Radar Cross-Section (RCS) Measurements of a Dismount with Rocket-Propelled Grenade (RPG) Launcher at Ka-Band

by Suzanne R. Stratton and Robert L. Bender

ARL-TR-3855

July 2006

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Radar Cross-Section (RCS) Measurements of a Dismount with Rocket-Propelled Grenade (RPG) Launcher at Ka-Band

Suzanne R. Stratton and Robert L. Bender
Sensors and Electron Devices Directorate, ARL
REPORT DOCUMENTATION PAGE

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<td>The U.S. Army Research Laboratory’s (ARL’s) Radio Frequency and Electronics Division sponsored and conducted a series of measurements to characterize the millimeter wave (MMW) signatures of one Soldier carrying a rocket-propelled grenade (RPG) launcher with grenade at 34 GHz over three depression angles and for three different body postures: prone, kneeling, and standing. The measurements were taken by ARL at its outdoor signature research facility at Aberdeen Proving Ground, MD, on 6 through 18 August 2003. A statistical summary of the measurements is presented in this report, along with a full set of radar cross section (RCS) plots of the measurements for four linear polarization combinations. Measurements of the Soldier holding an RPG launcher show that the mean RCS of the target decreases with decreasing body profile over all depression angles. The mean RCS does not depend on launcher angle or depression angle in most cases. The co-polarized means are much more sensitive than the cross-polarized terms to changes in body posture and launcher angle. The RPG launcher contributes the largest component to the signature.</td>
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Acknowledgments

The authors wish to acknowledge Donald Testerman, SEDD/ARL, for his able assistance in setting up and documenting the targets and in conducting the measurements.
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1. Introduction

There is much interest today in the detection and classification of troop dismounts in a variety of environments. Before detection and classification algorithms can be developed, a basic understanding of the signature associated with a single dismount must be acquired. The U.S. Army Research Laboratory (ARL) has a triband millimeter wave (MMW) polarimetric inverse synthetic aperture radar (ISAR) that is used for a broad range of MMW research, including target signature measurements. High-resolution radar cross section (RCS) measurements of a dismount taken with this equipment can be used in computer simulations that combine this information with data about various types of environmental background to assist in the radar hardware and waveform design process for detection optimization and to test classification algorithms.

ARL’s Radio Frequency and Electronics Division sponsored a series of measurements to characterize the MMW signature of a man holding a rocket-propelled grenade (RPG) launcher with (inert) grenade at 34 GHz over three depression angles and for three body positions. The measurements were made by ARL at its outdoor signature research facility at Aberdeen Proving Ground (APG), MD, over the two-week period of 6 through 18 August 2003. A statistical summary of the measurements is presented in this report, along with the full set of RCS plots of the measurements for linear polarizations.

2. Instrumentation Description

The 34-GHz fully polarimetric instrumentation radar at the ARL signature research facility was used to collect the data. The radar uses a stepped frequency waveform. A listing of the important system parameters at Ka-Band is given in table 1, while a full description of the operation of the radar and data acquisition system is presented in ARL-TR-1421 (Stratton et al., 1997).
Table 1. Radar characteristics.

<table>
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<th>Parameter</th>
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<td>Center frequency</td>
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</tr>
<tr>
<td>RF bandwidth</td>
<td>1599.359 MHz</td>
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<tr>
<td>Frequency step</td>
<td>6.272 MHz</td>
</tr>
<tr>
<td>Peak transmitted power</td>
<td>+17 dBm</td>
</tr>
<tr>
<td>Pulse width</td>
<td>100 ns</td>
</tr>
<tr>
<td>Pulse repetition frequency</td>
<td>1.0 MHz</td>
</tr>
<tr>
<td>Transmitted polarization</td>
<td>V and H</td>
</tr>
<tr>
<td>Received polarization</td>
<td>V and H</td>
</tr>
<tr>
<td>3-dB beam width (one way)</td>
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<tr>
<td>System noise figure</td>
<td>5.4 dB SSB</td>
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<tr>
<td>Polarization isolation</td>
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Notes: V = vertical
       H = horizontal
       SSB = single sideband

Measurements made with the system are taken with the radar mounted on an elevator on a 125-ft tower. The radar is pointed at an in-ground turntable 153 ft away. The target sits on this turntable. Figure 1 shows the range setup. A television camera is boresighted with the radar and provides a video image of the target that is recorded as the target rotates. A 35-mm camera is also boresighted with the radar, and photographs are taken every 45 degrees of azimuth during the rotation. Target rotation is always counterclockwise. A complete rotation at 34 GHz takes about 10 min. A fully calibrated RCS plot can be ready 10 min after the measurement. A series of ISAR images displayed on a monitor as a “movie” is available 10 to 15 min after each measurement.

(a) ARL’s high-resolution fully polarimetric radars. (b) View of the tower from the turntable.

Figure 1. Measurement setup at air base range 8, APG, MD.
3. Test Setup and Procedures

A rocket-propelled grenade launcher and RPG-7 were delivered via the National Ground Intelligence Center (NGIC) for these signature measurements. The main objective was to characterize the RCS of the man holding the launcher and to obtain some high-quality ISAR imagery. To do this, it was also necessary to characterize the radar stability and accuracy of the measurements by measuring a calibrated reflector at each of the depression angles used in the test. The test plan called for measurements of the man at three depression angles at 34 GHz. The exact sequence of measurements is shown in table 2, along with the assigned target numbers. A complete record of the measurements and radar calibrations is in the logbook synopsis in appendix A.

