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NRL REPORT R-3388







# AN INVESTIGATION OF FOUR BALLOON-CARRIED RADAR REFLECTORS



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NRL REPORT R-3388

# AN INVESTIGATION OF FOUR BALLOON-CARRIED RADAR REFLECTORS

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November 19, 1948



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CONTENTS

## ABSTRACT

The performance characteristics of four types of balloon-carried radar reflectors were investigated and the results are reported. Two reflectors of British design exhibited superior characteristics.

## PROBLEM STATUS

This is an interim report on only one phase of the problem. Investigation on the basic problem is continuing.

## AUTHORIZATION

NRL Problem No. R06-26R (BuShips Problem S1263X-C)

# AN INVESTIGATION OF FOUR BALLOON-CARRIED RADAR REFLECTORS

## INTRODUCTION

Scientific groups frequently have need of radar reflectors which can be carried aloft by free balloons and tracked to extreme ranges. This report presents the operational-performance characteristics of four such reflectors.

The work was carried out at the Chesapeake Bay Annex of the Naval Research Laboratory during the summer of 1948. Due to the physical location of the tracking radars, balloon flights could be conducted only when winds were in a particular direction. This frequently resulted in a considerable lapse of time between comparison flights of different reflectors. However an attempt was made to conduct tests under normal propagation conditions.

Two different radar sets were used for tracking, one an SP-1 and the other an SP-1M with 30-degree and 90-degree vertical tilt, respectively, in the antenna. Both radars operate at 2800 Mc with 0.5 megawatt peak power.

The test procedure consisted of a careful study of each reflector from the standpoint of mechanical strength, size and weight, assembly time, and ease of launching. Several radar-tracking runs or flights were then made. On each flight the reflector was tracked until its signal was lost in receiver noise. The maximum ranges attained are reported as well as the "useful" ranges which might be expected with fair consistency.

The four reflectors tested are listed below.

(1) ML-306/AP.

(2) NRL Experimental Curtains.

(3) Expanding Balloon Cover.

(4) M.O. Radar Reflector, Mark II B.

The first reflector is in standard use within the U. S. Navy, reflector (2) was used by the Laboratory during some special investigations, and reflectors (3) and (4) are used by the British Navy and are obtainable in this country from the Suchy Division of the Okonite Company, Passaic, New Jersey. Each reflector will be treated separately in the following discussion.

Fig. 1 - ML-306/AP Reflector

Fig. 2 - NRL Experimental Curtain

## DESCRIPTION AND OPERATIONAL PERFORMANCE OF THE REFLECTORS

### ML-306/AP

This reflector, designed primarily for meteorological studies, is in general use by the U.S. Navy. As seen in Figure 1, the device consists of a series of corner reflectors composed of adjacent rectangular reflecting surfaces bisected by a third plane. Supported by a balsa-wood frame, these surfaces are made of paper-backed aluminum surfaces. Each corner edge measures approximately 24 inches and when folded the device measures 4 ft x 2 ft x 1 3/4 inches. When opened, the extended length of the reflector is 10 feet. The total weight is 2.19 lb.

A release mechanism is provided with the reflector to permit launching in the more convenient folded condition. Upon release of constraining cords, the reflector assumes the form shown in Figure 1. The release mechanism feature was not tested. Comments on this mechanism have been previously reported.*

Since another group within the Laboratory had just completed tracking tests using this reflector, only two flights were made to check their results. The first flight recorded a range of but 15 miles† due to failure of the SP-1M radar. A second flight was made, using the SP-1 radar, during which a maximum range of 47 miles was obtained. This confirmed the consistent 40-mile range reported by the other group.

### NRL Experimental Curtain

This experimental reflector consisted of 0.002 inch thick aluminum sheet, 2 feet wide and 25 feet long, perforated with holes 1/4 inch in diameter. The sheet was attached to a 3-foot propeller which when suspended beneath a rising balloon would cause the sheet to rotate. At ascension rates of 500 feet per minute, the wind velocity was sufficient to produce rotation at approximately 1 rotation per second.

