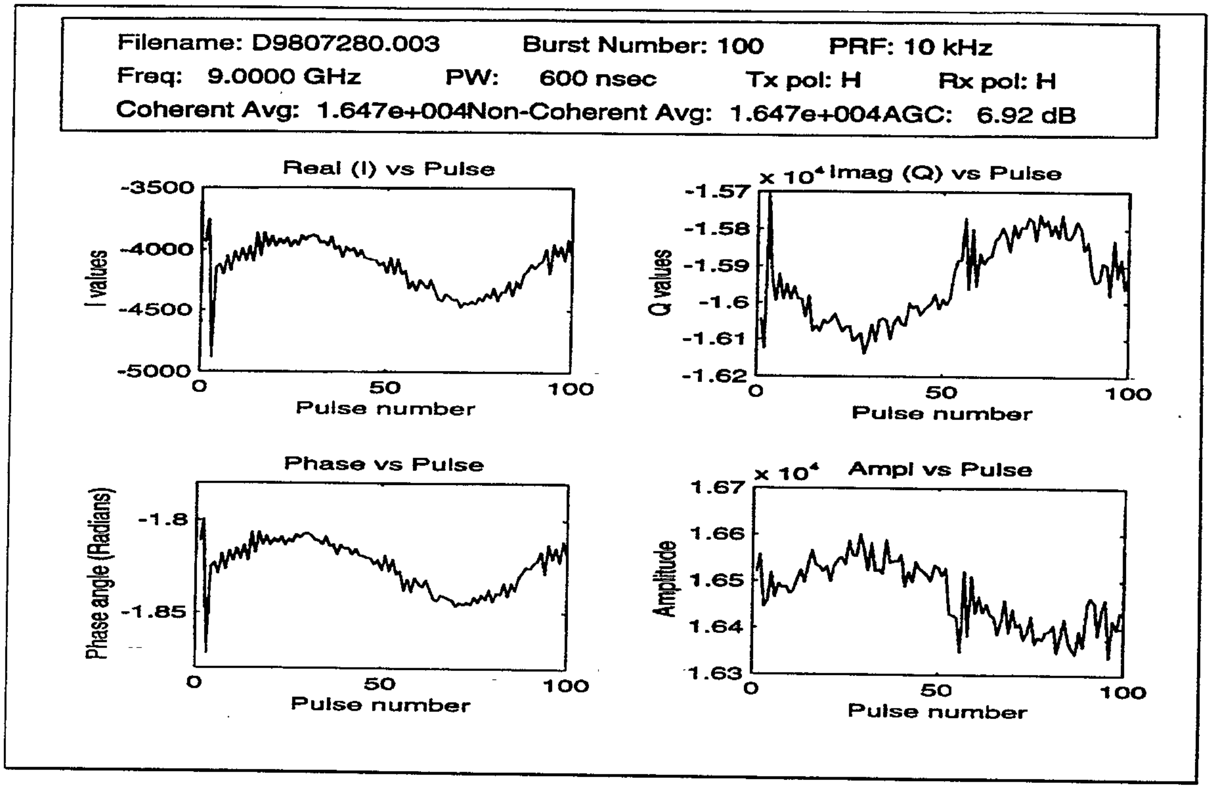

Figure 5: File 3 Burst 100 (Raw Data view of Signal Processing software of DRMS).

The *Coherency Value* (c.f. Figure 1) is the tolerance to be used by the processing software to determine whether the calibration target is coherent. The burst coherent average of the RCS calculated using the Calibration Target Coherency Time is compared to the non-coherent average. If the two values are not within the tolerance entered in this field, the calibration is not considered valid. The recommended value is 3 dB [3].

Range correction allows the user to account for delays in the radar signal transmit or receive circuitry. The target range stored in the data files includes the leakage pulse and pulsewidth of the transmitted signal. This requires that we do an actual measurement of the distance computed by DRMS, which we did not have during the trial at Area 5. For that reason, we have used the value that was measured during the SWG-4 trial [4], that is 85 m. This is reasonable because none of the components of the DRMS system have been changed.

DSP Offset Values (c.f. Figure 1) describe the true "zero" values of the I and Q signals sampled by the DT2838 A/D. We have used the same values that were obtained during the SWG-4 trial. This is probably reasonable.

