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VULNERABILITY OF FIRE-CONTROL RADAR TO CONFUSION REFLECTORS

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VULNERABILITY OF FIRE-CONTROL RADAR TO CONFUSION REFLECTORS

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February 6, 1951

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ABSTRACT

A new technique has been developed for the dispensing of confusion reflectors which enables a single aircraft to protect itself against high-resolution fire-control radar. Theory of operation is outlined and test results obtained from flights made by R4D and AD aircraft are included.

This technique has been demonstrated with a single-package dispenser. When a multiple-package dispenser of comparable performance is designed, the use of confusion reflectors will be an effective countermeasure against modern fire-control radar.

PROBLEM STATUS

This is an interim report on one phase of the general problem, "Defensive and Deceptive Countermeasures;" work is continuing.

AUTHORIZATION

NRL Problem R06-26R
NE 071-402

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VULNERABILITY OF FIRE-CONTROL RADAR TO CONFUSION REFLECTORS

INTRODUCTION

A basic need exists for a suitable countermeasure capable of protecting a single aircraft against modern radar-controlled gunfire. The use of confusion reflectors for this purpose is a new approach to the problem of fulfilling this need. The conventional method of using these reflectors was to have a lead plane or planes dispense them in such a manner that protection was afforded to the remainder of the formation but no protection was given to the dispensing plane. With the coming of high-resolution fire-control radar, the problem of laying down a suitable screen of confusion reflectors became more difficult, and although this method is still theoretically useful where considerable number of aircraft are used in close formation, there will probably be many tactical situations where the screening method is no longer feasible.

As the design of the aircraft tends to the use of longer ranges, higher altitudes, and more destructive bomb loads, it is only reasonable to assume that smaller numbers will be employed on any given mission. Under such conditions the lack of protection for the lead aircraft becomes a serious deficiency. Furthermore, if a suitable countermeasure by means of which a single aircraft is able to protect itself can be developed, some of the necessity for close coordination and extremely accurate navigation on the part of following aircraft attempting to fly within the protection of the confusion-reflector trail will be eliminated. For these reasons, the possibility that a single aircraft using confusion reflectors can protect itself against modern high-resolution fire-control has been investigated.

DESCRIPTION OF CONFUSION REFLECTORS

The particular type of confusion reflector used during this investigation was the newest design of half-wave dipoles resonant at X band. These dipoles are approximately one-half inch long and cut from aluminum foil 0.00045 inch thick and provided with a slip coating to improve dispersal characteristics. The standard width of these dipoles is 0.036 inch; and, with the dimensions given, a pound of material produces about one million dipoles, which in echo return is equivalent to the echo of a B-36 aircraft. Half a million dipoles gives an echo return equivalent to a B-29 or a B-50 and a quarter million dipoles is equivalent to a P2V or a R4D. Test material was also made up with dipoles cut 0.021 inch wide instead of 0.036 inch, with proportional increase in numbers of dipoles obtained from a specific quantity of material. The packaging and dispensing of the reflectors are outlined under the description of tests.

THEORY

The purpose of a fire-control radar is to provide continuous and extremely accurate data on the position of a tracked target. To accomplish this, the radar's field of vision is limited to the area immediately surrounding the target. In the tracking condition the target appears near the center of this field of vision, or tracking cell as it will be referred to hereafter. Circuits are provided in the radar which generate error signals whenever the target moves away from the center of the tracking cell. These error signals in turn correct the position of the antenna and the range gate so that data are provided automatically and continuously.

The size of the tracking cell is determined in two dimensions by the antenna characteristics and, in the third dimension by the range gate. In the case of the Mark 25, Mod. 2, which was used in all tests, the range gate is 200 feet long and the field coverage of the antenna in the conical scan condition is 2.6^{0}. From the point of view of the aircraft using confusion reflectors, two more items of information are important. They are the course of the target aircraft with respect to the axis of the radar beam and its distance from the radar. The distance becomes important only on courses which are not along the axis of the radar beam.

