Group Report 1964-16

Cross-Section Measurements of the Echo II Satellite by the Millstone L-Band Radar

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D. P. Hynek
7 April 1964

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CROSS-SECTION MEASUREMENTS OF THE ECHO II SATELLITE
BY THE MILLSTONE L-BAND RADAR

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ABSTRACT

This report is a summary of the Millstone Radar tracking activities during the early revolutions of Echo II. Eight revolutions were tracked and cross-section measurements taken during the satellite's first four days in orbit followed by four additional tracks during the next three weeks.

All cross-section measurements beginning with Rev. 4, the first observable at Millstone, display a fading pattern indicating that the balloon had not attained full sphericity, or at least contained significant surface irregularities. No essential change in the fading pattern was noted throughout the period that measurements were taken, except for perhaps more frequent fading during the later passes.

Starting with Rev. 5, the first complete horizon-to-horizon measurement made, a periodicity of approximately $10^4$ seconds was observed. This periodicity was also apparent during the later passes.

The estimated average radar cross section during these observations was about one-half the theoretical 1330 square meters.

A pulse-to-pulse cross section vs time record is included for Rev. 5 and Rev. 321, the last covered in this report.
INTRODUCTION

This report is a summary of the tracking activities at Millstone during the early revolutions of the Echo II passive communications satellite.

The satellite was launched from the Pacific Missile Range on January 25, 1964, and placed in a near-circular polar orbit at a mean altitude of 635 nautical miles. This 135-foot diameter sphere has a rigidized skin to retain its shape after inflation. Full pressurization of this structure was to take place within two hours after launch.

The earliest passes visible to Millstone were tracked to assist NASA in determining the extent and success of the initial inflation effort. Later passes were tracked to observe possible anomalies in the balloon's structure.

RADAR PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1295 Mcs</td>
</tr>
<tr>
<td>Antenna</td>
<td>84-foot paraboloid, 46.5 db gain</td>
</tr>
<tr>
<td>Peak transmitted power</td>
<td>400 kw min., 5 Mw max.</td>
</tr>
<tr>
<td>Pulse repetition frequency</td>
<td>15 pps</td>
</tr>
<tr>
<td>Pulse length</td>
<td>2 millisec.</td>
</tr>
<tr>
<td>Transmitted polarization</td>
<td>right circular</td>
</tr>
<tr>
<td>Received polarization</td>
<td>left circular</td>
</tr>
<tr>
<td>Receiving system noise temperature</td>
<td>300°K</td>
</tr>
<tr>
<td>System losses</td>
<td>1.5 db</td>
</tr>
</tbody>
</table>

DATA RECORDING

During each track radar returns were recorded on magnetic tape and processed in the CG-24 computer to output averaged values of elevation, azimuth, range, and range rate. The raw signal strength data on tape were processed to
produce a plot of the pulse-by-pulse radar cross section as a function of time. In addition, signal strength vs time measurements were taken on a Sanborn pen recorder for real-time observation of events.

A block diagram of the recording system is shown in Fig. 1. Recording noise-bandwidth was 100 kcs. Target Doppler frequencies covered a band of approximately ± 55 kcs, reaching these maximum values on high elevation passes. Although target Doppler is automatically corrected at the 2-Mcs I.F. level by an appropriate shift in the 28-Mcs L.O. permitting a much narrower receiver bandwidth, the wider bandwidth was used to prevent possible Doppler false alarms from distorting the signal strength measurement.

The transmitter peak power was reduced to 400 kw (from a normal 5 Mw for tracking) during most of these operations to handle the range of signal strength variations from this relatively huge radar target more easily.