3.2 DATA PROCESSING

We have processed the data described in Table 1 using the system configuration parameters that are given in Figure 1. The Signal Processing Software of DRMS calculates the RCS plots of collected data. Figure 6 gives the RCS of file #3 when file #1 is used as a calibration file and Figure 7 gives the Summary Page. From the Summary Page we get the average RCS which is 6.67 dBSM. The average RCS have been obtained for all the data collected during this trial and the results are tabulated. Table 2 gives the average RCS for the collections of Table 1 that include only one frequency. Table 3 gives the average RCS for the collections at two frequencies and Table 4 gives the average RCS for the collections at three frequencies. We can see that there is an appreciable difference in the average RCS of each data file depending on the calibration file used. For that reason, we have included in those tables a row that gives the extent of that variation. Conversely, we see from those tables that there is not much variation in the average RCS of different data collections when the same calibration file is used and an extra column in those tables shows this.

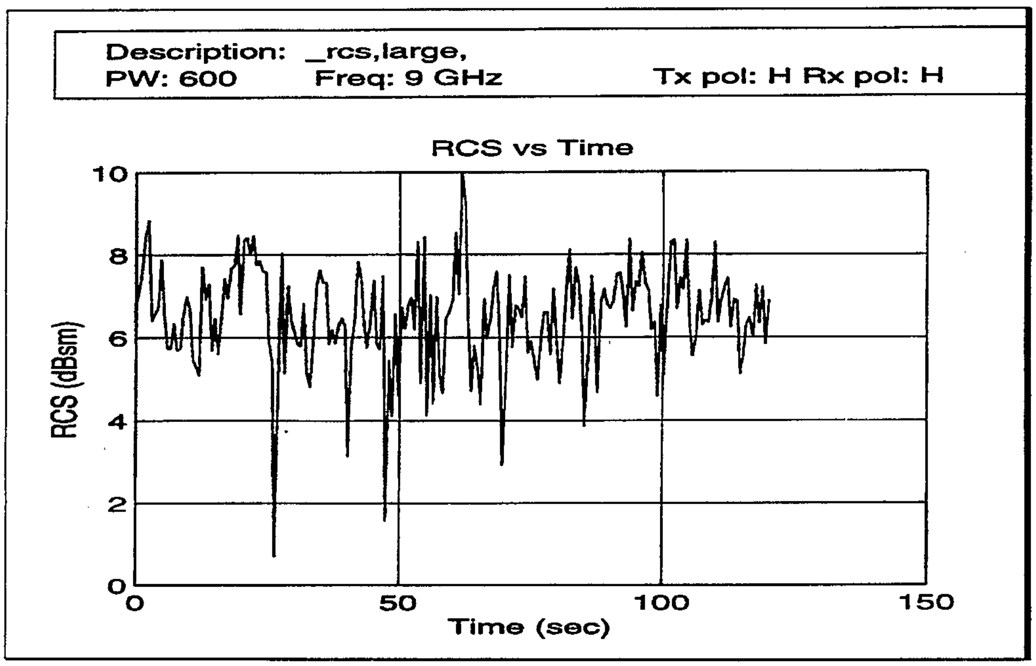

Figure 6: RCS of file 3 with file 1 as calibration.

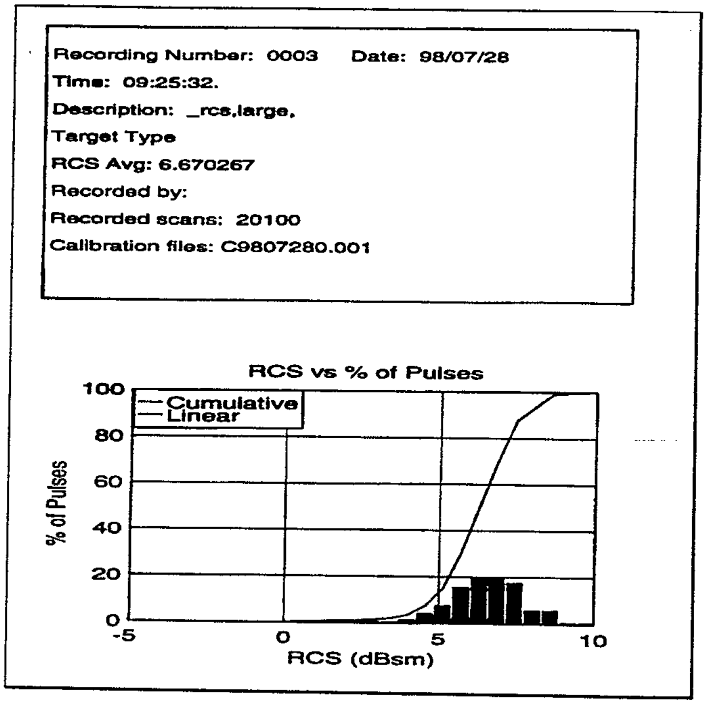

Figure 7: Summary Page of file 3 with file 1 as calibration.

