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RADAR SCATTERING ANALYSES I, II AND III

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Final Report

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This is the Final Report of work performed for Purdue University under P.O. 8398-6 during the period June 1977 to October 1978 as part of the RADC Post Doctoral Program: Prime Contract F 30602-75-C-0082, Tasks 4.1.1 - 4.1.4.

The study was primarily experimental and its objective was to obtain scattering data for three specific missiles. Early in 1977 we took over operation of an existing anechoic chamber which is now the nucleus of the Radiation Laboratory's experimental facility at Willow Run Airport. The chamber is rectangular in shape with internal dimensions 15 m (length) by 9 m (width) by 4.5 m (height), and together with shop and instrument rooms, occupies an entire building. It was originally designed as a high performance chamber and when constructed in the early 1960's all of the absorber used was checked to ensure conformity with its rating. The central portion (an area of about 1.2 m square) of the back wall is covered with B.F. Goodrich VHP 24 absorber. VHP 18 material is used on the rest of the back wall, the front wall and about half of the side walls, with HP4 material on the remaining surfaces. The room is equipped with an azimuth rotator, motor control unit, rectangular and polar analog recorders, microwave receiver, universal Klystron power supply and a Klystron frequency stabilizer. The RF plumbing available is sufficient to permit measurements over most of the frequency range 0.5 to 90 GHz.

The room had not recently (if ever) been used for high precision scattering measurements, and difficulties were experienced when our first experiments were attempted. The task was to obtain backscattering data using small scale models of the missiles at X-band, and to ensure satisfaction of the far field requirement, it was necessary to place the model close to (within 3 m) of the back wall. Since the measurements were CW, the procedure used was the standard one in which the returns from the room and the support pedestal were balanced out or nulled prior to the placement of the model on the pedestal, but difficulties were experienced in maintaining the balance throughout the time (several minutes) necessary to measure the backscattering for a full 360 degree rotation of the model. Part of the difficulty was poor frequency stabilization, and this was overcome by going to a phase-locked loop system, but even so the problem still remained. On the off-chance that it was caused by differential heating of the room by the sun shining on the roof of the building, we tried operating in the early morning or late evening or on overcast days. The improvement was little if any, and the main cause was eventually found to be a mechanical vibration of the support pedestal produced by movement in the shop and instrument rooms adjacent to the chamber. Installation of a concrete foundation for the pedestal to mechanically isolate it from the rest of the building proved to be effective and, coupled with a repositioning of some of the VHP absorber, brought the room return down to a sufficiently low and stable level. Even with a 25 cm diameter sphere placed close to the back wall, back and forth displacement (or 'rock') now produced only a 1.5 dB total variation in the return, diminishing to less than 1 dB when the sphere was more than 3 m from the wall.

The three missiles are, full scale, 6 to 8 m long, and will be identified simply as missile numbers 1, 2 and 3. All have a circular cylindrical fuselage. The first has a rounded nose with four small and four large fins located respectively near the nose and tail. The engine is non-airbreathing, with exhaust through the rear of the fuselage. Missile No. 2 has an airbreathing engine with two rectangular intake ducts on either side of the fuselage extending from the middle to the rear. The missile has four large fins at the rear and a pointed nose. Missile No. 3 differs only in that its engine, also airbreathing, has four symmetrically placed cylindrical intakes starting halfway down the fuselage and tapering in at the rear.

The initial and primary task was to obtain backscattering data at two L-band frequencies approximately 5 MHz apart for each missile at two or three roll angles (as appropriate) and two linear polarizations as a function of angle from nose-on ($\theta = 0°$) to tail-on ($\theta = 180°$). One-twelfth scale models of the three missiles were constructed from brass tubing and plates. In the case of missiles Nos. 2 and 3, part of the nose could be removed so as to simulate the effect of an electromagnetically transparent nose radome.

The measurements were made at 12.14 and 12.23 GHz. With each missile the data were recorded for a full 360° rotation in the yaw plane and calibrated against the return from a 14-inch or 10-inch diameter sphere whose cross-sections at both measurement frequencies are -10.0 and -12.9 dBm^2 respectively. The analogue data were also digitized at 0.5° increments in angle and recorded on magnetic tape.

With missile No. 1, the analogue data (8 patterns, resulting from two polarizations, two roll angles and two frequencies) were furnished to Mr. D. Tauroney of RADC along with a brief memorandum describing the measurement conditions. At Mr. Tauroney's request, the analogue and digital data were also sent to Mr. J. Belyea of Advanced Sensor Systems, Arlington, Virginia. Similar data for missile No. 2 (3 roll angles) and missile No. 3 (2 roll angles), with and without the nose cone, to produce a total of 40 patterns, were sent on 24 February. Figure 1 is typical of the analogue plots, with the small horizontal line at 150° on the left (just below the -20 dB level) showing the cross section of the 10-inch diameter calibration sphere. Because of the low cross section of missile No. 2 for vertical polarization, three of the patterns were later re-run with a higher transmitter power to provide better definition in the aspect range about nose-on, and these data, analogue and digital, were sent on 30 March.

