SECRET
SECURITY INFORMATION

NRL REPORT 4040

COPY NO. 122

COATED DIPOLES AS CONFUSION REFLECTORS

D. B. Christman

Countermeasures Branch
Radio Division II

September 11, 1952

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

DOWNGRADING AT 12-YEAR INTERVALS

NOT AUTOMATICALLY DECLASSIFIED

DOD DIR 5200.10

SECRET

UNCLASSIFIED
UNCLASSIFIED
SECRET

SECURITY

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. The transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Reproduction of this document in any form by other than activities of the Department of Defense and the Atomic Energy Commission is not authorized unless specifically approved by the Secretary of the Navy or the Chief of Naval Operations as appropriate.

ABSTRACT

Several new types of X-band dipoles which employ a very thin conductive coating on a nonmetallic base have been obtained for evaluation. These dipoles have been compared by experimental methods in the flight tests with aluminum-foil dipoles to determine the relative efficiency of the new units and the standard types. One type, manufactured by the Minnesota Mining and Manufacturing Co., reduced the weight to one-fifth and the space to one-half of those of the RR-12A/U package. It is anticipated that further development will improve the efficiency of this type of dipole.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem R06-26
RDB Project NE 071-402

Manuscript submitted August 14, 1952

UNCLASSIFIED
UNCLASSIFIED
SECRET
SECURITY INFORMATION

SECRET
CONFIDENTIAL
UNCLASSIFIED

COATED DIPOLES AS CONFUSION REFLECTORS

INTRODUCTION

It has been found that an aircraft can obtain a substantial degree of self-protection against automatic-tracking fire-control radars by dispensing suitable quantities of confusion reflectors in the proper manner.[1] To obtain the maximum self-protection possible for the amount of weight and space allowed for this purpose, the confusion reflectors used must be as small and light as possible while providing and an echo of the proper size.[2] Several new types of X-band dipoles which are smaller and lighter than the standard types have been obtained for evaluation.

DESCRIPTION OF MATERIALS

The Minnesota Mining and Manufacturing Company of St. Paul, Minnesota has developed four types of vacuum-process dipoles. These dipoles have the following characteristics:

Physical Characteristics of Minnesota Mining and Manufacturing Company (MMM) Dipoles

Type	Diameter of Package of 500,000 (in.)	Dipole Dimensions			Conductive Coating
		Length (in.)	Width (in.)	Thickness (in.)	
A	2-3/8	9/16	0.007	0.001	Aluminum
B	1-13/16	9/16	0.004	0.0009	Aluminum
C	1-5/16	9/16	0.003	0.0005	Aluminum
D	---	9/16	0.004	0.0009	Silver

[1] "Vulnerability of Fire-Control Radar to Confusion Reflectors" by J. C. Link, NRL Report 3777 (Secret), February 6, 1951

[2] "Optimum Characteristics for Radar-Reflecting Materials" by W. L. Emery, NRL Report R-3427 (Confidential), March 7, 1949

SECRET
SECURITY INFORMATION
CONFIDENTIAL
UNCLASSIFIED

Types A, B, and C are shown in Figure 1 together with a few loose dipoles of each type. These packages contain 500,000 dipoles. Type D dipoles are packaged in units of 100,000.