Table 2: Average RCS Measurements at One Frequency

Calibration file #	RCS of measurement file #3 at 9.0 GHz, 2 minutes	RCS of measurement file #4 at 9.0 GHz, 2 minutes	Difference: Col 2 – Col 3
1	6.7 dB	5.5 dB	1.2
2	6.2 dB	5.0 dB	1.2
5	8.6 dB	7.4 dB	1.2
6	9.5 dB	8.3 dB	1.2
Variation (dB)	3.3	3.3	0.0
Calibration file #	RCS of measurement file #9 at 11.0 GHz, 2 minutes	RCS of measurement file #10 at 11.0 GHz, 2 minutes	Difference: Col 2 – Col 3
7	12.57 dB	12.52 dB	0.05
8	10.20 dB	10.14 dB	0.06
11	14.01dB	13.95 dB	0.06
12	12.19 dB	12.13 dB	0.06
Variation (dB)	3.81	3.81	0.0

Calibration file #	RCS of measurement file #15 at 13.0 GHz, 2 minutes	RCS of measurement file #16 at 13.0 GHz, 2 minutes	Difference: Col 2 – Col 3
13	15.63 dB	15.29 dB	0.34
14	15.27 dB	14.93 dB	0.34
17	11.54 dB	11.19 dB	0.35
18	15.98 dB	15.63 dB	0.35
Variation (dB)	4.44	4.44	0.0
Calibration file #	RCS of measurement file #21 at 15.0 GHz, 2 minutes	RCS of measurement file #22 at 15.0 GHz, 2 minutes	Difference: Col 2 – Col 3
19	14.96 dB	15.65 dB	-0.69
20	16.85 dB	17.54 dB	-0.69
23	17.25 dB	17.94 dB	-0.69
24	17.09 dB	17.78 dB	-0.69
Variation (dB)	2.29	2.29	0.0
Calibration file #	RCS of measurement file #39 at 9.0 GHz, 5 minutes	RCS of measurement file #40 at 9.0 GHz, 6 minutes	Difference: Col 2 – Col 3
37	9.38 dB	9.04 dB	0.34
38	11.59 dB	11.25 db	0.34
41	10.28 dB	9.94 dB	0.34
42	13.24 dB	12.90 dB	0.34
Variation (dB)	3.86	3.86	0.0

Table 3: Average RCS Measurements at Two Frequencies

Calibration file #	file #27 at 9.0 GHz	file #28 at 9.0 GHz	C2 – C3	file #27 at 15.0 GHz	file #28 at 15.0 GHz	C5 – C6
25	8.37 dB	8.04 dB	0.33	15.94 dB	16.30 dB	-0.36
26	10.44 dB	10.10 dB	0.34	19.15 dB	19.50 dB	-0.35
29	8.56 dB	8.23 dB	0.33	16.35 dB	16.71 dB	-0.36
30	10.11 dB	9.78 dB	0.33	19.57 dB	19.93 dB	-0.36
Variation (dB)	2.07	2.06	0.01	3.63	3.63	0.0

Table 4: Average RCS Measurements at Three Frequencies

Cal file #	file #33 9.0 GHz	file #34 9.0 GHz	Δ	file #33 at 12.0 GHz	file #34 at 12.0 GHz	Δ	file #33 at 15.0 GHz	file #34 at 15.0 GHz	Δ
31	15.56 dB	16.28 dB	-.7	16.02 dB	16.40 dB	-.4	18.45 dB	18.50 dB	-.1
32	11.59 dB	12.32 dB	-.7	13.42 dB	13.81 dB	-.4	17.30 dB	17.39 dB	-.1
35	7.33 dB	8.06 dB	-.7	15.48 dB	15.87 dB	-.4	18.52 dB	18.60 dB	-.1
36	7.77 dB	8.50 dB	-.7	16.09 dB	16.47 dB	-.4	22.18 dB	22.27 dB	-.1
Δ (dB)	8.23	8.22	.01	2.67	2.66	.01	4.88	4.88	0.0

