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RCS Measurements of a PT40 Remote Control Plane at Ka-Band

by Thomas J. Pizzillo

ARL-TN-238 **March 2005**

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14. ABSTRACT
Static radar cross-section (RCS) and high-range resolution profile measurements of a Great Planes Model PT40 remote controlled (RC) Trainer at Ka-band are reported. Measurements are from 32.4-GHz to 35.6-GHz using a vertically polarized transmit and receive stepped frequency waveform providing resolution of 4.7-cm in range. The target was measured at several azimuth and elevations angles from –15-degrees to +15-degrees in 5-degree increments. The data was collected 23 October 2003 at the Army Research Laboratory's (ARL) millimeter wave anechoic chamber research facility located at the Adelphi Laboratory Center (ALC), Maryland.

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Introduction

In August 2003, a field test supporting the Multi-Function Radio Frequency (MFRF) program was conducted in Idaho to determine the radar's ability to simultaneously amplitude threshold detect and Doppler track an unmanned aerial vehicle (UAV). As part of this test, a Great Planes Model PT40 RC Trainer was used as a simulant of a UAV and subsequent data analysis showed significant anomalies in the tracking of this target. To determine if the data was actually a track of this target, the RCS of the PT40 needed to be determined. I hung the plane in the anechoic chamber and measured a number of static plane configurations. These static positions were chosen to represent the very large number of actual target positions during flight. The following sections detail this one day measurement effort.

Target Description

Figure 1 shows a top view, and figure 2 shows a profile view of the Great Planes PT40 RC Trainer. It is 1.37 m in length, has a wingspan of 1.52 m, has a stabilizer span of 69 cm, and has a fin height of 23 cm. The fuselage is wood as is the wing frame, which is covered by fabric and held to the fuselage by rubber bands.

Figure 1. Top view of Great Planes Model PT40 RC Trainer.

Figure 2. Profile of Great Planes Model PT40 RC Trainer.

Radar Description

The radar used to collect the high-range-resolution (HRR) signature data was designed and developed at ARL. The antenna is a fully polarimetric monopulse antenna. The radar data was collected using a pulsed stepped frequency waveform. A detailed description of the radar is provided in ARL-TR-2947 "High-Range Resolution Profiles and RCS Measurements of Three Canonical Shapes at Ka-Band," a summary of the radar specifications are shown in table 1.

Table 1. ARL Ka-band radar system specifications.

Parameter	Value
Peak transmit power	1.6 watts
Frequency	32.4 to 35.6 GHz
Waveform description	Stepped frequency, 512 steps, 3.2 GHz bandwidth
Receiver noise figure	5 dB
Losses	4 dB
IF bandwidth	80 MHz
Antenna diameter	6 inches
Antenna Gain	30 dBi
I/Q gain error	5 %
I/Q phase error	2 degrees
A/D voltage range	±1 volt
A/D sample rate	10 MHz
A/D bits	12 bits
Pulse width	35×10^{-9} sec
Pulse rise and fall time	2×10^{-9} sec
Gain in receiver	42 dB
Polarization	Transmit vertical, receive vertical (VV)
TWT gain	42 dB
TWT noise figure	32 dB

Experiment Description

The radar was located on a platform outside the anechoic chamber and aligned so as to be at 0-degree elevation when pointed through the chamber aperture opening. This provided a 0.8-m diameter beam at the target location 1.9-m above the absorber-covered turntable in the quiet zone of the chamber. The target was suspended by the center-of-mass from the chamber ceiling using 0.15-mm diameter 40-lb test monofilament fishing line as shown in figure 3.

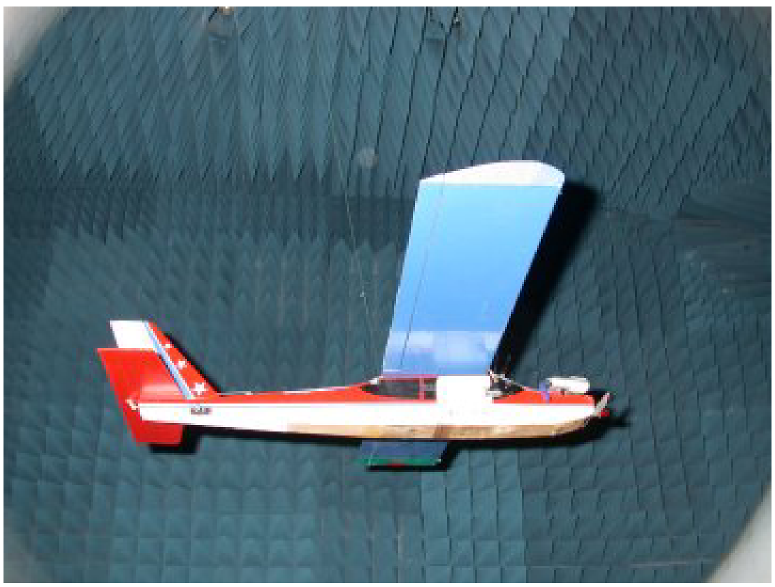

Figure 3. View of the target hanging in the chamber.

