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ABSORBENT MATERIALS FOR RADIO WAVES SECTION

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APPLICATION OF HARP FOR THE ELIMINATION OF THE ALTITUDE LINE

By

R. W. Wright
M. H. Johnson

FR-2973

- Report R-2973 -

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Preliminary Pages .... a-c
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NRL Problem A-26OR-6

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APPLICATION OF HARP FOR THE ELIMINATION OF THE ALTITUDE LINE

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NRL Problem A-268R-C

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ABSTRACT

A study has been made of the effectiveness of Harp material in eliminating the altitude line from the AN/APS-6 radar. Flight tests showed that the line may be completely removed for this installation without impairing the normal functions of the radar. It has also been shown that absorbing material which has a power reflection coefficient of 10% or less is adequate for this purpose.

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TABLE OF CONTENTS

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1. INTRODUCTION

1-1. The altitude line is a common feature of airborne radar. In a presentation of range versus azimuth it appears as a line across the scope for all azimuths at a range equal to the altitude of the aircraft. It is particularly strong over water and has seriously hampered naval radar interceptions of enemy aircraft. In closing for an attack, the signal from the target aircraft, which must be followed to the point of visual contact, disappears in this line and is thereby often lost.

1-2. The appearence of an altitude line over water even for the highly directive antenna system of a microwave radar results from the mirror-like reflection of the water surface. Energy radiated downward which may be very small in comparison to the energy in the main lobe of the antenna pattern is thus able to produce a signal comparable to the echo from a target. Treating the surface of the water as a perfect mirror, it can readily be shown that the signal from a target of cross section, σ , becomes equal to the altitude signal at a range, r, given by

$$r \simeq \frac{\sqrt{\sigma}}{p} \qquad (1)$$

where, p, is the side lobe intensity of the antenna system in a vertically downward direction. For a cross section of 100 sq. ft. and a downward side lobe intensity of 20 db., eq. 1. gives a range of 1000'. Hence, the altitude signal would be more intense than the target signal for all altitudes above 1000'. It is evident that the downward radiation must be very small in order that this signal be eliminated from normal radar operation.

1-3. The elimination of the altitude line can be achieved by screening out the downward radiation. Absorbent materials have a twofold advantage over a metal foil for this purpose. Energy reflected from the metal foil may be again reflected into the downward direction or it may, by entering the antenna, disturb the operation of the transmitter. Both possibilities are eliminated when Harp material is used.

1-4. Operational trials of the effectiveness of Harp in reducing the altitude line have been made. In reference 1 the results of such tests are described in which the altitude line was sucessfully removed from the AN/APS-6 radar in F6F aircraft. The Harp installation was made in accordance with the instructions from the Naval Air Materiel Center, Philadelphia, Pennsylvania, contained in reference 2.

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1-5. Problem A-268R-C was established by the Bureau of Aeronautics to study the reduction of the altitude line in the AN/APS-6 radar by use of Harp material. It has two objectives: to determine the area of the radome which should be covered by Harp and to determine the required electrical specifications of the absorbing material. The tests herein described were conducted with these objectives in view.

2. EQUIPMENT

2-1. Inasmuch as photographic records were desired the tests were made on an AN/APS-6 radar in a PBJ rather than an F6F aircraft. The test gear for the latter aircraft would be essentially complicated by the fact that only a pilot can be carried while both radar and photographic operators can be carried in a PBJ. The same radome is used in both installations. However, inspection of Plate 1 shows that the radomes are differently located in the two aircraft. In the PBJ all parts of the aircraft are behind a plane drawn perpendicular to the axis of the aircraft through the base of the transparent section of the radome. In the F6F a considerable portion of the fuselage is ahead of this plane. Nevertheless, the radome is so far out on the wing that this difference is believed to have no significance.

2-2. A 3" repeating B scope was installed by the Aircraft Radio Division (which also maintained the radar equipment during the flight tests) in a PBJ aircraft assigned to and operated by Project North at the Anacostia Naval Air Station. A 35 mm. movie camera, provided by the Missile Control Division, was mounted 7 and 1/2" in front of this scope. It was manually operated to expose each frame for the duration of a single scan. Successive scans could thus be photographed over any desired period. An operator and photographic services were provided by the Photographic Laboratory at NRL.

2-3. The Harp installations were made with Bostick L-115 cement in accordance with the instructions in reference 2. The solvent of this cement is toluene and consequently should have absolutely no effect on a bakelite radome. For a polystyrene radome the precautions described in reference 2 are believed entirely adequate to insure that no weakening of the radome can be caused by the cement. Even though four separate installations were made in a polystyrene radome in the course of the present tests, no weakening of the radome could be detected.