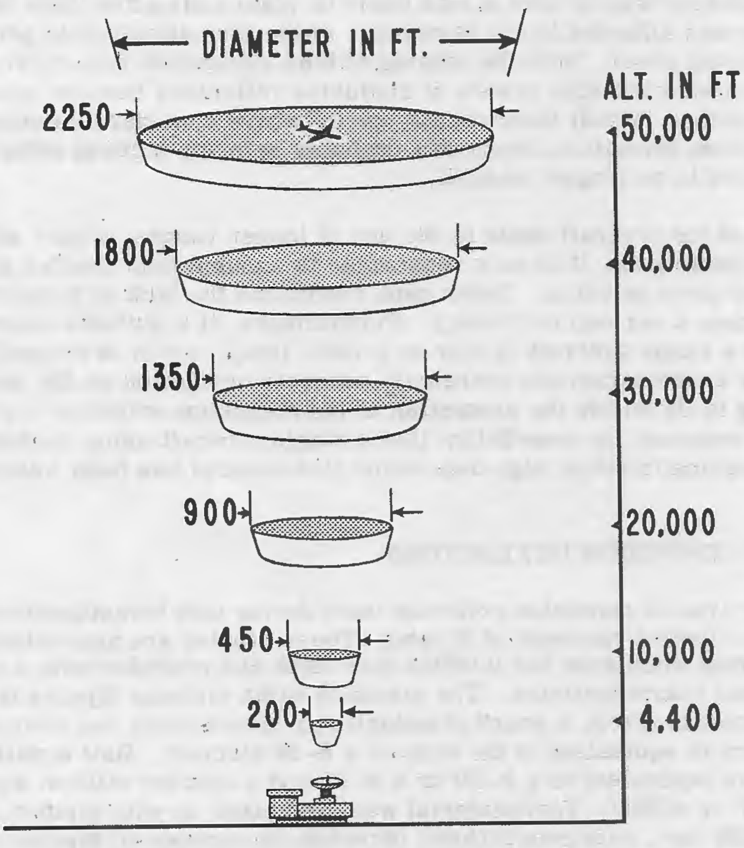

Figure 1 - Mark 25, Mod. 2 fire-control radar pointed directly up. Radar tracking cells and B-36 aircraft drawn to same scale.

This can be visualized more easily by referring to Figure 1, where the Mark 25 radar is pictured pointing directly up. The dimensions of the tracking cell at various altitudes are shown. The dimension along the axis of the radar beam is determined by the range gate and is 200 feet regardless of the distance from the radar. The dimensions of the tracking cell at right angles to the axis of the radar beam are determined by the antenna pattern and by the distance from the radar. The values for the Mark 25, Mod. 2 are as

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indicated in Figure 1. The aircraft in the highest tracking cell is a B-36 drawn to the same scale as the tracking cells. Only one tracking cell can be operative at any particular time, and when the radar is operating in the automatic tracking condition, the target will appear at the center of the tracking cell. The problem from a countermeasures' point of view is to produce within the limits of the effective tracking cell a false echo comparable to or greater than the true echo. If confusion reflectors are dispensed outside the tracking cell they do not affect the tracking in any way. If they are dispensed within the tracking cell in quantities insufficient to equal the echo of the true target, the accuracy of the tracking will be lessened but tracking will not be destroyed. If the confusion reflectors dispensed within the tracking cell produce false echoes greater than the echo of the tracked target, automatic tracking is destroyed and the radar becomes useless.

VULNERABILITY FIGURE

Since the tracked target normally appears in the center of the effective tracking cell, confusion reflectors can be dispensed between this approximate point and the boundary of the tracking cell, which is intersected by a line originating at the center and extending aft along the line of flight of the aircraft. The length of this line will be determined by the course of the aircraft and the dimensions of the tracking cell, and will in all cases be roughly a measure of the vulnerability of the tracking radar to confusion reflectors under various tactical conditions. Figure 1 shows that the vulnerability figure becomes large at high altitudes directly above the radar but at low altitudes the size of the tracking cell becomes much smaller and the vulnerability of the radar becomes proportionately less. In Figure 2, the aircraft is shown flying along the axis of the radar beam, and for this course the dimension of the tracking cell along the line of flight of the aircraft is determined by the range gate of the radar. The same definition of vulnerability figure still applies, but the figure in general is smaller for courses along the axis of the radar beam than for the courses at right angles to the radar beam. This is no longer true when the target aircraft is very close to the radar, which is no longer considered a normal tactical situation.