3.3 ANALYSIS OF RESULTS

Since the corner reflector measured was previously measured in DFL's anechoic chamber [2], we can verify the accuracy of the measurements performed at Area 5. Figure 8 gives the result of the DFL measurements of the corner reflector that was the target measured in this trial. This figure gives the monostatic vertical polarisation case. The measurements that we did at Area 5 were done with DRMS, which is a bistatic radar in its present configuration. The bistatic angle was calculated to be 0.2 degrees because there is a separation between the transmit and receive antenna of approximately 1 m. and the targets were approximately 250 m. away. In addition, the measurements at Area 5 used the horizontal polarisation. However, from [5] it is determined that the DFL values obtained in Figure 8 are applicable for comparison because the bistatic angle is small and because of the geometry of the corner reflector. For comparison, the applicable values obtained from the DFL measurements in Figure 8 are given in Table 5.

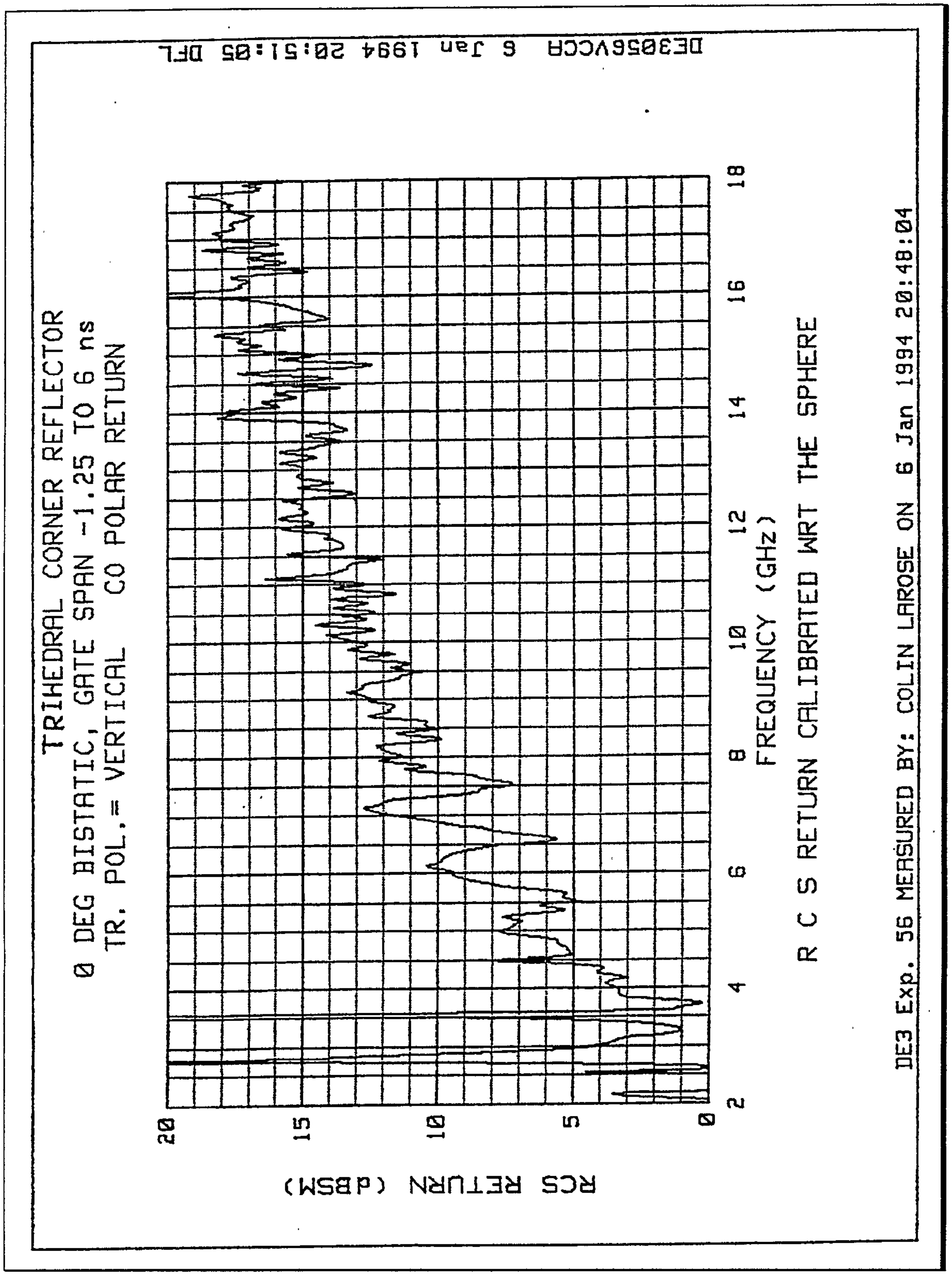

Figure 8: DFL measurements of corner reflector.