Table 2. Test matrix.

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<td>TGT77AI</td>
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<td>2</td>
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<tr>
<td></td>
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<td>TGT77DD</td>
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A trihedral corner reflector of known cross section was placed on the turntable for an initial set of measurements at the required depression angles. This provided a method to check the accuracy of the measurement process at each depression angle, which could be used to attest to the accuracy of subsequent measurements of the target. At each depression angle, the trihedral was adjusted in elevation so that the face was perpendicular to the line of sight to the antenna, providing for the maximum return. All data were calibrated in decibels relative to one square meter (dBsm). Trihedral data were collected at 34 GHz. The RCS measurements are different from the known value by no more than 0.8 dB. In another report (Stratton et al., 1997), the repeatability of measurements is shown to be less than 1 dB.

Figure 2 shows the RPG launcher that was used in the measurements at Air Base Range 8. The turntable measurements were taken at depression angles of 2, 5, and 15 degrees, with the antenna boresight aimed directly in the center of mass of the man. The body posture of the man changed from standing to kneeling to prone during the course of the measurements, and the position of the RPG launcher the man was holding changed from 0, 22.5, 45, and 90 degrees from the horizontal. During a target rotation, the radar transmitted vertical and horizontal polarizations, alternating between four vertical transmit pulses and four horizontal transmit pulses. Both vertical (V) and horizontal (H) receiver channels were recorded to provide fully polarimetric data.

The system was calibrated before and after each measurement. A detailed description of the calibration method is given in ARL-MR-318 (Bender, 1996).
Table 3a shows the summary statistics taken from the plots of the target measurements for the
vertical-vertical (VV) polarization combination at 34 GHz and 2-degrees depression angle, with
the man turned facing aft with respect to the radar at the start of the rotation. Table 3b gives the
same statistics for the measurements made at a depression angle of 5 degrees, and table 3c gives
the results when the depression angle is 15 degrees.
Table 3a. RCS summary statistics for the man with RPG at 2-degrees depression angle for VV polarization in dBsm.

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<td>−4.8</td>
<td>6.7</td>
</tr>
<tr>
<td>22.5</td>
<td>kneeling</td>
<td>−6.6</td>
<td>−7.4</td>
<td>8.4</td>
</tr>
<tr>
<td>45</td>
<td>standing</td>
<td>−4.4</td>
<td>−5.2</td>
<td>6.8</td>
</tr>
<tr>
<td>45</td>
<td>kneeling</td>
<td>−5.0</td>
<td>−6.4</td>
<td>7.3</td>
</tr>
<tr>
<td>90</td>
<td>standing</td>
<td>−4.4</td>
<td>−4.8</td>
<td>6.8</td>
</tr>
<tr>
<td>No RPG</td>
<td>standing</td>
<td>−6.1</td>
<td>−6.6</td>
<td>8.0</td>
</tr>
<tr>
<td>No RPG</td>
<td>kneeling</td>
<td>−9.7</td>
<td>−10.4</td>
<td>9.9</td>
</tr>
<tr>
<td>No RPG</td>
<td>prone</td>
<td>−17.4</td>
<td>−17.8</td>
<td>12.4</td>
</tr>
</tbody>
</table>

Table 3b. RCS summary statistics for the man with RPG at 5-degree depression angle for VV polarization in dBsm.

<table>
<thead>
<tr>
<th>RPG Angle (°)</th>
<th>Posture</th>
<th>Mean (dBsm)</th>
<th>Median (dBsm)</th>
<th>Standard deviation (dBsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>standing</td>
<td>−5.2</td>
<td>−5.6</td>
<td>7.4</td>
</tr>
<tr>
<td>0</td>
<td>kneeling</td>
<td>−6.4</td>
<td>−7.2</td>
<td>8.2</td>
</tr>
<tr>
<td>0</td>
<td>prone</td>
<td>−8.0</td>
<td>−8.8</td>
<td>9.1</td>
</tr>
<tr>
<td>22.5</td>
<td>standing</td>
<td>−4.4</td>
<td>−5.0</td>
<td>6.8</td>
</tr>
<tr>
<td>22.5</td>
<td>kneeling</td>
<td>−7.0</td>
<td>−7.6</td>
<td>8.6</td>
</tr>
<tr>
<td>45</td>
<td>standing</td>
<td>−4.7</td>
<td>−5.2</td>
<td>7.0</td>
</tr>
<tr>
<td>45</td>
<td>kneeling</td>
<td>−6.1</td>
<td>−6.6</td>
<td>8.0</td>
</tr>
<tr>
<td>90</td>
<td>standing</td>
<td>−5.2</td>
<td>−5.6</td>
<td>7.4</td>
</tr>
<tr>
<td>No RPG</td>
<td>standing</td>
<td>−7.0</td>
<td>−7.4</td>
<td>8.6</td>
</tr>
<tr>
<td>No RPG</td>
<td>kneeling</td>
<td>−7.8</td>
<td>−8.4</td>
<td>9.0</td>
</tr>
<tr>
<td>No RPG</td>
<td>prone</td>
<td>−10.0</td>
<td>−10.8</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Table 3c. RCS summary statistics for the man with RPG at 15-degree depression angle for VV polarization in dBsm.