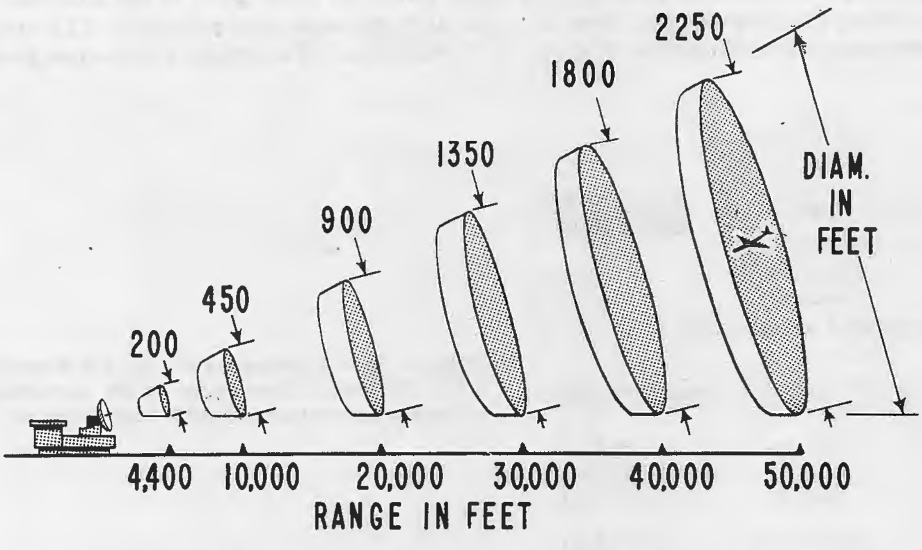

Figure 2 - Mark 25, Mod. 2 radar tracking cells and B-36 aircraft flying toward radar at low altitude

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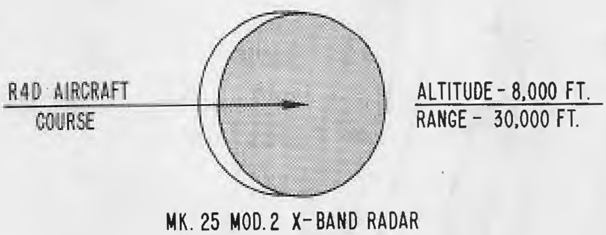
Exact vulnerability figures will not be calculated for various situations because the precise position of the plane within the tracking cell is not always known; hence for conditions where the dimensions of the aircraft are comparable to the dimensions of the tracking cell, large percentage errors could result. However it is evident that the vulnerability condition will be the same for all radial courses or courses along the axis of the radar beam, regardless of distance from the radar, but that the vulnerability figure will increase rapidly for all passing courses at right angles to the radar beam as the distance from the radar increases.

INCREASING VULNERABILITY FIGURE

From a countermeasures' point of view it is of interest to increase this vulnerability figure as much as possible. If an effective countermeasure can be provided for the radial course shown in Figure 2 it will automatically be useful for all courses except passing courses very near the radar. Even if complex forward-projection systems involving rockets and explosives are ignored, the vulnerability figure can be increased by two rather simple steps. These steps are the design of quick-opening packages, preferably packages where the wrapping is removed before ejection from the aircraft, and the relocation of the dispenser as far forward in the aircraft as possible. In this manner it may be possible to produce false echoes within the tracking cells. Flight tests were made to check the validity of this reasoning.

TESTS WITH R4D AIRCRAFT

Thirty-two flights were made for the specific purpose of checking the tracking performance of the Mark 25 against an aircraft target dispensing confusion reflector by conventional methods, and also against the same target dispensing reflectors from the forward part of the aircraft in quick-opening packages. The quick-opening packages for these runs were manually dispensed by the copilot through the copilot's window and opened quickly by virtue of the copilot's retaining a grip on the special wrapper provided for the purpose. Standard dispensing consisted of packages dropped from the after part of the aircraft and opening after hitting the slipstream. Speed of the aircraft was approximately 125 knots, and the courses were as indicated in Figures 3-6 inclusive. The results are also given in each figure.