Table 5: Measurements of the Corner Reflector in an Anechoic Chamber

FREQUENCY (GHZ)	RCS (DBSM)
9	12
11	13.5
12	14
13	15
15	16

After considering Table 2, Table 3, and Table 4, we can make the following two observations:

1) The Average RCS measurement is fairly stable. This can be verified by comparing the average RCS of two consecutive RCS measurements when the same calibration file is used for both. The maximum difference observed in the above tables is 0.73 dB.
2) The calibration measurement is not stable. This can be verified by comparing the average RCS of the same RCS measurement when different calibration files are used. The maximum difference observed in the above tables is 8.23 dB.

We note that the RCS measurements of files 3 and 4 in Table 2 give substantially lower values compared to those in files 39 and 40. However, we noted in Table 1 that there were anomalies observed during the collections of files 3 and 4. Files 39 and 40 in Table 2 (also at 9 GHz) give values that are closer to the DFL value.

For the RCS measurements at one frequency (Table 2), we note that the "true" RCS value of the corner reflector (i.e. measured in an anechoic chamber by DFL) falls within the variation of the average RCS. This is not always the case for the RCS measurements at two and three frequencies (Table 3 and Table 4). From Table 1, we see that the calibration files for two and three frequencies do not include a commensurately greater number of bursts with the number of frequencies. For example, files 31 and 32, which are calibration files for the measurement of three frequencies, have the pattern shown in Table 6 and similarly, files 35 and 36 have the pattern shown in Table 7. We see from these tables that two bursts are collected for two of the three frequencies and only one burst is used for the third frequency. This situation is clearly not acceptable when a sphere is used as a calibration target. Indeed, we have observed large variations in the average RCS at one frequency (see Table 2) and most of those calibration files had 4 or 5 bursts as can be seen in Table 1. That means that 4 or 5 bursts of 100 pulses per frequency are not enough to reduce the variation of the calibration measurement when a suspended sphere is used as a calibration target.

Table 6: Burst Pattern for Files 31 and 32

Burst Number	Frequency (GHz)
1	15
2	9
3	12
4	15
5	9

Table 7: Burst Pattern for Files 35 and 36

Burst Number	Frequency (GHz)
1	9
2	12
3	15
4	9
5	12

4.0 FUTURE WORK

From this trial, we can identify a number of areas that require further work:

a) Using a sphere to calibrate as opposed to a trihedral corner reflector is better because it reduces the background clutter if the sphere is raised such that it has the sky as background. However, the suspended sphere moves with the wind. We should investigate the possibility and advantage of compensating for that.

b) When suspending a sphere as a calibration target, we need to change the calibration target coherency time for every burst since it is clear that the coherency time varies greatly from burst to burst.

c) We need to modify the data acquisition software when a suspended sphere is used as a calibration target. In particular, we need to increase the number of bursts collected and make this commensurate with the number of frequencies included in the collection.

5.0 CONCLUSIONS

Absolute RCS measurements were previously obtained with the DREO RCS Measurement System (DRMS) by using a trihedral as a calibration target. To reduce the multipath in the calibration measurements, a suspended sphere will instead be used as a calibration target. For that reason, a trial was conducted to test the functionality of DRMS with a sphere as a calibration target and this report documented the results.

The trial was described and a detailed description of the collected data was given. The collected data was processed with the Signal Processing software of DRMS. Since a system configuration was required, it was specified and relevant explanations and justifications were given. The data was processed and average RCS measurements were obtained. Since the measured target had previously been measured in a laboratory, a more detailed analysis was possible and was given. Finally, suggestions for future work have been identified.

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[4] Atlantis Scientific, "Analysis of Data and Development of Improvements for the DREO RCS Measurement System (DRMS)", 14 May 1998.

[5] Private discussion with Dr. Satish Kashyap from DREO, 9 December 1998.

7.0 ACKNOWLEDGEMENTS

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(U) This report documents a trial conduced with the DREO RCS Measurement System (DRMS). The purpose of the trial was to test the functionality of DRMS using a sphere as a calibration target. Detailed description of the trial and the processing of the data is given along with the resultant future work required.

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Calibration
Trial
Sphere

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