Flight Tests of Long Range Early Warning

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FLIGHT TESTS OF LONG RANGE EARLY WARNING

OTTAWA

MAY, 1944

FLIGHT TESTS OF LONG RANGE EARLY WARNING

A short series of flight tests were conducted during the spring of 1943 on the 90 megacycle long range early warning system located at Ottawa. The tests have not been completed because of unavoidable difficulties in obtaining high altitude aircraft, but it was decided to publish the information available, especially as the present low priority of LREW did not warrant an excessive expenditure of effort on this work. Test flights were recorded on planes flying between heights of 250 feet and 15,000 feet only.

The radar equipment under test was fully described in a previous publication(1). The PPI antenna for this station was covered in another report(2). (See Figure 1). Briefly, the antenna is designed for 90 megacycles and consists of three 7-element collinear arrays stacked in front of an open-wire billboard. The array rotates at 4 r.p.m. The transmitters used with LREW have power capabilities up to better than a megawatt peak output at 90 megacycles, with a 15 microsecond pulse. However, the actual usable output during these tests was never more than about 300 peak kilowatts because of the power limitations of the coaxial feeder available at the time of installation of the antenna system. Larger coaxial has now been obtained but has not yet been installed.

At no time during the tests was the antenna stopped nor was the scanning speed altered from the continuous rotation speed of 4 r.p.m. All observations were made on the 12DP7 PPI tube.

The plotting technique was simplified as much as possible since the data of chief interest were signal strength and range. Complete plots were actually made of the flights, using the grid-square technique, but these would be of little interest here. No serious attempt was made to track the aircraft inside a 10-mile minimum range in the southern sector. The aircraft could be tracked through the permanent echoes to within 5 miles in this sector but the presence of many training aircraft from an airport two miles away made recognition difficult under most circumstances.

The antenna is mounted 200 feet above the ground. The terrain is nearly level for a 2-mile radius about the tower. A range of hills, rising to 3,000 feet, begins about 10 miles north of this site and extends indefinitely. As a result the permanent echoes are nearly solid for 40 miles in the northern sector. Planes may be tracked only with difficulty in this area though they may be followed to the extreme range in the northern sector beyond the permanent echoes. The composition of the ground in the neighbourhood of the tower is mainly sand with occasional patches of loam. Its reflection coefficient has not been determined accurately and was presumed to vary considerably during the tests. The nearest body of water (Lake Ontario) is 100 miles away.

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(1) N.R.C. Report PRA-85, Long Range Early Warning, July 1943.
(2) N.R.C. Report PRA-86, PPI Antenna for Long Range Early Warning, October 1943.

All flight tests were carried out between 10:00 a.m. and 4:00 p.m. approximately in order to avoid the conditions of higher refraction which frequently occur early or later in the day. The ranges to be obtained under these conditions are correspondingly greater but they do not give an accurate picture of the everyday performance of the set. Under some conditions the Adirondack Mountains, which are below the line of sight, appear on the PPI tube as an extensive mass of permanent echoes extending to 110 miles over an arc of about 45° in the south-east sector. No flight tests were run when these echoes were prominent. Mount Tremblant in Quebec, 80 miles to the north east, altitude 3,000 feet, is a steady permanent echo on the display under all conditions.

As mentioned above, controlled tests have not been made on target aircraft higher than 15,000 feet, but on numerous occasions aircraft have been tracked at ranges in excess of 170 miles (the limit of the range calibration at present). These aircraft have been presumed to be U.S. Army or Ferry Command planes operating at high altitudes.

Five rough levels of signal strength were employed as follows:-

S - Strong - Very strong saturating echo, sharply clipped by limiter circuits.

G - Good - Good echo, above 3:1 signal-to-noise ratio and still clipped.

F - Fair - Fair echo, under 3:1 signal-to-noise ratio and on the average usually about the limiter level.

P - Poor - Echo just discernible on PPI tube, well under the limiter level.

O - Out - No echo.