DIPOLE QUANTITY	AFT DISPERSAL	FORWARD DISPERSAL
180,000	TRACKED	TRACKED
360,000	TRACKED	BROKE TRACK
540,000	BROKE TRACK	BROKE TRACK
720,000	BROKE TRACK	BROKE TRACK

Figure 3 - Comparison of aft dispersal with forward dispersal with aircraft on passing course at 30,000-foot range

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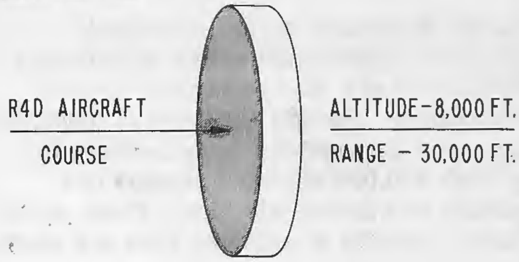
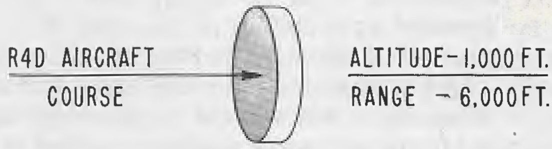


MK. 25 MOD. 2 X-BAND RADAR

DIPOLE QUANTITY	AFT DISPERSAL	FORWARD DISPERSAL
180,000	TRACKED	TRACKED
360,000	TRACKED	BROKE TRACK
540,000	TRACKED	BROKE TRACK
720,000	TRACKED	BROKE TRACK

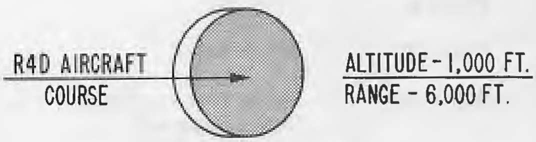
Figure 4 - Comparison of aft dispersal with forward dispersal with aircraft on radial course at 30,000-foot range



MK. 25 MOD. 2 X-BAND RADAR

DIPOLE QUANTITY	AFT DISPERSAL	FORWARD DISPERSAL
180,000	TRACKED	TRACKED
360,000	TRACKED	BROKE TRACK
540,000	TRACKED	BROKE TRACK
720,000	TRACKED	BROKE TRACK

Figure 5 - Comparison of aft dispersal with forward dispersal with aircraft on radial course at 6000-foot range



MK. 25 MOD. 2 X-BAND RADAR

DIPOLE QUANTITY	AFT DISPERSAL	FORWARD DISPERSAL
180,000	TRACKED	TRACKED
360,000	TRACKED	TRACKED
540,000	TRACKED	TRACKED
720,000	TRACKED	TRACKED

Figure 6 - Comparison of aft dispersal with forward dispersal on passing course at 6000-foot range

The echo equivalent of the R4D is 250,000 dipoles. It will be observed that 180,000 dipoles failed to break track regardless of conditions. In Figure 3 the use of additional dipoles would have broken track even with conventional dispensing, but improved operation was obtained by using quick-opening packages with forward dispensing. Figures 4-5 show the results of sixteen flights directly toward the radar. Here is where real improvement is obtained. Conventional dispensing failed to break track on any run. Forward dispensing with quick-opening packages broke track on all runs where sufficient dipoles were used to produce an echo equivalent to the echo obtained from the target aircraft. Figure 6 shows results of eight passing runs made at moderately close range. It was anticipated that tracking could be broken, but for reasons which are not quite clear the angular resolution of the radar proved too good on all runs. Results of subsequent tests made with higher speed aircraft were consistent with these results.

TESTS WITH AD AIRCRAFT

Results of tests made with the R4D were so encouraging that the question immediately arose concerning the part played by the slow speed of the aircraft. To answer this question,

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a carrier-based AD aircraft was equipped with a special dispenser designed to eject single packages of material. This dispenser, designed and constructed by the Electronics Test Department of the Naval Air Test Center at Patuxent River, Maryland, was located as far forward as possible, in this case in the pilot's cockpit. Special packages of material were supplied by Standard Rolling Mills for the tests. The packages were cylindrical in shape, about 4 inches in diameter and 4 inches long, with 900,000 dipoles enclosed in a single wrapping which was cut to pieces by the dispenser just before ejection. Tests made with the AD aircraft were made at a speed of 250 knots. Results of eighteen runs are shown in Table 1.