<table>
<thead>
<tr>
<th>RPG Angle (°)</th>
<th>Posture</th>
<th>Mean (dBsm)</th>
<th>Median (dBsm)</th>
<th>Standard deviation (dBsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>standing</td>
<td>−5.8</td>
<td>−5.8</td>
<td>7.8</td>
</tr>
<tr>
<td>0</td>
<td>kneeling</td>
<td>−6.2</td>
<td>−6.2</td>
<td>8.1</td>
</tr>
<tr>
<td>0</td>
<td>prone</td>
<td>−6.8</td>
<td>−7.2</td>
<td>8.5</td>
</tr>
<tr>
<td>22.5</td>
<td>standing</td>
<td>−14.7</td>
<td>−15.0</td>
<td>11.7</td>
</tr>
<tr>
<td>22.5</td>
<td>kneeling</td>
<td>−15.0</td>
<td>−15.2</td>
<td>11.8</td>
</tr>
<tr>
<td>No RPG</td>
<td>kneeling</td>
<td>−14.2</td>
<td>−15.0</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Table 4a shows the mean RCS values of the measurements for all four linear polarization combinations, 2-degree depression angle, table 4b gives the 5-degree depression angle results, and table 4c gives the 15-degree depression angle results. All the statistics were computed in square meters and then converted to a value with units of dBsm. The full set of RCS polar plots for the vehicle is shown in appendix B.
Table 4a. Mean RCS for four linear polarizations in dBsm, depression angle 2 degrees.

<table>
<thead>
<tr>
<th>RPG Angle (°)</th>
<th>Posture</th>
<th>TVRV (dBsm)</th>
<th>TVRH (dBsm)</th>
<th>THRV (dBsm)</th>
<th>THRH (dBsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>standing</td>
<td>–4.5</td>
<td>–17.1</td>
<td>–17.0</td>
<td>–4.6</td>
</tr>
<tr>
<td>0</td>
<td>kneeling</td>
<td>–6.0</td>
<td>–17.2</td>
<td>–17.2</td>
<td>–6.1</td>
</tr>
<tr>
<td>0</td>
<td>prone</td>
<td>–9.0</td>
<td>–18.4</td>
<td>–18.3</td>
<td>–9.2</td>
</tr>
<tr>
<td>22.5</td>
<td>standing</td>
<td>–4.3</td>
<td>–14.9</td>
<td>–14.8</td>
<td>–4.2</td>
</tr>
<tr>
<td>22.5</td>
<td>kneeling</td>
<td>–6.6</td>
<td>–15.4</td>
<td>–15.3</td>
<td>–6.3</td>
</tr>
<tr>
<td>45</td>
<td>standing</td>
<td>–4.4</td>
<td>–15.4</td>
<td>–15.3</td>
<td>–4.4</td>
</tr>
<tr>
<td>45</td>
<td>kneeling</td>
<td>–5.0</td>
<td>–14.5</td>
<td>–14.6</td>
<td>–5.1</td>
</tr>
<tr>
<td>90</td>
<td>standing</td>
<td>–4.4</td>
<td>–17.5</td>
<td>–17.4</td>
<td>–4.6</td>
</tr>
<tr>
<td>No RPG</td>
<td>standing</td>
<td>–6.1</td>
<td>–19.4</td>
<td>–19.4</td>
<td>–6.0</td>
</tr>
<tr>
<td>No RPG</td>
<td>kneeling</td>
<td>–9.7</td>
<td>–19.9</td>
<td>–19.9</td>
<td>–9.6</td>
</tr>
<tr>
<td>No RPG</td>
<td>prone</td>
<td>–17.4</td>
<td>–22.9</td>
<td>–23.1</td>
<td>–17.0</td>
</tr>
</tbody>
</table>

Notes: TVRV = Transmit Vertical, Receive Vertical.
TVRH = Transmit Vertical, Receive Horizontal.
THRV = Transmit Horizontal, Receive Vertical.
THRH = Transmit Horizontal, Receive Horizontal.

Table 4b. Mean RCS for four linear polarizations in dBsm, depression angle 5 degrees.

<table>
<thead>
<tr>
<th>RPG Angle (°)</th>
<th>Posture</th>
<th>TVRV (dBsm)</th>
<th>TVRH (dBsm)</th>
<th>THRV (dBsm)</th>
<th>THRH (dBsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>standing</td>
<td>–5.2</td>
<td>–16.0</td>
<td>–15.8</td>
<td>–5.1</td>
</tr>
<tr>
<td>0</td>
<td>kneeling</td>
<td>–6.4</td>
<td>–16.5</td>
<td>–16.4</td>
<td>–6.4</td>
</tr>
<tr>
<td>0</td>
<td>prone</td>
<td>–8.0</td>
<td>–17.3</td>
<td>–17.2</td>
<td>–8.3</td>
</tr>
<tr>
<td>22.5</td>
<td>standing</td>
<td>–4.4</td>
<td>–14.4</td>
<td>–14.2</td>
<td>–4.5</td>
</tr>
<tr>
<td>22.5</td>
<td>kneeling</td>
<td>–7.0</td>
<td>–15.7</td>
<td>–15.5</td>
<td>–7.0</td>
</tr>
<tr>
<td>45</td>
<td>standing</td>
<td>–4.7</td>
<td>–15.5</td>
<td>–15.3</td>
<td>–4.9</td>
</tr>
<tr>
<td>45</td>
<td>kneeling</td>
<td>–6.1</td>
<td>–15.8</td>
<td>–15.6</td>
<td>–6.4</td>
</tr>
<tr>
<td>90</td>
<td>standing</td>
<td>–5.2</td>
<td>–17.3</td>
<td>–17.2</td>
<td>–5.4</td>
</tr>
<tr>
<td>No RPG</td>
<td>standing</td>
<td>–7.0</td>
<td>–19.3</td>
<td>–19.2</td>
<td>–6.9</td>
</tr>
<tr>
<td>No RPG</td>
<td>kneeling</td>
<td>–7.8</td>
<td>–17.7</td>
<td>–17.6</td>
<td>–8.1</td>
</tr>
<tr>
<td>No RPG</td>
<td>prone</td>
<td>–10.0</td>
<td>–19.0</td>
<td>–18.8</td>
<td>–10.6</td>
</tr>
</tbody>
</table>

Table 4c. Mean RCS for four linear polarizations in dBsm, depression angle 15 degrees.