3. OPERATION

3-1. The radar performance of the AN/APS-6 was normal throughout the period of testing. At the beginning of each flight the set gain and scope intensity were adjusted to give a satisfactory picture. The controls were left unaltered during the flight unless a failure in the equipment necessitated a readjustment.

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3-2. The tests were made by overtaking a target plane at various altitudes, namely 2000', 5000' and 7000', above water. Small changes in radar performance from one flight to the next are thus not important inasmuch as the signal from the same target was compared to the altitude line. The relative strength of these two signals was the criterion used in judging a particular installation.

3-3. As the approaches were made at zero relative azimuth, the target appears on the center line of the scope photographs. In the AN/APS-6 the target appears as a double pip, the two pips being in general at slightly different ranges (see reference 4). The range displacement of the port with respect to the starboard pip serves to indicate the relative elevation of the target with respect to the PBJ.

4. TEST RESULTS

4-1. The first series of flights were made with an uncoated radome. Typical scope photographs are shown in Plate 2. The three photographs on the left are taken from a run at 7000' altitude with a five-mile range sweep while those on the right are from a run at 2000' altitude with one-mile range sweep. The top pictures show the target at a range somewhat greater than the altitude. In the middle pictures the range is equal to the altitude while in the lower pictures it is somewhat less than the altitude. In all the photographs the bottom edge corresponds to zero range. It may be parenthetically remarked that more noise appears on the five-mile range sweep because the receiver gain and scope intensity were left unaltered when the range sweep was changed.

4-2. In a second series of flights MX-410/AP Harp was installed in the radome in accordance with the NAMC pattern described in reference 2. Typical scope photographs are shown in Plate 3. The conditions of range and altitude are exactly the same as for the corresponding photographs in Plate 2. Arrows at the edges of each photograph indicate the range equal to the altitude for that flight. It will be observed that all traces of the altitude line have been removed. In this installation the altitude line has never been seen for the aircraft in level flight and appeared only when the aircraft was banked at a considerable angle.

4-3. So far as could be determined, the Harp installation did not affect the radar performance when the target plane was at a different altitude than the PBJ. Likewise, it appeared in the observation of surface targets that the covering had little or no effect on the visibility of such targets even for downward angles of 45°. Although the tests were not precise, they were sufficiently good to show that the normal functions of the AN/APS-6 were impaired in no way by the Harp installation.

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4-4. In a third series of flights, MX-410/AP Harp was placed over a smaller area of the radome. This reduced pattern was obtained from the NAMC pattern by cutting out a strip 4" wide from the entire upper edge. Typical scope photographs are shown in Plate 4. The conditions of altitude and range are exactly the same as for the corresponding photographs in Plate 2. It will be noted that a faint altitude line appears at 7000' altitude and a somewhat stronger line at 2000' altitude. In both cases the target is clearly discernible when the range and altitude are equal.

4-5. In a fourth series of flights, Harp with poorer electrical characteristics was installed in accordance with the NAMC pattern. The power reflection coefficient of this material was 15% at the operating wavelength in contrast to the 4% or less required by the specifications for MX-410/AP. No difference could be detected between the installation and that made with MX-410/AP.

4-6. The manufacturing tolerance for Harp in this installation could certainly be increased. Specifications which called for a power reflection coefficient less than 10% at the operating wavelength would provide material with an ample safety factor. The effectiveness of absorbing material with a 10% reflection coefficient can readily be understood if it is remembered that energy reflected from the Harp screen which contributes to the altitude line must be twice reflected, once in transmission and once in reception.

4-7. In a fifth series of tests aluminum foil was installed in the radome in accordance with the NAMC pattern. The altitude line now appeared at all altitudes for the aircraft in level flight. Its strength relative to the target echo was less than for the uncoated radome but somewhat greater than for the reduced Harp pattern (Plate 4).

5. CONCLUSIONS

5-1. The flight tests show that MX-410/AP Harp installed in accordance with the NAMC pattern in AN/APS-6 radar completely eliminates the altitude line for an aircraft in level flight without impairing the operation of the set in any of its normal functions.

5-2. Flight tests show that a faint altitude line may be left on the scope if Harp is installed on a smaller area of the radome (Paragraph 4-4).

5-3. Flight tests show that absorbing materials which have a reflection coefficient of 10% at the operating wavelength would be entirely satisfactory for screening out the altitude line.

5-4. The satisfactory results obtained in eliminating the altitude line from the AN/APS-6 strongly indicate the desirability of investigating the effectiveness of Harp for the same purpose in other AI radar and in airborne fire control radar.