The definitions of signal strength as referred to the limiter level were evolved by correlating the echo as observed on an A scope and on the PPI tube in the preliminary trials only. After some experience with this technique the operators were then able to define signal strength on the PPI tube directly without further reference to the A scope. A "Poor" echo on the PPI tube was frequently not visible on the A scope since the video system had been set up to favour the PPI presentation.

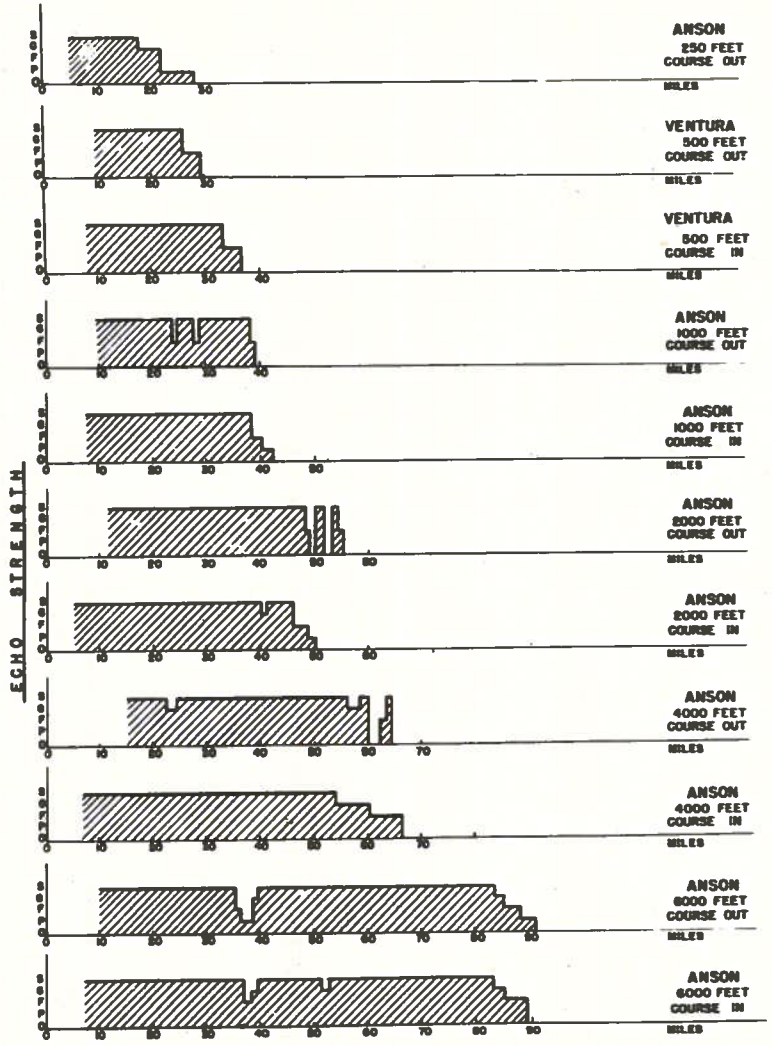
A "Poor" echo was rejected as "Out" unless both operators could clearly identify it as an aircraft echo without strain on the imagination. To cover intermittent fading conditions as contrasted to a definite disappearance of the echo in a null, an arbitrary rule was laid down as follows. If an aircraft echo, which was being tracked with an echo strength of "poor" or stronger, disappeared for one scan only and then re-appeared, the echo was not marked "Out". But if it disappeared for two or more successive scans, it was then plotted as "Out". Conversely, if the aircraft had dropped into a null and only intermittent flashes on isolated scans were seen, the