TABLE 1
Tracking Performance of Mark 25, Mod. 2 Radar Against AD Aircraft Using Confusion Reflectors

Run	Bearing	Range (Yards)	Alt. (Ft.)	Course	Remarks
1	100	10,000	7,000	Radial In	Broke track
2		>10,000	7,000	Radial Out	Broke track
3*	90	11,800	7,000	Passing	Tracked
4*	90	11,000	7,000	Passing	Tracked
5*	90	7,000	7,000	Passing	Tracked
6*	90	6,200	4,000	Passing	Tracked
7	100	2,000	3,000	Radial In	Broke track
8		3,500	3,000	Radial Out	Broke track - Plane flew course not strictly radial; bearing was changing
9	110	3,000	3,000	Passing	Radar jumped out of track before drop
10	90	12,000	7,000	Passing	Tracked
11	85	9,000	7,000	Passing	Broke track
12	90	7,300	7,000	Passing	Tracked
13	90	3,000	7,000	Passing	Tracked
14	90	11,000	7,000	Passing	Broke track
15	90	6,000	7,000	Passing	Broke track
16	90	7,000	7,000	Passing	Broke track
17	90	2,800	4,000	Passing	Tracked
18	90	7,000	4,000	Passing	Broke track

* Trouble developed in dispenser on above runs 3, 4, 5, and 6 because of overloading. Radar's successful tracking probably due to faulty operation of the dispenser by the operator

[redacted]

After the elimination of runs 3, 4, 5, 6, and 9 because of operator failure or equipment failure, substantially the same results are obtained as were previously obtained from the R4D tests. Track was broken on all radial runs and on five out of seven passing runs made at ranges of 6,000 yards or greater. Close-in passing runs were tracked consistently.

EVASIVE ACTION TEST

The pilot of the AD aircraft was instructed to remain within the area where the Mark 25 was capable of operating but was permitted to fly any course at any altitude and any speed, and was also permitted to dispense confusion reflectors without warning. The Mark 25 was manned by an extremely competent crew who were thoroughly familiar with its operation. They were carefully briefed regarding the confusion reflectors aboard the plane and the probable maneuvers of the plane. The Mark 25 crew were instructed to use every means at their diposal to maintain track on the target. They chose not to use the associated computer, indicating that the least vulnerable condition of the setup was to use the radar alone. In case automatic track was broken, the crew would get back on track as quickly as possible. The only facility denied the Mark 25 crew was the use of the optical telescope for the purpose of getting back on track. This simulated conditions where operations would be entirely dependent on radar. During this test, six individual dispensings were made. Track was broken on five of the six dispensings. An important conclusion can be drawn from the opinion of the Mark 25 operators, that in spite of the ability to break track, a good countermeasure against fire-control radar has not been provided when a single-package dispenser is used, because the fire-control operators are able to get back on track very quickly, usually in a matter of about three seconds. Consequently it is essential to have a dispenser capable of putting confusion reflectors into the tracking cell in a series of packages spaced closely enough in time so that the radar will be unable to get on track and feed accurate data to the computer long enough to obtain a gunfire solution. Multiple-package operation, instead of single-package operation, should supply an effective countermeasure against fire-control radar.

ALTITUDE TEST

No high-altitude tests have been made. Four runs made at a 10,000-foot altitude resulted in perfect operation of the radar on all runs. The results obtained on the passing runs at various ranges indicate that it should be possible to break track at altitudes of approximately 20,000 feet and above, when operating against fire-control radar whose performance is comparable to that of the Mark 25.

FUTURE PROGRAM

A very considerable amount of work remains to be done—much of it outside of the scope of the Naval Research Laboratory. Some of these items are:

a. The design and the installation of multiple-package dispensers in forward part of aircraft for further operational testing. If this system proves successful in further operational tests, the dispenser will need only a single rate of dispensing and probably only a single type of material. This should simplify the design considerably.

b. The design and production of packages of material covering the entire microwave spectrum. This can be done by the supplier of the material.

c. Careful evaluation of the MX-900 dispenser, which is a bomb-shaped dispenser mounted under the wing and uses standard packages. This project is now in progress.

d. The development of a simple wide-open warning receiver capable of receiving signals characteristic of fire-control, aircraft AI and AGL, and homing missiles. A warning receiver which responds only to this type of signal and which operates the dispenser automatically will insure the most ecomonical use of material.

CONCLUSIONS

A new technique in the dispensing of confusion reflectors has been demonstrated with a single-package dispenser. When a multiple-package dispenser of comparable performance is designed, the use of confusion reflectors will be an effective countermeasure against modern high-resolution fire-control radar, and will enable a single aircraft to protect itself by using reasonable quantities of reflectors.

* * *