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REFERENCES

1. BuAer letter Aer-EL-32-JWJ, F42-5/36 to Dir., NRL dated 29 April 1946.

2. Naval Aircraft Factory Radome Section Report 1-45, PE-1.15-MAH, F42(R), entitled "Procedure For Installation of MX-410/AP Material in CW-22/A and CW-22A/A Radomes".

3. BuAer letter Aer-EL-32-EWY, F42-5/36(AN/APS-6) of 1 March 1946 to Dir. NRL.

4. Westinghouse Confidential Report CO-AN-08-30APS6-2 entitled, "Operating, Maintenance Handbook for AN/APS-6A Aircraft Radar Equipment".

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F6F AIRCRAFT

PBJ AIRCRAFT

RADOME LOCATIONS

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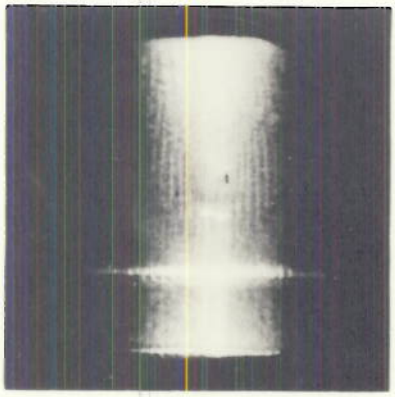
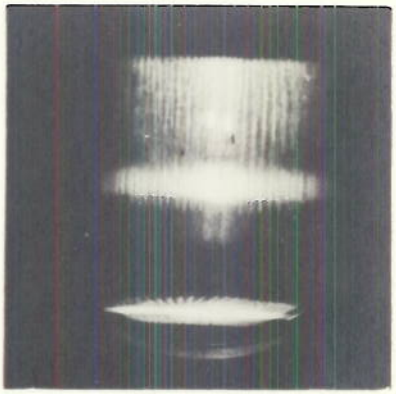
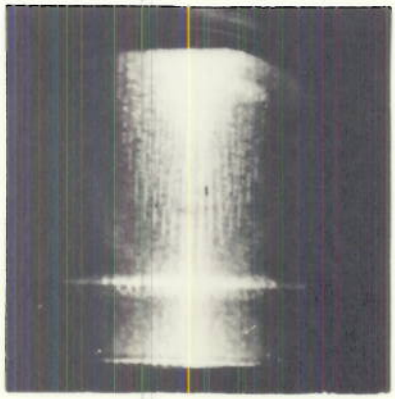
PLATE I