<table>
<thead>
<tr>
<th>RPG Angle (°)</th>
<th>Posture</th>
<th>TVRV (dBsm)</th>
<th>TVRH (dBsm)</th>
<th>THRV (dBsm)</th>
<th>THRH (dBsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>standing</td>
<td>–5.8</td>
<td>–13.6</td>
<td>–13.6</td>
<td>–7.7</td>
</tr>
<tr>
<td>0</td>
<td>kneeling</td>
<td>–6.2</td>
<td>–13.8</td>
<td>–13.8</td>
<td>–8.4</td>
</tr>
<tr>
<td>0</td>
<td>prone</td>
<td>–6.8</td>
<td>–14.3</td>
<td>–14.3</td>
<td>–9.1</td>
</tr>
<tr>
<td>22.5</td>
<td>standing</td>
<td>–14.7</td>
<td>–20.9</td>
<td>–21.0</td>
<td>–16.0</td>
</tr>
<tr>
<td>22.5</td>
<td>kneeling</td>
<td>–15.0</td>
<td>–21.3</td>
<td>–21.3</td>
<td>–16.4</td>
</tr>
<tr>
<td>No RPG</td>
<td>kneeling</td>
<td>–14.2</td>
<td>–20.6</td>
<td>–20.6</td>
<td>–15.8</td>
</tr>
</tbody>
</table>

The range of RCS means for TVRV polarization is –4.3 to –15.0 dBsm over all depression angles and RPG angles for the man holding the RPG launcher. In general, as the body posture changes so that the profile of the man decreases (i.e., going from standing to kneeling to prone), the mean RCS decreases. For the man who is not carrying an RPG launcher, the RCS is lower.
for all depression angles and postures than that of the man of corresponding body posture with RPG launcher. The angle of the launcher does not have a significant impact on the mean RCS value for the 2- and 5-degree depression angle, but there is a large change in RCS between the 0- and 22.5-degree launcher angle data for the 15-degree depression angle. The cross-polarized RCS mean values are much lower than the co-polarized means and tend to be less sensitive than the co-polarized mean values to the body posture of the man, although they also follow the general rule of decreasing as the body posture decreases.

It can be seen from the linear RCS curves that the co-polarized measurements show peaks at broadsides for the man holding the RPG launcher, whereas for the man without the launcher, there are no peaks at broadsides. Also, with the man holding the RPG launcher at 90 degrees from the horizontal, the peaks at broadsides are greatly diminished. There are no obvious features that correspond to a man without the launcher, no matter what the body position. The curves are fairly flat over these 360-degree rotations. An examination of the ISAR images for the man with and without the RPG launcher at comparable depression angles reveals that the launcher is by far the most significant part of the signature, as can be seen in figures 3 and 4.

Figure 3. ISAR image of man standing (a) with and (b) without the RPG launcher at 2-degree depression angle, 0-degree RPG angle and 90-degree turntable angle.

Figure 4. ISAR image of man prone (a) with and (b) without the RPG launcher at 2-degree depression angle, 0-degree RPG angle and 90-degree turntable angle.
5. Summary

Measurements of the man holding an RPG launcher show that the mean RCS of the target decreases with decreasing body profile over all depression angles. The mean RCS does not depend on launcher angle or depression angle except for the case of the 22.5-degree launcher angle and 15-degree depression angle. The linear RCS curves are roughly similar for the man without RPG launcher at each depression angle. The co-polarized means are much more sensitive than the cross-polarized terms to the changes in body posture and launcher angle. The RPG launcher contributes the largest component to the signature.
6. References


Appendix A. Logbook Synopsis

8/06/03 Sunny, warm, 70's Operators: Bob Bender
Tim Burcham

RPG Launcher with soldier

tgt77aa  79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77ab  dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ac  dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ad  dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ae  sky @ 34 GHz @ 152 ft, gate 450 ns
tgt77af  Man with RPG standing nose on, 0 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77ag  Man with RPG standing rear on, 0 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77ah  Man with RPG kneeling rear on, 0 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 184 ft, gate 520 ns
tgt77ai  Man with RPG prone, rear on, 0 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 184 ft, gate 520 ns
tgt77aj  Man with RPG standing rear on, 90 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 184 ft, gate 520 ns
tgt77ak  Man without RPG kneeling rear on @ 2 degrees
depression @ 34 GHz @ 184 ft, gate 520 ns
tgt77al  79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77am  dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77an  dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ao  dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ap  sky @ 34 GHz @ 152 ft, gate 450 ns
tgt77aq  Man with RPG standing rear on, 22.5 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77ar  Man with RPG kneeling rear on, 22.5 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77as  Man without RPG standing rear on @ 2 degrees
depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77at  Man with RPG standing rear on, 45 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77au  Man with RPG kneeling rear on, 45 degrees RPG angle @ 2
degrees depression @ 34 GHz @ 152 ft, gate 450 ns

---corrupted data file (see tgt77dd for repeat of this
measurement)
tgt77av   Man without RPG prone looking rear on @ 2 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77aw   79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77ax   dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ay   dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77az   dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ba   sky @ 34 GHz @ 152 ft, gate 450 ns

8/07/03   Cloudy, cool, 70's       Operators: Bob Bender
                      Don Testerman
tgt77bb   79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77bc   dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bd   dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77be   dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bf   sky @ 34 GHz @ 152 ft, gate 450 ns
tgt77bg   Man standing with RPG looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
                      missing a lot of angles. Will troubleshoot angle encoder and try to collect data again next week.