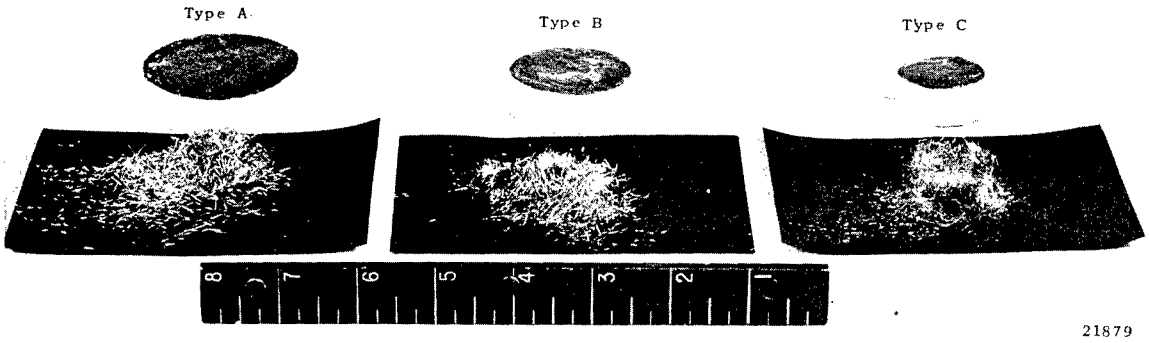

Figure 1 - Minnesota Mining and Manufacturing Co. dipoles

Suchy Holdings, Ltd.,of London, England has developed a "sucalized" nylon bristle dipole 9/16 inch long and 0.003 inch in diameter. Two types of packages containing 500,000 dipoles were received. One package is 2-3/4 inch by 2-3/4 inch by 3/4 inch; the other is 9/16 inch thick and 3-1/4 inch in diameter. These two packages and some loose dipoles of this type are shown in Figure 2.

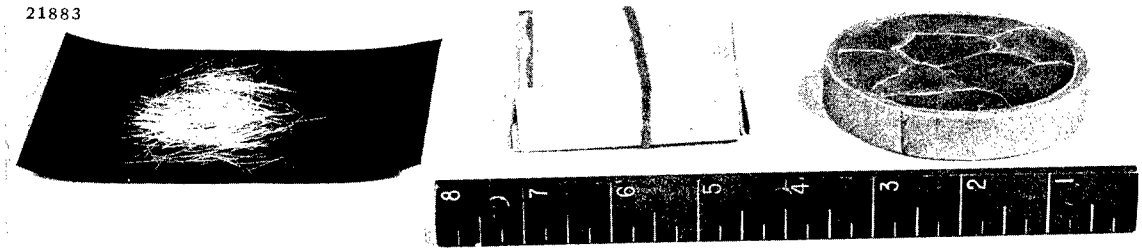

Figure 2 - Suchy dipoles

For comparison with the coated dipoles, special packages of 180,000 standard slip-coated aluminum foil dipoles were used. These dipoles are made in two sizes: 0.036 inch by 0.00045 inch by 9/16 inch, and 0.021 inch by 0.00045 inch by 9/16 inch, exclusive of the slip coating. The packages containing these dipoles are shown in Figure 3. A standard package of X-band dipoles, RR12A/U, was also used in comparison. This package contains 250,000 dipoles 0.036 inch by 0.00045 inch by 3/4 inch, and 500,000 dipoles 0.036 inch by 0.00045 inch by 9/16 inch. The outside dimensions of this package are 9-1/2 inch by 3-1/4 inch by 7/8 inch. This package is shown in Figure 4. For comparison, the dipole packages are shown together in Figure 5.