The curtain could be rolled into a cylinder 2 inches in diameter weighing 1 lb. With attached propeller the total weight was 2 lbs. Figure 2 shows the unrolled curtain before release.

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*ComOpDevFor Final Report on Project OP/V63/H4-7 "Evaluation of A High Altitude (100,000 feet) Aerological Balloon for Shipboard Use." September 1948.

†Nautical Miles, here and throughout this article.

Previous use of this arrangement had indicated that at low altitudes extremely strong reflections could be obtained. It was hoped such might continue to exist at high altitudes.

Though on one flight a curtain was tracked to 60 miles, it became apparent after a few runs that as the reflector gained altitude above approximately 10,000 feet at ranges of 8 to 10 miles, the echo response fell rapidly. Easily observable echoes were obtained to greater ranges but these were of the order obtainable with smaller, less-complicated devices.

At close range the rotation of the curtain produced sharp strong flashes on the radar "A" scope. Under AGC (Automatic gain control) action this flashing made the target presentation unsteady and tracking somewhat difficult. Where accurate tracking is required this would be a disadvantage.

Expanding Balloon Cover

This type of reflector consists of an electrically-conductive expanding hemispherical cover placed over a 100-g meteorological balloon. The cover consists of 1/4-inch silver-plated nylon mesh called Sucal with an elastic hem around the equator. Total weight of the cover is 2 1/4 oz.

The balloon is placed inside the Sucal cover and inflated to a diameter of 3 feet. The reflector is then released. As altitude is gained the balloon and cover expand to the elastic limit of the equatorial band of the cover. This occurs at a diameter of 5 feet. As further altitude is gained the portion of uncovered balloon continues to expand. The various attitudes of the device, as simulated on ground, are shown in Figures 3 and 4. The results of several ground tests indicated no tendency of the cover to slip from the balloon.

Several flights using this reflector were made at the Chesapeake Bay Annex of the Laboratory. The release procedure consisted merely of placing the 100-g balloon inside the Sucal cover, inflating the balloon with helium to a diameter of about 3 feet, tying off the balloon throat, then releasing the device. The balloon ready for release is shown in Figure 5.

The SP-1 radar was used for all tracking runs. The range results, together with antenna elevation angles, are shown in Table I. No attempt has been made to translate

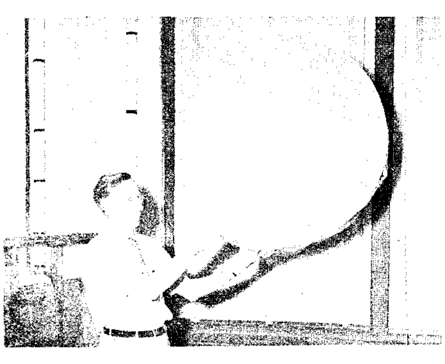


Fig. 3 - Expanding Balloon Cover - Degree of Balloon Inflation at Release

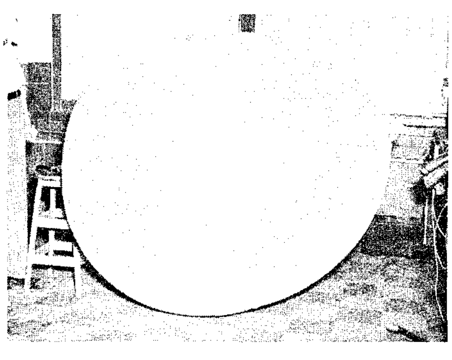


Fig. 4 - Expanding Balloon Cover - Maximum Size

elevation angle to altitude above the earth. This information is unimportant for this test, and the usual use of an effective earth radius of 4/3 at low altitude to correct for radar beam refraction is open to question at altitudes above 10 km. On flight No. 1 the balloon burst but on the remaining flights the target signal was lost in receiver noise before there was any evidence of balloon failure.

Considerable difficulty was experienced in obtaining ranges beyond 40 miles. It is felt that the useful range of this reflector should be considered as 30 miles.