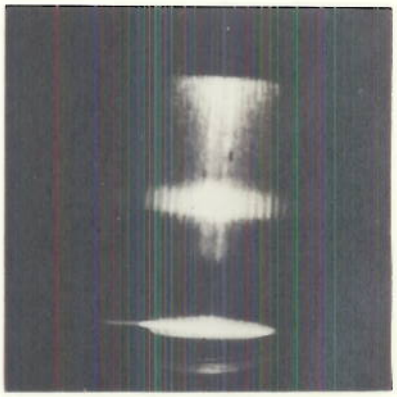
7,000 FT. ALTITUDE
5 MILE RANGE SWEEP

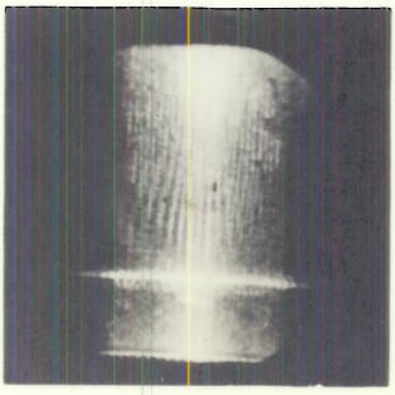
2,000 FT. ALTITUDE
1 MILE RANGE SWEEP











RADOME WITHOUT HARP

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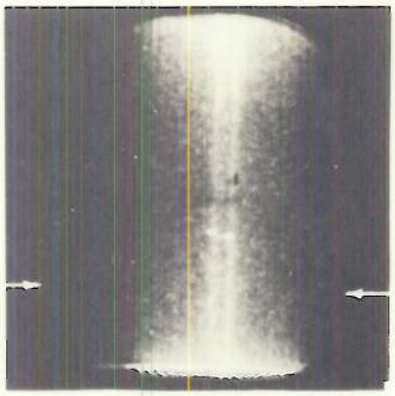
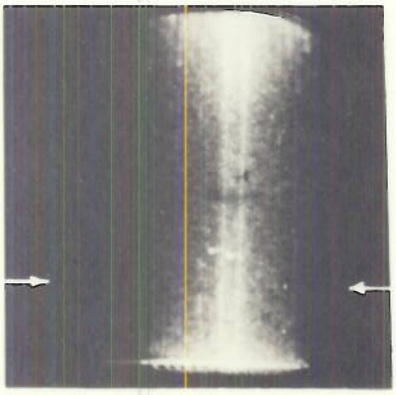
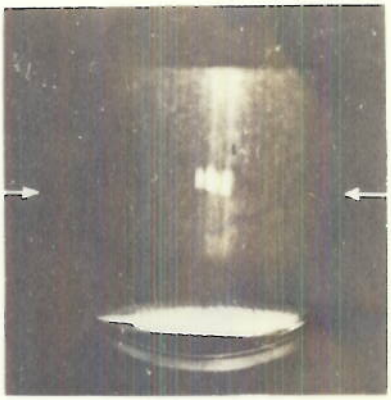
PLATE 2

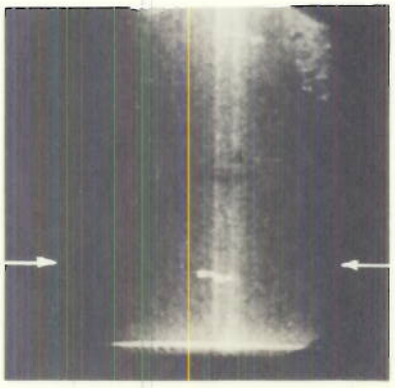
7,000 FT. ALTITUDE
5 MILE RANGE SWEEP

2,000 FT. ALTITUDE
1 MILE RANGE SWEEP









RADOME COATED WITH N.A.M.C. HARP PATTERN

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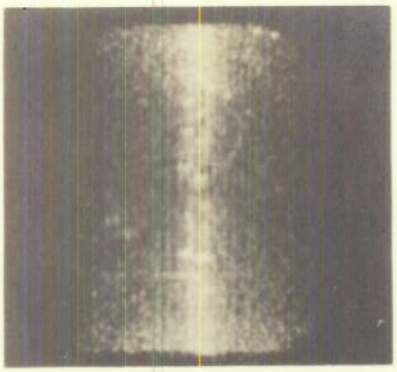
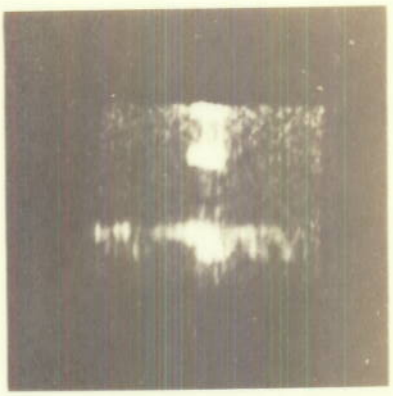
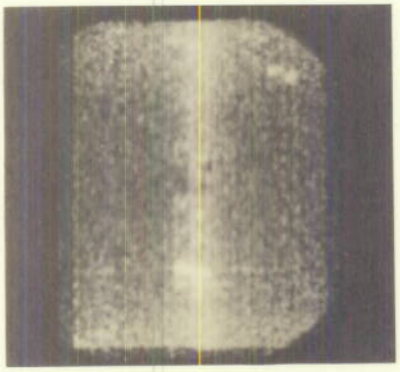
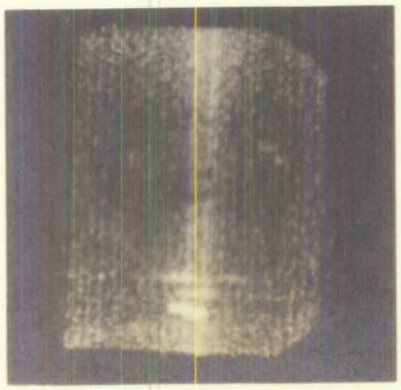
7,000 FT. ALTITUDE
5 MILE RANGE SWEEP

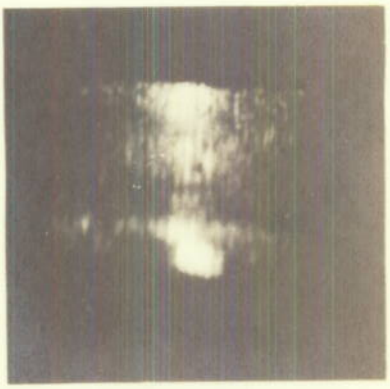
2,000 FT. ALTITUDE
1 MILE RANGE SWEEP











RADOME COATED WITH REDUCED HARP PATTERN

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