UNCLASSIFIED

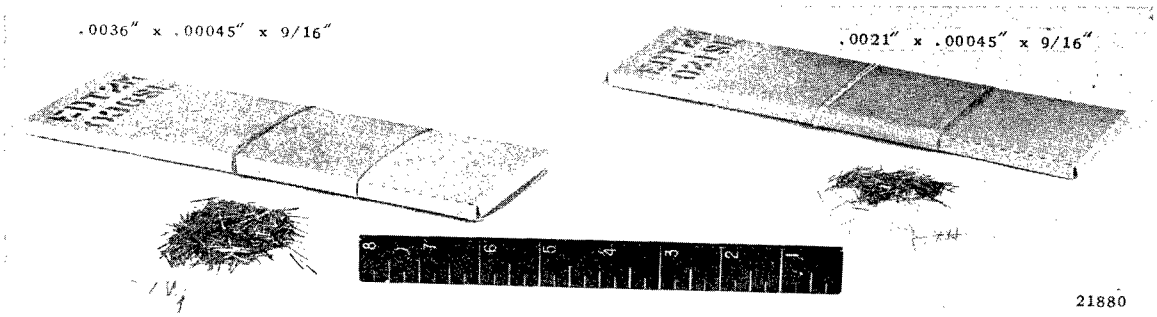

Figure 3 - Slip-coated aluminum foil dipoles

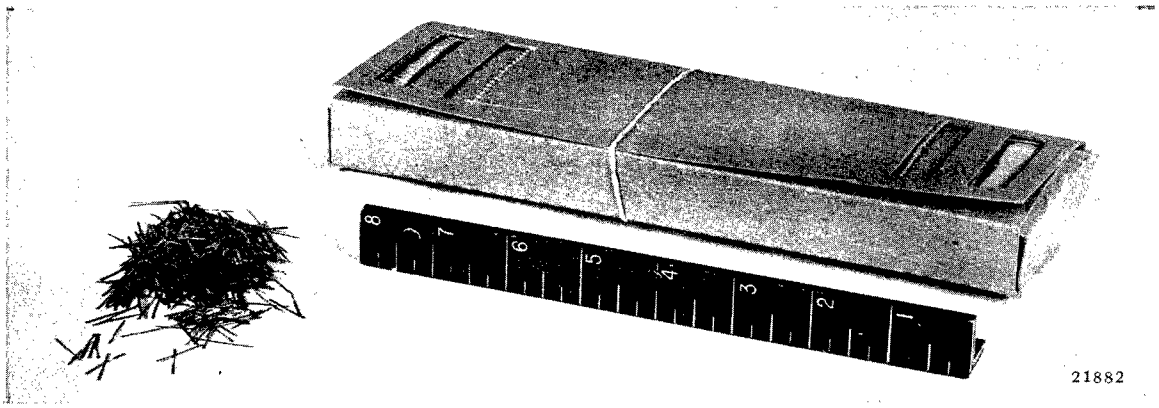

Figure 4 - RR12A/U

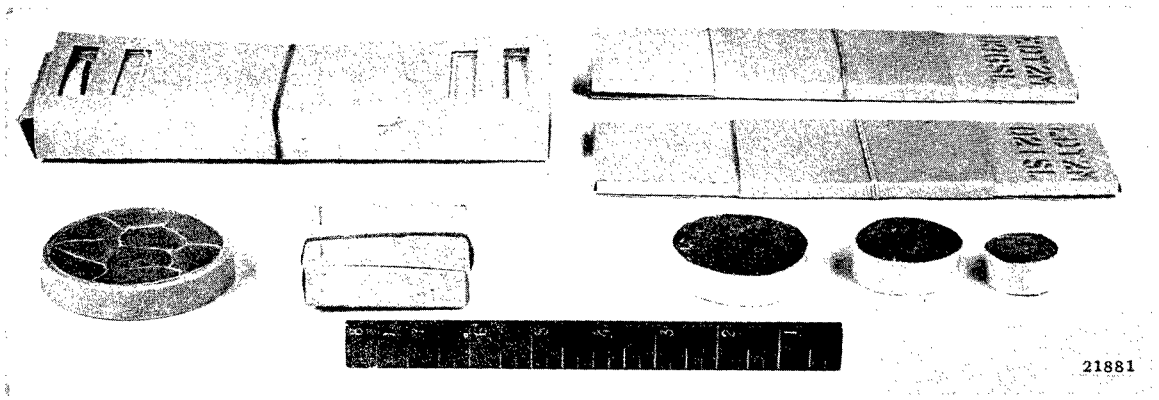

Figure 5 - Packages of dipoles used in the evaluation of coated dipoles

EVALUATION

Laboratory Tests

A first indication of the ability of a dipole to reflect an incident radio wave is the ohmic resistance of the dipole. For the larger aluminum-foil dipoles, an ohmmeter may be used in the normal manner by placing a test prod at each end of a dipole and reading the resistance. To measure the resistance of the Minnesota Mining and Manufacturing and Suchy dipoles, it was necessary to place each end of the dipole under test between two brass blocks to make contact with the conductive coating. When this was done, the ohmmeter was used in the normal manner.

To obtain a closer measurement of the ability of the experimental dipoles to reflect X-band energy for comparison with standard dipoles, dipoles of each type were placed on sheets of gummed paper in random orientation. The sheets were then placed between X-band energy source and a detector. Dipoles were added until the reflectometer indicated that 50 percent of the energy was received at the detector. The number of dipoles needed to produce this condition was an indication of the ability of the dipole type to produce an echo when illuminated by a radar at the frequency for which the dipole was cut. As a quick check on the effects of aging on the dipoles, these sheets were preserved and remeasured periodically.