Similar results have been reported by the British.

Fig. 5 - Expanding Balloon Cover Before Release

M.O. Radar Reflector, Mark II B

This reflector, like the hemispherical reflector, is used by the British for meteorological observations. The reflector, weighing 1 3/4 lb, is issued in a package measuring 40 x 5 x 2 inches.

The four horizontal arms of the reflector (Figure 6) are made of aluminum tubing and slide over short projecting stubs permanently attached to the vertical support of the reflector. Steel guy wires run between all arms and are made taut by the king post on top of the reflector. Sucalized 1/4-inch nylon-mesh vanes are then tied to the arms as shown. This assembly operation can be completed by an experienced man in 15 minutes.

The reflector is carried aloft by a hydrogen-filled 500-g balloon. When using heavier helium gas, a 700-g balloon should be used. A photograph of this reflector before release is seen in Figure 7.

Several balloon flights with this reflector were conducted, the tracking being carried out with an SP-1 radar unless otherwise noted.

The results of these flights are given in Table II.

On flight No. 1 the target reversed course, returning towards the radar. The 30° tilt-angle limit of the SP-1 radar prevented further tracking. On flights No. 2 and 3 the balloon

TABLE I

RANGE RESULTS ON EXPANDING BALLOON COVER

| Flight Number | Maximum Range | Antenna Elevation Angle |
|---|---|---|
| 1 | 25 miles | 25 degrees |
| 2 | 41 | 13 |
| 3 | 49 | 11.2 |
| 4 | 41 | 19.5 |

TABLE II

RANGE RESULTS ON MARK II B RADAR REFLECTOR

| Flight Number | Maximum Range | Antenna Elevation Angle |
|---|---|---|
| 1 | 26 miles | 17.degrees |
| 2 | 53.6 | 12.2 |
| 3 | 25.2 | 19.5 |
| 4 | 28 * | 11. |
| 5 | 59.6 | 7.2 |
| 6 | 57. | 16.8 |

* Using SP-1M radar

burst while the signal return was still observable. Successive flights were made, using a larger 700-g helium-filled balloon instead of the 500-g balloon supplied with the reflector. No evidence of balloon failure was noticed on these flights. Flight No. 4 was conducted with the SP-1M which developed modulator trouble before the range run could be completed.

Though a maximum range of 60 miles was obtained using the Mark II B, it is considered that the useful range would be 45 miles with the SP-1 radar.

## DISCUSSION

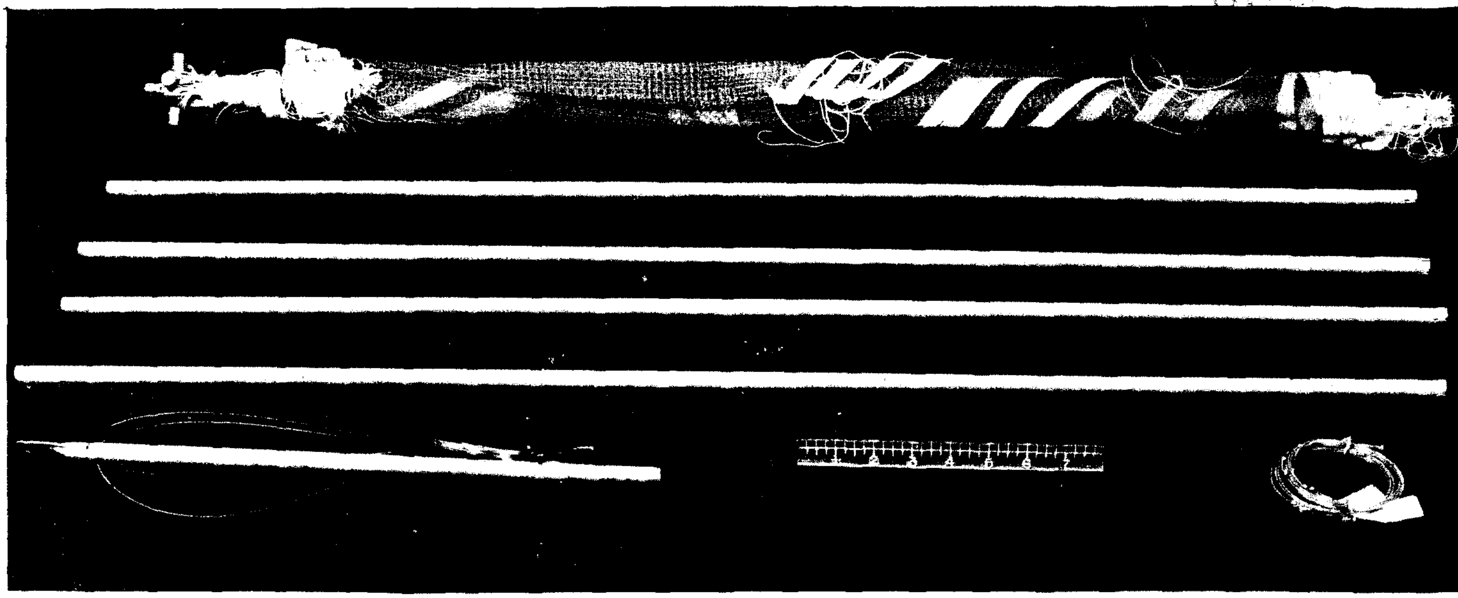
Each reflecting device has its own merits and specific application; comparisons must therefore be made with care.