The cross-section plots represent a pulse-by-pulse record of the solution to the equation:

\[ \sigma = \frac{(4\pi)^3}{\lambda^2} \frac{R}{G^2} \frac{S}{L} \frac{P}{P} \]

where
- \( \sigma \) = target cross section in square meters
- \( \lambda \) = wavelength in meters
- \( R \) = target range in meters
- \( S \) = peak received power in watts
- \( G \) = antenna gain
- \( L \) = system losses
- \( P \) = peak transmission power in watts
RESULTS

The satellite was first detected at Millstone during Rev. 4 and tracked for about 40 seconds before it receded over the horizon. The first complete horizon-to-horizon track was made during Rev. 5.

From the outset, Echo II displayed a very irregular cross-section pattern and maintained this behavior throughout the period covered by this report. No significant change was observed from run to run except for perhaps larger and more frequent fades during the last passes. Fades of the order of 10 db were rather common with fades of the order of 20 db frequently recorded.

During Rev. 5 a slow periodic behavior was observed with an average period of approximately 104 seconds. This period was made evident by deep fades of several seconds' duration and was observed on most of the following passes. More rapid fades of the order of one per second appear throughout the recordings and strongly suggest a correlation with the gore structure of the balloon. This rate is compatible with the period observed and the number of gores (106) comprising the balloon.

Table I is a summary of the revolutions for which cross-section data are available. Listed in the Table are the maximum, minimum and estimated average cross-section values recorded for each run in decibels relative to one square meter.

In Figs. 2 and 3 are given pulse-to-pulse cross section vs time plots for Rev. 5, the first complete track, and Rev. 321, the last covered in this report.
<table>
<thead>
<tr>
<th>Rev. No.</th>
<th>Date</th>
<th>Duration Of Data</th>
<th>Max. $\sigma$ (Est)</th>
<th>Min. $\sigma$ (Est)</th>
<th>Ave. $\sigma$ (Est)</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td>25 Jan 64</td>
<td>40 sec.</td>
<td>37 db</td>
<td>17 db</td>
<td>28 db</td>
</tr>
<tr>
<td>05</td>
<td>25 Jan 64</td>
<td>16m 42s</td>
<td>40 db</td>
<td>9 db</td>
<td>31 db</td>
</tr>
<tr>
<td>06</td>
<td>25 Jan 64</td>
<td>15m 45s</td>
<td>45 db</td>
<td>14 db</td>
<td>33 db</td>
</tr>
<tr>
<td>11</td>
<td>26 Jan 64</td>
<td>16m 12s</td>
<td>45 db</td>
<td>10 db</td>
<td>31 db</td>
</tr>
<tr>
<td>12</td>
<td>26 Jan 64</td>
<td>1m 45s</td>
<td>36 db</td>
<td>15 db</td>
<td>28 db</td>
</tr>
<tr>
<td>31</td>
<td>27 Jan 64</td>
<td>15m 10s</td>
<td>37 db</td>
<td>8 db</td>
<td>27 db</td>
</tr>
<tr>
<td>44</td>
<td>28 Jan 64</td>
<td>14 min.</td>
<td>34 db</td>
<td>8 db</td>
<td>24 db</td>
</tr>
<tr>
<td>136</td>
<td>4 Feb 64</td>
<td>12m 45s</td>
<td>42 db</td>
<td>14 db</td>
<td>29 db</td>
</tr>
<tr>
<td>137</td>
<td>4 Feb 64</td>
<td>17 min.</td>
<td>37 db</td>
<td>5 db</td>
<td>25 db</td>
</tr>
<tr>
<td>229</td>
<td>11 Feb 64</td>
<td>15 min.</td>
<td>40 db</td>
<td>10 db</td>
<td>28 db</td>
</tr>
<tr>
<td>321</td>
<td>18 Feb 64</td>
<td>9m 30s</td>
<td>41 db</td>
<td>10 db</td>
<td>29 db</td>
</tr>
</tbody>
</table>

*The theoretical radar cross section is approximately 31.2 db (1330 sq. meters).
Fig. 1. Signal recording block diagram.
Fig. 3. Radar cross-section vs. time plot for revolution no. 321.
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