The average resistance per dipole and the number of dipoles necessary to provide 50-percent reflection of X-band energy are shown in Table 1 together with dipole sizes, weights, and conductive coatings. When exposed continuously to air on the sheets used for reflection measurement, both sample dipoles using silver as the conductive coating had deteriorated. The Minnesota Mining and Manufacturing Co. type D dipoles lost approximately 50 percent of their reflectivity after two weeks and 90 percent after four weeks. The Suchy dipoles lost less during the same period, because of the heavier coating of silver. These dipoles lost approximately 35 percent of their reflectivity in two weeks, and 70 percent after four weeks.

TABLE 1
Physical and Electrical Characteristics of Dipoles

Dipole Type	Dimensions (in.)	Wt. & No. of Dipoles in Standard Pkg.		Ohms per Dipole (avg)	Necessary Dipoles to Decrease Reflectometer 50 Percent	Conductive Coating or Reflecting Material
		Weight	Quantity (no.)			
Minnesota Mining A	0.001 x 0.007 x 9/16	31.25 g	500,000	47	325	Aluminum
Minnesota Mining B	0.0009 x 0.004 x 9/16	14.0 g	500,000	350	830	Aluminum
Minnesota Mining C	0.0005 x 0.003 x 9/16	8.25 g	500,000	178	1000	Aluminum
Minnesota Mining D	0.0009 x 0.004 x 9/16	4.65 g	100,000	35	720	Silver
Suchy	0.003 x 9/16	53.1 g	500,000	5	506	Silver
RR12A/U	0.00045 x 0.036 x 3/4	1.1 lb	250,000	~0	147	Aluminum
	0.00045 x 0.036 x 9/16		500,000	~0		
Standard 0.036″	0.00045 x 0.036 x 9/16	104 g	180,000	~0	147	Aluminum
Standard 0.021″	0.00045 x 0.020 x 9/16	56 g	180,000	~0	182	Aluminum

UNCLASSIFIED

Balloon Tests

As another preflight test, 0.1-gram samples of each type of dipole were placed in two-foot-diameter pilot weather balloons. The dipoles in each sample were dispersed as completely as possible in the balloons and then were sprayed with water to hold them to the inner surface of balloons during flights. Each balloon was tracked automatically by the Mark 25 radar, and the range at which this radar lost track was recorded.

The results of the balloon tests are given in Table 2. The use of an automatic tracking radar in this phase of the evaluation eliminated the human element of hand tracking, leaving the reflective qualities of the dipoles, the dispersal of the dipoles in the balloons, and the atmospheric propagation conditions as variables. During this phase, it was noted that the conductive coating of the Minnesota Mining and Manufacturing type D dipoles flaked off. Because of the poor mechanical characteristics and the rapid aging of the material, this type of dipole was not tested further.

TABLE 2
Balloon Flight Test Results

Dipole Type	Flights (no.)	Average Range (yd)	Median Range (yd)	Lowest Range (yd)	Highest Range (yd)
Minnesota Mining A	10	9120	9185	6810	10770
Minnesota Mining B	11	7730	7600	7120	8670
Minnesota Mining C	10	8330	9220	8030	10660
Suchy	10	11960	11790	10540	13740
Standard 0.036″	10	11220	11305	6540	16620
Standard 0.021″	9	10540	10600	7620	12570

Comparison of the various types of dipoles by the maximum range to which a small sample of dipoles placed in a pilot balloon can be tracked automatically is not satisfactory. Although the averages of these balloon flights place the dipole types in the same order as the results of the echo comparison in the flight test, Table 2 shows that the variation in maximum range between samples of the same dipole type is considerably greater than the variation between the averages of different types of dipoles. Consequently, no determination can be made from this data of the number of dipoles needed to give an echo equivalent to the echo of another type of dipole.

Flight Tests

Direct comparisons of the echoes from the test samples with the echoes obtained from standard dipoles were made during a flight test. From a single-engined carrier-based

UNCLASSIFIED

attack aircraft, the AD, flying an approach course, a test sample was dropped between packages of standard material at a range of approximately 10,000 yards. These drops were made approximately 300 yards apart. Photographs of these echoes were taken of the precision sweep of the Mark 25 radar range presentation. Finally, to obtain an approximation of the opening time of these sample dipoles and the quantity of dipoles needed for tactical use, break-lock tests were flown with a P2V-2 aircraft, a twin-engined long-range patrol bomber, and recorded by the Mark 25 radar. Varying quantities of the materials were used on both passing and approach courses, and the effects on radar tracking were noted. The results of the break-lock tests are given in Table 3. It was found that all types of window break lock when a sufficiently large quantity of material was used.