As a result of RADC's expressed interest in the backscattering behavior of missile No. 1 at other frequencies, 4 additional models of this missile were constructed with scale factors 1:16, 1:24, 1:100 and 1:200, but no measurements were made using them. The two smaller models were intended for use at a simulated 5 MHz, and at this low frequency, the missile is no more

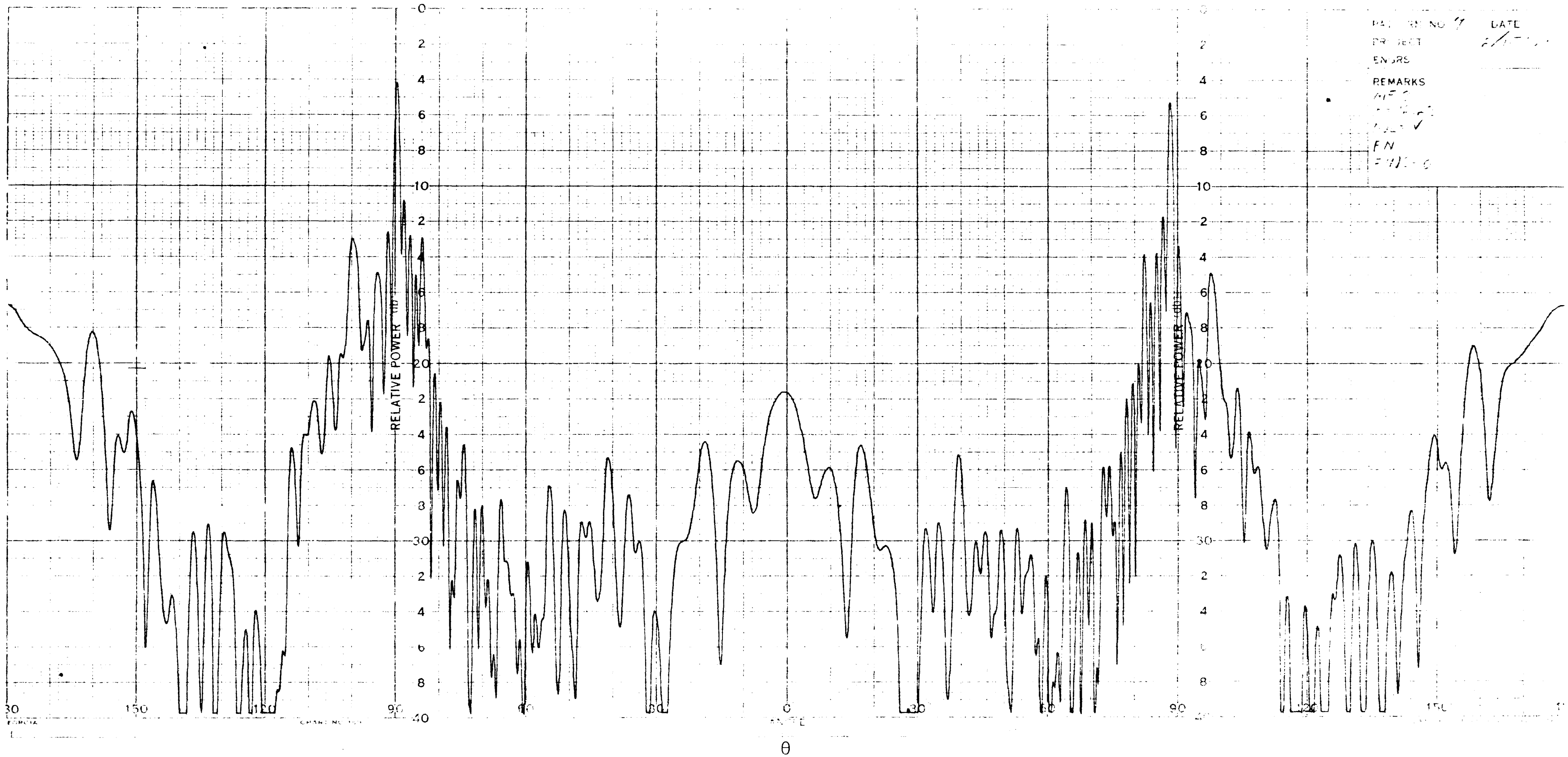

Figure 1: Backscatter characteristics of missile #3; frequency 12.23 GHz, vertical polarization, without nose cone, ϕ = 0°, 10" calibration sphere.

than $\lambda/10$ long where λ is the wavelength. It is therefore in the Rayleigh region and to an adequate approximation the scattered field can be attributed to the induced electric and magnetic dipoles.

Using the theory in [1, 2] (see [3] for specific applications to space objects), the far zone scattered field can be expressed in terms of the electric and magnetic polarizability tensors, and for a body of rotation a computer program is available [4] for computing the tensor elements. As shown in [5], the fins contribute no more than about 1 dB to the cross-section, and using the computer program to compute the scattering from the fuselage, it is found that at 5 MHz the backscattering cross section for horizontal polarization varies uniformly from -13.7 dBm^2 broadside to -40.5 dBm^2 end-on, and the vertical return from -42.7 dBm^2 broadside to -40.5 dBm^2 end-on.

We also examined the possibility of measuring bistatic scattering on our outdoor antenna range and obtained some preliminary data for missile No. 1 at 12.14 GHz simulating L-band full scale. The range has a cleared area 600 feet long and about 200 feet wide. The transmitting tower with an 18 inch dish antenna was placed 150 feet away from the target and slabs were set at 30° increments in angle on a 150 ft. circle centered on the target where a receiving antenna could be located. Trial measurements made with a bistatic angle of 30° showed that slight movement of the grass and distant trees did produce a measureable signal which was impossible to null out because of its fluctuation, and that the high gain transmitting and receiving antennas must be very firmly anchored to prevent any motion. However, the most severe problem was a gradual drift of the signal level indicating a loss of balance, and due to expansion and contraction of the long lengths of waveguide inevitable with a CW set-up of this type. Because of this, it proved impossible to obtain valid and consistent data and we are now implementing a long-pulse (or gated) system which we hope to use in the future.

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