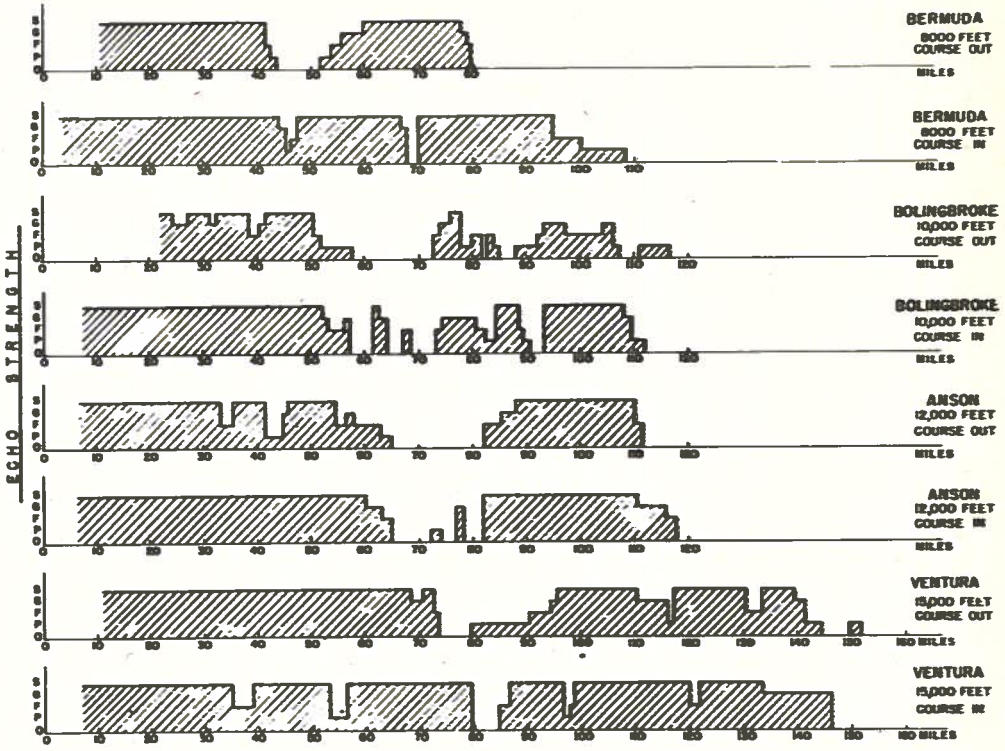
target was still marked "Out" even though the single scan echo might be rated "Strong". To generalize, no change in echo strength rating was recorded until it had been observed on two successive scans (i.e. at 15 second intervals with 4 r.p.m. rotation speed). This appears to be a reasonably satisfactory criterion for long range PPI plotting except for the obvious anomalous case where the echo appears on exactly alternate sweeps for some time, but this circumstance may never occur in long wave work where the fading is usually slow and where either solid tracking or zero tracking is the rule. The M.I.T. system as applied to centimetre PPI plotting, which is based on estimating the percentage of strikes (with the echo strength estimated as either "In" or "Out") over a longer period of time, is not particularly suited to the LREW system.

The signal strength plots of typical flights at heights from 250 feet to 15,000 feet are shown in Fig.2. These are plotted in rectangular coordinate form with signal strength as ordinate and range as abscissae. In most cases two plots are given for each altitude, one in which the aircraft is going out and presenting a tail aspect, and the other in which the aircraft is coming in and presenting a "head-on" aspect.

A vertical coverage diagram plotted on an M.I.T. optical horizon chart is given in Fig.3. In this case only "in" plots are used, and the first two ground-interference lobes of the antenna are plotted. It is seen that complete coverage is obtained at all angles above 2°, while the first gap is not completely empty. The coverage diagram was plotted using an estimated 200 miles maximum range. It is seen that there is a close correlation between the theoretical curves and the experimental results obtained.