The target was aligned relative to the bottom skid plate. When the target was hung with the skid plate parallel to the ground, it was above the lens of the radar by approximately 2 feet. This placed the plane approximately 2.5 degrees above the radar's horizontal line-of-sight. Figure 4 shows a radar view of the plane in this configuration. The target was measured from –15 degrees to +15 degrees in 5-degree increments in this attitude. The aircraft was hung in a "nose up" position 5- and –15- degrees relative to the skid plate, as well as "nose down" 5- and 15- degrees relative to the skid plate. Not all azimuth angles were measured in every elevation configuration. All elevation measurement series were repeated. An 11.7-cm trihedral was used to correct errors in the radar and to scale the measurements to square meters.

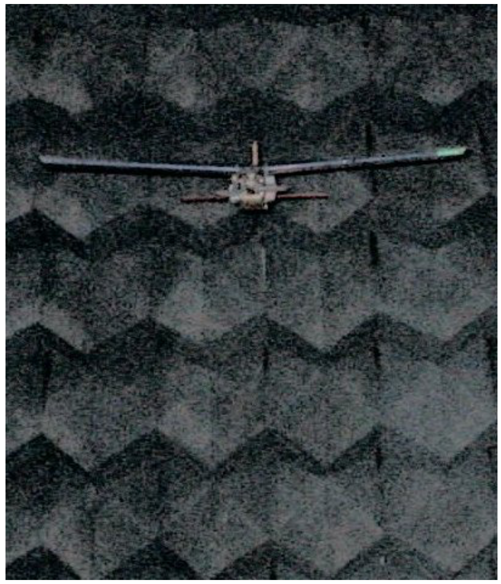

Figure 4. View of the PT40 parallel to the ground and approximately 2.5 degrees above radar.

Data

The data was collected using a 250-KHz PRF providing 40-range gates with the target in the 1st gate.

The transmitted waveform was swept, in 6.25 MHz steps, from 32.4–35.6 GHz using 512-frequency steps. This provides a range resolution of 4.7-cm. Only transmit vertical, receive vertical (VV) polarization data was collected. Though high range-resolution images were not measured during this field test, it is of some interest to note where the primary scattering centers are located as this provides insight into the overall RCS signature of the target. In all cases, the fuel tanks mounted on either side of the fuselage below the wings were empty. The RCS may vary significantly with both tanks full of fuel. Table 2 provides a list of the target configurations, measurement angle relative to the radar, and the total RCS for each measurement in square meters (sm) and dBsm. The last two rows give the average and standard deviation for all the data. The average RCS is –14.55 dBsm.

Table 2. Dataset details

Elevation (degrees)	Azmuth (degrees)	RCS (sm)	RCS (dBsm)
Nose up 2.5	-15	0.0282	-15.50
	-10	0.0490	-13.09
	-5	0.0454	-13.43
	0	0.0691	-11.60
	5	0.0168	-17.75
	10	0.0223	-16.51
	15	0.0258	-15.89
Nose up 7.5	-15	0.0238	-16.23
	-10	0.0329	-14.83
	-5	0.0725	-11.40
	0	0.0459	-13.38
Nose up 17.5	-15	0.0007	-31.77
	-10	0.0320	-14.95
	-5	0.0295	-15.30
Nose down 2.5	0	0.0417	-13.79
Nose down 7.5	0	0.0481	-13.18
Nose down 13.5	0	0.0131	-18.82
Average		**0.0351**	**-14.55**
Standard Deviation		**0.0188**	**-2.71**

The largest RCS measured was for the nose down 2.5 degree configuration as shown in figure 5. A scaled photo of the plane in profile is superposed for reference. The largest scattering is from the front half of the plane. The peak RCS is associated with the wing-fuselage junction which is where the battery and flight surface controls are located. What effect, if any, of full fuel tanks on the peak RCS is unknown and should be investigated. A Similar RCS was measured for nose up 7.5 degree and 5 degrees CCW relative to the radar as shown in figure 6. Again, the predominant scattering is from the front half of the plane with the peak response associated with the muffler on the side of the engine. In all measurement scenarios, the dominant scattering, hence RCS, is due to the front half of the plane. The smallest RCS measured was –31.8 dBsm for nose up 17.5 degrees and 15 degrees CCW relative to the radar.