The NRL experimental curtain with attached propeller produced considerably more signal return than any other reflector tested when viewed at vertical angles less than $20^{\circ}$ and ranges less than 10 miles. The curtain is light, is of small size when packaged, and can be easily launched. The signal return, though considerable, is unsteady due to the rotation of the propeller.

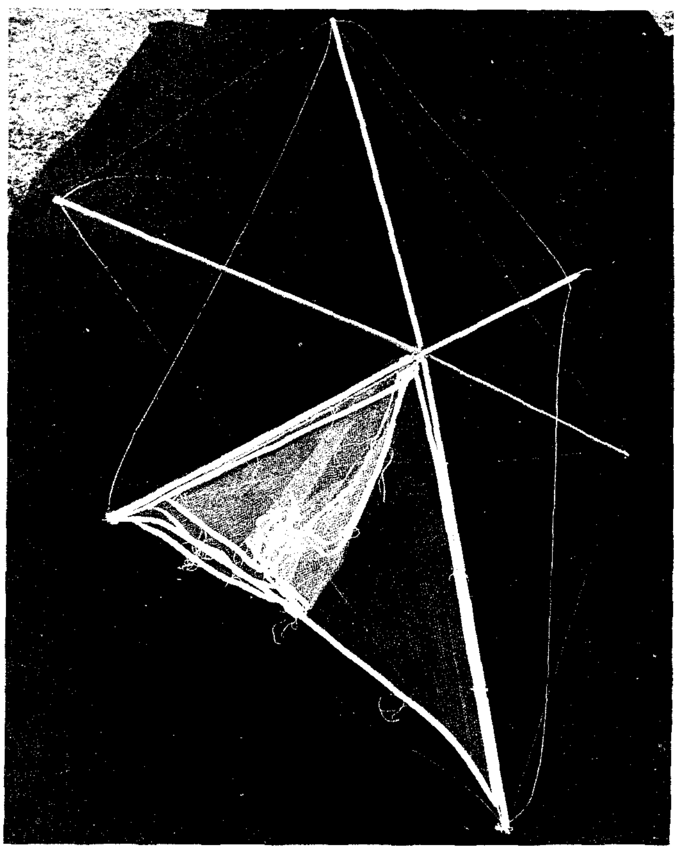
The ML-306/AP reflector, from the standpoint of orientation and reflection efficiency, is well designed. The signal return is steady--making for ease in tracking. These targets have a useful range of 40 miles. The chief disadvantage in the ML-306/AP reflector is the difficulty experienced in launching and the flimsy construction. In some launching where winds were moderate and gusty it was nearly impossible to launch the reflector without some damage to the balsa-wood framework. ComOpDevFor, as previously noted, carried out similar investigations of the Ml-306/AP. They reported: "The ML-306 radar reflector is not practicable for use at sea with the J-2000 aerological balloon due to its flimsy construction and the unreliability of the release attachments."