N.R.C. PHOTO
FIG. 1





NOTE:

S — STRONG
G — GOOD
F — FAIR
P — POOR
O — OUT

FIGURE 2

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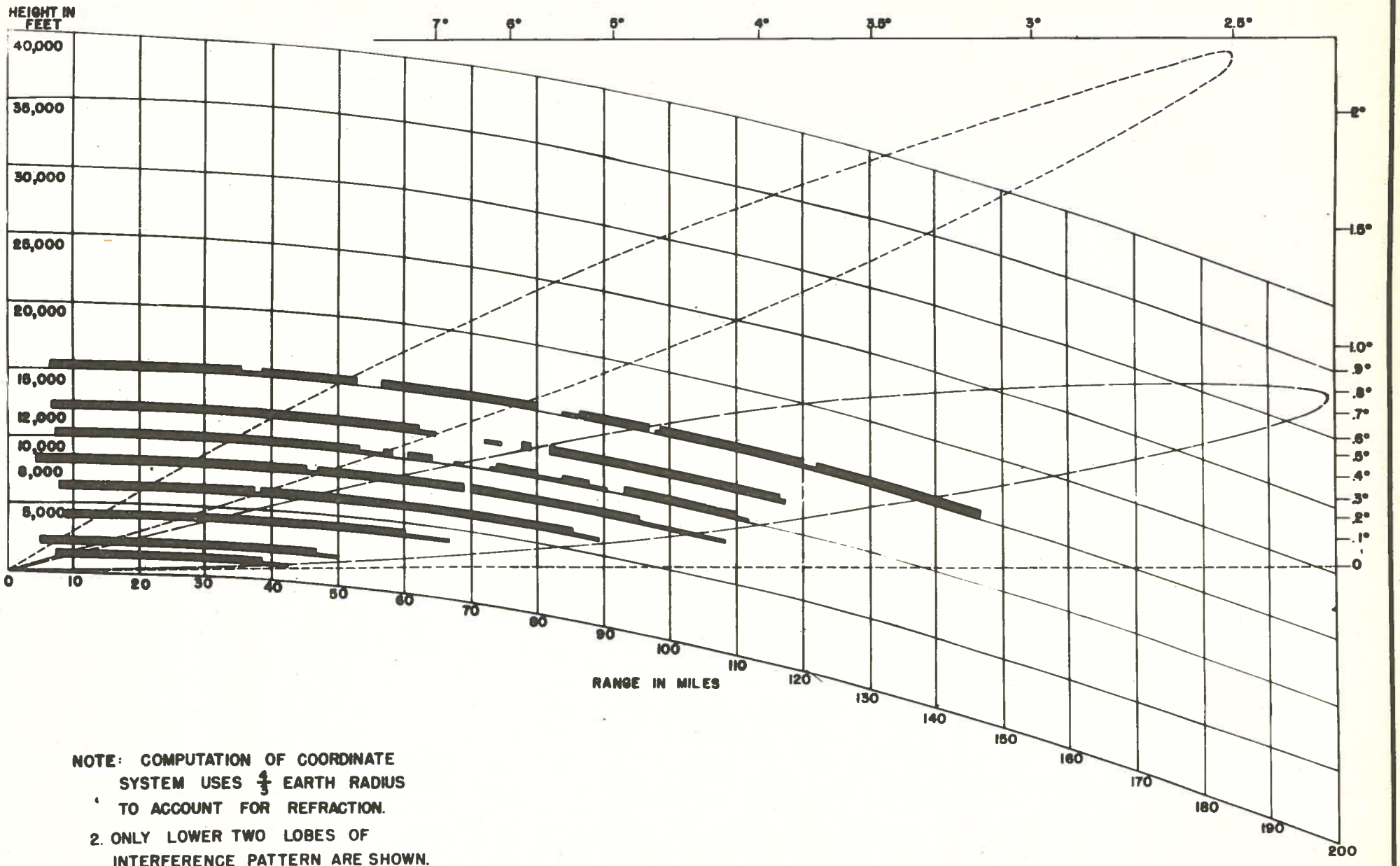
LAKE RANGE PLOTS



NOTE: COMPUTATION OF COORDINATE SYSTEM USES $\frac{4}{3}$ EARTH RADIUS TO ACCOUNT FOR REFRACTION.

2. ONLY LOWER TWO LOBES OF INTERFERENCE PATTERN ARE SHOWN.
3. PLOTS ARE FOR INCOMING AIRCRAFT.

FIGURE 3

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NAME T.R.W. COVERAGE DIAGRAM