8/12/03   Cloudy, warm, 80's       Operators: Bob Bender
                      Don Testerman
tgt77bh   79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77bi   dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bj   dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bk   dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bl   sky @ 34 GHz @ 152 ft, gate 450 ns
tgt77bm   Man standing with RPG at 0 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77bn   Man kneeling with RPG at 0 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77bo   Man prone with RPG at 0 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77bp   Man standing with RPG at 90 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77bq   Man standing without RPG looking rear on @ 5 degrees
8/13/03 Cloudy, warm, 80's Operators: Bob Bender
Don Testerman

tgt77br 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77bs dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bt dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bu dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77bv sky @ 34 GHz @ 152 ft, gate 450 ns
tgt77bw Man standing with RPG at 22.5 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77bx Man kneeling with RPG at 22.5 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns

8/14/03 Sunny, warm, 80's Operators: Bob Bender
Don Testerman

tgt77by 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77bz dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ca dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77cb dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77cc sky @ 34 GHz @ 152 ft, gate 450 ns
tgt77cd Man kneeling without RPG looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77ce Man standing with RPG at 45 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77cf Man kneeling with RPG at 45 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77cg Man prone without RPG looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns

tgt77ch 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77ci dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77cj dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77ck dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77cl sky @ 34 GHz @ 152 ft, gate 450 ns
tgt77cm Man standing with RPG at 0 degrees looking rear on @ 15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77cn  Man kneeling with RPG at 0 degrees looking rear on @
15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77co  Man prone with RPG at 0 degrees looking rear on @ 15
degrees depression @ 34 GHz @ 152 ft, gate 450 ns

8/18/03  Sunny, warm, 80's
Operators: Bob Bender
Don Testerman

tgt77cv  79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77cw  dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77cx  dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77cy  dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77cz  sky @ 34 GHz @ 152 ft, gate 450 ns

tgt77da  Man standing with RPG at 22.5 degrees looking rear on @
15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77db  Man kneeling with RPG at 22.5 degrees looking rear on @
15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77dc  Man kneeling without RPG looking rear on @ 15 degrees
depression @ 34 GHz @ 152 ft, gate 450 ns
tgt77dd  Man with RPG kneeling rear on, 45 degrees RPG angle @
2 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  (repeat of
au--corrupted data file)

tgt77de  79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns
tgt77df  dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77dg  dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77dh  dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns
tgt77di  sky @ 34 GHz @ 152 ft, gate 450 ns
Appendix B. Polar Plots

The RCS values for the plots shown in this appendix are computed with the following parameter values:

Center Frequency 34 GHz  
Range Bandwidth 1599.359 MHz  
Range Bin Size 4.00 m  
Angle Interval 0.090°  
Window Size 0.090°  
Window Step 0.090°

The range bin size defines the software gate centered around the target. Signals that are outside this “window” do not contribute to the RCS. The angle interval for the plots is 0.09 degree, although an angle increment of 0.015 degree was used to collect the data at Ka-band. Therefore, at Ka-Band, every sixth point is plotted. The plotted data are averaged with a moving average scheme where the window size divided by the angle interval defines the number of points in each averaging step, and the window step divided by the angle increment gives the number of points to slide to reach the start of the next window for averaging. Therefore, for these plots, there is no averaging.

A clutter subtraction algorithm is applied to each data set. The algorithm computes the coherent background signal level for a section of aspect angle around the angle for which the RCS is currently being calculated and subtracts that background value from the signal at the current angle.

The linear polarized plots are shown next. A detailed listing of measurements is given in the logbook in appendix A.
Figure B-1. RCS plots for trial TGT77AF, 2-degree depression, 0-degree RPG angle, man standing.
(a) Polarization = TVRV, Mean = –4.3 dBsm, Median = –5.4 dBsm, Standard Deviation = 6.7 dBsm

(b) Polarization = TVRH, Mean = –17.0 dBsm, Median = –17.6 dBsm, Standard Deviation = 12.3 dBsm

(c) Polarization = THRV, Mean = –17.0 dBsm, Median = –17.6 dBsm, Standard Deviation = 12.3 dBsm

(d) Polarization = THRH, Mean = –4.5 dBsm, Median = –5.6 dBsm, Standard Deviation = 6.9 dBsm

Figure B-2. RCS plots for trial TGT77AG, 2-degree depression, 0-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –6.0 dBsm, Median = –7.2 dBsm, Standard Deviation = 8.0 dBsm

(b) Polarization = TVRH, Mean = –17.2 dBsm, Median = –17.8 dBsm, Standard Deviation = 12.4 dBsm

(c) Polarization = THRV, Mean = –17.2 dBsm, Median = –17.6 dBsm, Standard Deviation = 12.4 dBsm

(d) Polarization = THRH, Mean = –6.1 dBsm, Median = –7.2 dBsm, Standard Deviation = 8.0 dBsm