The British Expanding Balloon cover proved to be an excellent reflector. Of all reflectors tested this obviously is the most easily launched. Its useful tracking range was found to be 30 miles. For short-range tracking this reflector merits serious consideration.

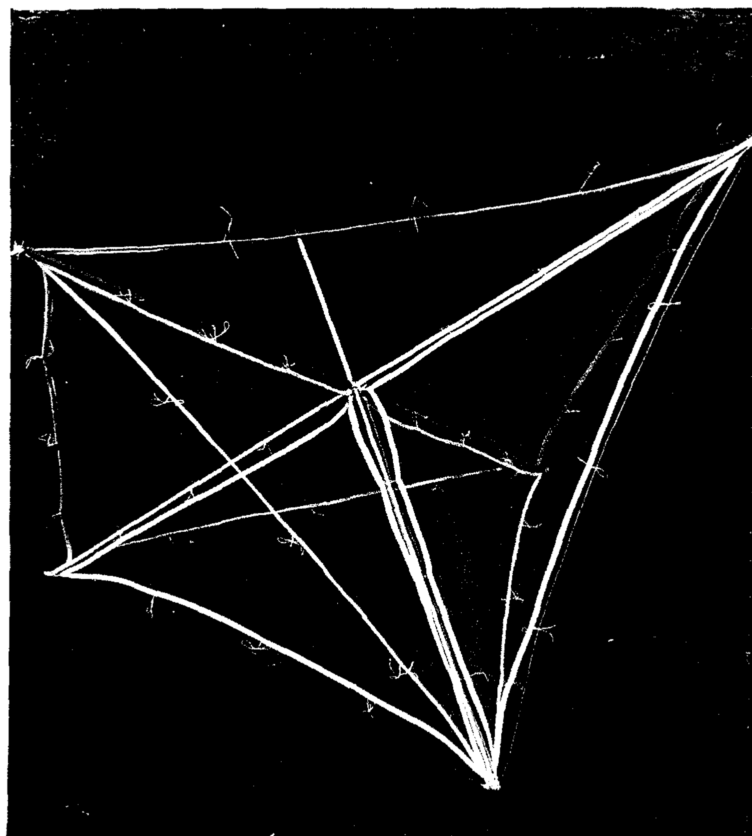
Of the four types of reflectors tested, the British Meteorological Radar Reflector Mark II B exhibited the best overall characteristics. This reflector is light, easily assembled, launched with ease, and can consistently be tracked to ranges 45 miles or greater. Its performance as a reflector is comparable to the ML-306/AP. It might well be argued



A - Component Parts



B - Partially Assembled



C - Assembled

Fig. 6 - M.O. Radar Reflector Mark II B

Fig. 7 - M.O. Radar Reflector Mark II B
Before Release

that the ML-306/AP can be unpackaged, assembled and launched faster than the Mark II B. This slight advantage is outweighed, however, by the superior mechanical characteristics of the Mark II B, its dependability, and its ease of launching.

CONCLUSIONS

As a result of the above investigation of balloon-carried reflectors it is concluded that:

1. The NRL curtain reflector can be used where strong reflections are needed at low altitudes and where a steady signal is not required.

2. The ML-306/AP is a well designed device from the reflection standpoint but is too cumbersome to handle. It can be tracked to 40 Miles.‡

3. The Expanding Balloon cover is a very efficient reflector. It is quickly and easily launched and can be tracked to consistent ranges of 30 miles.‡

4. The Mark II B reflector is similar to the ML-306/AP in its signal return but is mechanically superior and launched with ease. It takes one man 15 minutes to assemble. This reflector can be tracked consistently to 45 miles.‡

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‡ All ranges reported were obtained on an SP-1 radar.

* * *



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