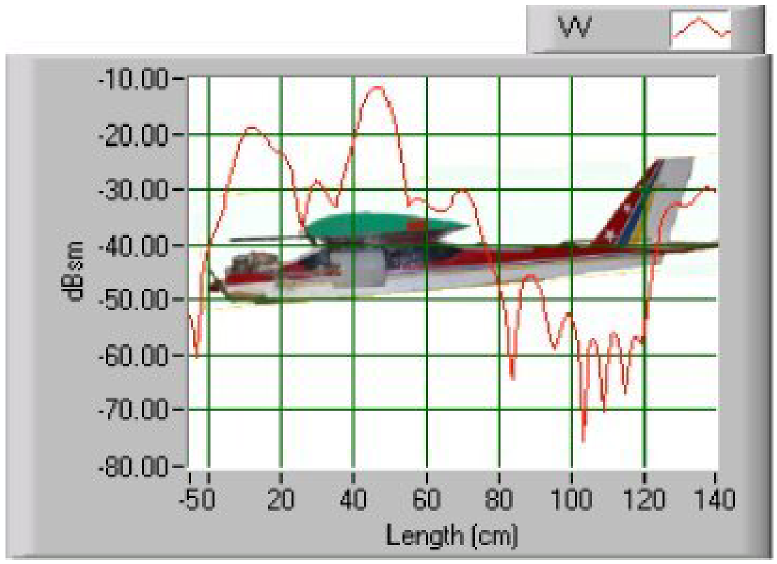

Figure 5. High-range resolution profile for the largest RCS target configuration of the plane nose down 2.5 degrees relative to the radar.

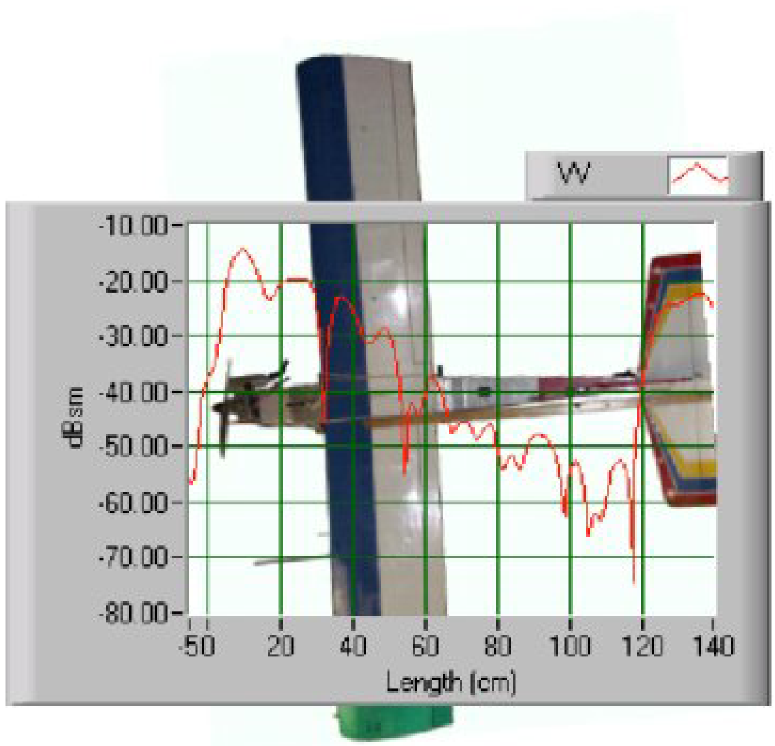

Figure 6. High-range resolution profile for another large RCS target configuration of the plane nose up 7.5 degrees and 5 degrees CCW relative to the radar.

Conclusions

Based on a variety of anechoic chamber head-on and near head-on Ka-band RCS measurements of a Great Planes Model PT40 RC Trainer, a statistical estimate of RCS was determined to be –14.55 dBsm +/–2.05 dB. However, individual RCS values as large as –10.9 dBsm and as low as –38.2 dBsm were observed in the 38 datasets collected.

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