Figure B-3. RCS plots for trial TGT77AH, 2-degree depression, RPG angle 0-degree, man kneeling facing aft.
(a) Polarization = TVRV, Mean = –9.0 dBsm, Median = –10.4 dBsm, Standard Deviation = 9.6 dBsm

(b) Polarization = TVRH, Mean = –18.4 dBsm, Median = –19.2 dBsm, Standard Deviation = 12.6 dBsm

(c) Polarization = THRV, Mean = –18.3 dBsm, Median = –19.2 dBsm, Standard Deviation = 12.6 dBsm

(d) Polarization = THRH, Mean = –9.2 dBsm, Median = –11.0 dBsm, Standard Deviation = 9.7 dBsm

Figure B-4. RCS plots for trial TGT77AI, 2-degree depression, 0-degree RPG angle, man prone facing aft.
(a) Polarization = TVRV, Mean = –4.4 dBsm, Median = –4.8 dBsm, Standard Deviation = 6.8 dBsm

(b) Polarization = TVRH, Mean = –17.5 dBsm, Median = –18.0 dBsm, Standard Deviation = 12.4 dBsm

(c) Polarization = THRV, Mean = –17.4 dBsm, Median = –17.8 dBsm, Standard Deviation = 12.4 dBsm

(d) Polarization = THRH, Mean = –4.6 dBsm, Median = –5.0 dBsm, Standard Deviation = 6.9 dBsm

Figure B-5. RCS plots for trial TGT77AJ, 2-degree depression, 90-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –9.7 dBsm, Median = –10.4 dBsm, Standard Deviation = 9.9 dBsm

(b) Polarization = TVRH, Mean = –19.9 dBsm, Median = –20.8 dBsm, Standard Deviation = 13.0 dBsm

(c) Polarization = THRV, Mean = –19.9 dBsm, Median = –20.8 dBsm, Standard Deviation = 13.0 dBsm

(d) Polarization = THRH, Mean = –9.6 dBsm, Median = –10.2 dBsm, Standard Deviation = 9.9 dBsm

Figure B-6. RCS plots for trial TGT77AK, 2-degree depression, man without RPG kneeling facing aft.
(a) Polarization = TVRV, Mean = –4.3 dBsm, Median = –4.8 dBsm, Standard Deviation = 6.7 dBsm

(b) Polarization = TVRH, Mean = –14.9 dBsm, Median = –15.6 dBsm, Standard Deviation = 11.8 dBsm

(c) Polarization = THRV, Mean = –14.8 dBsm, Median = –15.4 dBsm, Standard Deviation = 11.7 dBsm

(d) Polarization = THRH, Mean = –4.2 dBsm, Median = –4.6 dBsm, Standard Deviation = 6.6 dBsm

Figure B-7. RCS plots for trial TGT77AQ, 2-degree depression, 22.5-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –6.6 dBsm, Median = –7.4 dBsm, Standard Deviation = 8.4 dBsm

(b) Polarization = TVRH, Mean = –15.4 dBsm, Median = –15.8 dBsm, Standard Deviation = 11.9 dBsm

(c) Polarization = THRV, Mean = –15.3 dBsm, Median = –15.8 dBsm, Standard Deviation = 11.9 dBsm

(d) Polarization = THRH, Mean = –6.3 dBsm, Median = –7.2 dBsm, Standard Deviation = 8.2 dBsm

Figure B-8. RCS plots for trial TGT77AR, 2-degree depression, 22.5-degree RPG angle, man kneeling facing aft.
(a) Polarization = TVRV, Mean = –6.1 dBsm, Median = –6.6 dBsm, Standard Deviation = 8.0 dBsm

(b) Polarization = TVRH, Mean = –19.4 dBsm, Median = –19.8 dBsm, Standard Deviation = 12.9 dBsm

(c) Polarization = THRV, Mean = –19.4 dBsm, Median = –19.8 dBsm, Standard Deviation = 12.9 dBsm

(d) Polarization = THRH, Mean = –6.0 dBsm, Median = –6.4 dBsm, Standard Deviation = 8.0 dBsm

Figure B-9. RCS plots for trial TGT77AS, 2-degree depression, man without RPG standing facing aft.
(a) Polarization = TVRV, Mean = –4.4 dBsm, Median = –5.2 dBsm, Standard Deviation = 6.8 dBsm

(b) Polarization = TVRH, Mean = –15.4 dBsm, Median = –15.8 dBsm, Standard Deviation = 11.9 dBsm

(c) Polarization = THRV, Mean = –15.3 dBsm, Median = –15.8 dBsm, Standard Deviation = 11.8 dBsm

(d) Polarization = THRH, Mean = –4.4 dBsm, Median = –5.0 dBsm, Standard Deviation = 6.8 dBsm

Figure B-10. RCS plots for trial TGT77AT, 2-degree depression, 45-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = −17.4 dBsm, Median = −17.8 dBsm, Standard Deviation = 12.4 dBsm

(b) Polarization = TVRH, Mean = −22.9 dBsm, Median = −22.8 dBsm, Standard Deviation = 13.6 dBsm

(c) Polarization = THRV, Mean = −23.1 dBsm, Median = −23.0 dBsm, Standard Deviation = 13.6 dBsm

(d) Polarization = THRH, Mean = −17.0 dBsm, Median = −17.0 dBsm, Standard Deviation = 12.3 dBsm

Figure B-11. RCS plots for trial TGT77AV, 2-degree depression, man without RPG, prone facing aft.
(a) Polarization = TVRV, Mean = –5.2 dBsm, Median = –5.6 dBsm, Standard Deviation = 7.4 dBsm

(b) Polarization = TVRH, Mean = –16.0 dBsm, Median = –16.6 dBsm, Standard Deviation = 12.0 dBsm

(c) Polarization = THRV, Mean = –15.8 dBsm, Median = –16.6 dBsm, Standard Deviation = 12.0 dBsm

(d) Polarization = THRH, Mean = –5.1 dBsm, Median = –5.8 dBsm, Standard Deviation = 7.3 dBsm

Figure B-12. RCS plots for trial TGT77BM, 5-degree depression, 0-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –6.4 dBsm, Median = –7.2 dBsm, Standard Deviation = 8.2 dBsm

(b) Polarization = TVRH, Mean = –16.5 dBsm, Median = –17.0 dBsm, Standard Deviation = 12.2 dBsm

(c) Polarization = THRV, Mean = –16.4 dBsm, Median = –16.8 dBsm, Standard Deviation = 12.2 dBsm

(d) Polarization = THRH, Mean = –6.4 dBsm, Median = –7.4 dBsm, Standard Deviation = 8.2 dBsm

Figure B-13. RCS plots for trial TGT77BN, 5-degree depression, 0-degree RPG angle, man kneeling facing aft.
(a) Polarization = TVRV, Mean = −8.0 dBSm, Median = −8.8 dBSm, Standard Deviation = 9.1 dBSm

(b) Polarization = TVRH, Mean = −17.3 dBSm, Median = −18.0 dBSm, Standard Deviation = 12.4 dBSm

(c) Polarization = THRV, Mean = −17.2 dBSm, Median = −17.8 dBSm, Standard Deviation = 12.4 dBSm

(d) Polarization = THRH, Mean = −8.3 dBSm, Median = −9.2 dBSm, Standard Deviation = 9.2 dBSm

Figure B-14. RCS plots for trial TGT77BO, 5-degree depression, 0-degree RPG angle, man prone facing aft.
Figure B-15. RCS plots for trial TGT77BP, 5-degree depression, 90-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –7.1 dBsm, Median = –7.6 dBsm, Standard Deviation = 8.6 dBsm

(b) Polarization = TVRH, Mean = –20.1 dBsm, Median = –20.2 dBsm, Standard Deviation = 13.0 dBsm

(c) Polarization = THRV, Mean = –20.1 dBsm, Median = –20.2 dBsm, Standard Deviation = 13.0 dBsm

(d) Polarization = THRH, Mean = –7.0 dBsm, Median = –7.4 dBsm, Standard Deviation = 8.6 dBsm

Figure B-16. RCS plots for trial TGT77BQ, 5-degree depression, man standing without RPG facing aft.
(a) Polarization = TVRV, Mean = –4.4 dBsm, Median = –5.0 dBsm, Standard Deviation = 6.8 dBsm

(b) Polarization = TVRH, Mean = –14.4 dBsm, Median = –15.0 dBsm, Standard Deviation = 11.6 dBsm

(c) Polarization = THRV, Mean = –14.2 dBsm, Median = –14.8 dBsm, Standard Deviation = 11.5 dBsm

(d) Polarization = THRH, Mean = –4.5 dBsm, Median = –5.2 dBsm, Standard Deviation = 6.8 dBsm

Figure B-17. RCS plots for trial TGT77BW, 5-degree depression, 22.5-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –7.0 dBsm, Median = –7.6 dBsm, Standard Deviation = 8.6 dBsm

(b) Polarization = TVRH, Mean = –15.7 dBsm, Median = –16.2 dBsm, Standard Deviation = 12.0 dBsm

(c) Polarization = THRV, Mean = –15.5 dBsm, Median = –16.0 dBsm, Standard Deviation = 11.9 dBsm

(d) Polarization = THRH, Mean = –7.0 dBsm, Median = –7.8 dBsm, Standard Deviation = 8.6 dBsm

Figure B-18. RCS plots for trial TGT77BX, 5-degree depression, 22.5-degree RPG angle, man kneeling facing aft.
(a) Polarization = TVRV, Mean = –7.8 dBsm, Median = –8.4 dBsm, Standard Deviation = 9.0 dBsm

(b) Polarization = TVRH, Mean = –17.7 dBsm, Median = –18.0 dBsm, Standard Deviation = 12.5 dBsm

(c) Polarization = THRV, Mean = –17.6 dBsm, Median = –17.8 dBsm, Standard Deviation = 12.5 dBsm

(d) Polarization = THRH, Mean = –8.1 dBsm, Median = –8.8 dBsm, Standard Deviation = 9.1 dBsm

Figure B-19. RCS plots for trial TGT77CD, 5-degree depression, man without RPG kneeling facing aft.
Figure B-20. RCS plots for trial TGT77CE, 5-degree depression, 45-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –6.1 dBsm, Median = –6.6 dBsm, Standard Deviation = 8.0 dBsm

(b) Polarization = TVRH, Mean = –15.8 dBsm, Median = –16.2 dBsm, Standard Deviation = 12.0 dBsm

(c) Polarization = THRV, Mean = –15.6 dBsm, Median = –16.0 dBsm, Standard Deviation = 11.9 dBsm

(d) Polarization = THRH, Mean = –6.4 dBsm, Median = –7.2 dBsm, Standard Deviation = 8.2 dBsm

Figure B-21. RCS plots for trial TGT77CF, 5-degree depression, 45-degree RPG angle, man kneeling facing aft.
(a) Polarization = TVRV, Mean = –10.0 dBsm, Median = –10.8 dBsm, Standard Deviation = 10.0 dBsm

(b) Polarization = TVRH, Mean = –19.0 dBsm, Median = –19.0 dBsm, Standard Deviation = 12.8 dBsm

(c) Polarization = THRV, Mean = –18.8 dBsm, Median = –18.8 dBsm, Standard Deviation = 12.7 dBsm

(d) Polarization = THRH, Mean = –10.6 dBsm, Median = –11.6 dBsm, Standard Deviation = 10.3 dBsm

Figure B-22. RCS plots for trial TGT77CG, 5-degree depression, man without RPG prone facing aft.
Figure B-23. RCS plots for trial TGT77CM, 15-degree depression, 0-degree RPG angle, man standing facing aft.

(a) Polarization = TVRV, Mean = –5.8 dBsm, Median = –5.8 dBsm, Standard Deviation = 7.8 dBsm

(b) Polarization = TVRH, Mean = –13.6 dBsm, Median = –13.6 dBsm, Standard Deviation = 11.4 dBsm

(c) Polarization = THRV, Mean = –13.6 dBsm, Median = –13.6 dBsm, Standard Deviation = 11.3 dBsm

(d) Polarization = THRH, Mean = –7.7 dBsm, Median = –7.8 dBsm, Standard Deviation = 9.0 dBsm
(a) Polarization = TVRV, Mean = –6.2 dBsm, Median = –6.2 dBsm, Standard Deviation = 8.1 dBsm

(b) Polarization = TVRH, Mean = –13.8 dBsm, Median = –13.8 dBsm, Standard Deviation = 11.4 dBsm

(c) Polarization = THRV, Mean = –13.8 dBsm, Median = –13.8 dBsm, Standard Deviation = 11.4 dBsm

(d) Polarization = THRH, Mean = –8.4 dBsm, Median = –8.4 dBsm, Standard Deviation = 9.3 dBsm

Figure B-24. RCS plots for trial TGT77CN, 15-degree depression, 0-degree RPG angle, man kneeling facing aft.
(a) Polarization = TVRV, Mean = –6.8 dBsm, Median = –7.2 dBsm, Standard Deviation = 8.5 dBsm

(b) Polarization = TVRH, Mean = –14.3 dBsm, Median = –14.4 dBsm, Standard Deviation = 11.6 dBsm

(c) Polarization = THRV, Mean = –14.3 dBsm, Median = –14.4 dBsm, Standard Deviation = 11.6 dBsm

(d) Polarization = THRH, Mean = –9.1 dBsm, Median = –9.4 dBsm, Standard Deviation = 9.6 dBsm

Figure B-25. RCS plots for trial TGT77CO, 15-degree depression, 0-degree RPG angle, man prone facing aft.
(a) Polarization = TVRV, Mean = –14.7 dBsm, Median = –15.0 dBsm, Standard Deviation = 11.7 dBsm

(b) Polarization = TVRH, Mean = –20.9 dBsm, Median = –20.8 dBsm, Standard Deviation = 13.2 dBsm

(c) Polarization = THRV, Mean = –21.0 dBsm, Median = –21.0 dBsm, Standard Deviation = 13.2 dBsm

(d) Polarization = THRH, Mean = –16.0 dBsm, Median = –16.2 dBsm, Standard Deviation = 12.1 dBsm

Figure B-26. RCS plots for trial TGT77DA, 15-degree depression, 22.5-degree RPG angle, man standing facing aft.
(a) Polarization = TVRV, Mean = –15.0 dBsm, Median = –15.2 dBsm, Standard Deviation = 11.8 dBsm

(b) Polarization = TVRH, Mean = –21.3 dBsm, Median = –21.4 dBsm, Standard Deviation = 13.3 dBsm

(c) Polarization = THRV, Mean = –21.3 dBsm, Median = –21.4 dBsm, Standard Deviation = 13.3 dBsm

(d) Polarization = THRH, Mean = –16.4 dBsm, Median = –16.6 dBsm, Standard Deviation = 12.2 dBsm

Figure B-27. RCS plots for trial TGT77DB, 15-degree depression, 22.5-degree RPG angle, man kneeling facing aft.
(a) Polarization = TVRV, Mean = −14.2 dBsm, Median = −15.0 dBsm, Standard Deviation = 11.5 dBsm

(b) Polarization = TVRH, Mean = −20.6 dBsm, Median = −21.2 dBsm, Standard Deviation = 13.1 dBsm

(c) Polarization = THRV, Mean = −20.6 dBsm, Median = −21.4 dBsm, Standard Deviation = 13.1 dBsm

(d) Polarization = THRH, Mean = −15.8 dBsm, Median = −16.6 dBsm, Standard Deviation = 12.0 dBsm

Figure B-28. RCS plots for trial TGT77DC, 15-degree depression, man without RPG kneeling facing aft.
(a) Polarization = TVRV, Mean = –5.0 dBsm, Median = –6.4 dBsm, Standard Deviation = 7.3 dBsm

(b) Polarization = TVRH, Mean = –14.5 dBsm, Median = –14.8 dBsm, Standard Deviation = 11.6 dBsm

(c) Polarization = THRV, Mean = –14.6 dBsm, Median = –15.0 dBsm, Standard Deviation = 11.6 dBsm

(d) Polarization = THRH, Mean = –5.1 dBsm, Median = –6.4 dBsm, Standard Deviation = 7.4 dBsm

Figure B-29. RCS plots for trial TGT77DD, 2-degree depression, 45-degree RPG angle, man kneeling facing aft.
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