TABLE 3
Break-Lock Test Results

Run	Dipole Type	Quantity of Dipoles (millions)	Range (yd)	Results
		Passing Course		
1	Minnesota Mining A	0.5	14,000	Echo visible, radar tracked
2	Minnesota Mining A	1.0	13,000	No echo
3	Minnesota Mining A	1.5	14,000	Broke track
4	Minnesota Mining B	0.5	14,000	Echo visible, radar tracked
5	Minnesota Mining B	1.0	14,000	Echo visible, radar tracked
6	Minnesota Mining B	2.0	16,000	Broke track
7	Minnesota Mining B	2.5	14,000	No echo
8	Minnesota Mining C	0.5	12,500	Good echo, radar tracked
9	Minnesota Mining C	1.0	13,000	Good echo, radar tracked
10	Minnesota Mining C	1.5	13,000	Broke track
11	Suchy	0.5	14,000	No echo
12	Suchy	0.5	14,000	Broke track
13	Suchy	1.0	14,000	Broke track
14	Suchy	1.0	14,000	Broke track
15	0.036″ Coated	0.18	14,000	Echo visible, radar tracked
16	0.036″ Coated	0.36	14,000	Echo visible, radar tracked
17	0.021″ Coated	0.18	15,000	Echo visible, radar tracked
18	0.021″ Coated	0.36	15,000	Broke track
19	RR12A/U	0.75	15,000	Broke track
		Approach Course		
A1	Suchy	1.0		Broke track
A2	Suchy	1.0		Good echo, radar tracked

The analysis of the photographic data on the comparison drops from the AD aircraft is summarized in Table 4. The response of the test samples of flights 2a and 4 was considerably below the other drops of their respective types and was not included in the over-all averages for these types. The material used in Flight 4 had been on hand for several months and had apparently aged considerably. This sample was packed in the rope-type container shown in the center of Figure 2. This packaging is looser than the round-type package containing the same material shown at the right of Figure 2. This allows increased air circulation which increases the rate of oxidation of the silver coating thereby destroying the conductivity of the conductive coating.

UNCLASSIFIED

TABLE 4
Echo Comparison Results

Dipole Type	Flignt Number	Response of 500,000 Test Dipoles Relative to that of 180,000 Standard Coated Dipoles	
		db	Average db of all flights
Minnesota Mining Type C	1	-3	-4
	1a	-4	
	1b	-1	
	1c	-5	
Minnesota Mining Type B	2	-4	-5
	2a	-11*	
	2b	-6	
	2c	-4	
Minnesota Mining Type A	3	-4	-3
	3a	-1	
	3b	-4	
	3c	-2	
Suchy	4	-8*	0
	4a	+4	
	4b	-1	
	4c	-2	

* Not included in averages of all flights

Some of the data photographs of the comparison drops are reproduced in Figures 6 through 17. Since the drops were made on an approach course and the range in the photographs decreases from right to left, the echoes are numbered from right to left with the right echo designated as echo 1, etc. Figure 6 shows the echoes to the right of the range gate; the remainder of the photographs show the echoes to the left of the range gate. During Flight 1, in which Figure 6 was taken, it was found that the radar had a tendency to resume tracking the aircraft when it flew through the range gate; therefore in succeeding flights the range gate was moved to the right or out in range from the window drops which produced the echoes.

From direct echo comparison between the new types of window and the standard 0.036-inch coated aluminum foil dipoles, the number of new dipoles needed to be equivalent to a standard dipole were estimated. For comparison, the same ratio obtained from the reflectometer is also listed in Table 5.

In tactical use, the echo produced by the standard RR12A/U package, consisting of 750,000 dipoles and equivalent to a B-29 aircraft, is of most interest. From the results of the echo comparison test, the number of dipoles of the new types needed to produce an echo equivalent to that of the RR12A/U was estimated. The size and weight of the equivalent packages, extrapolated from the present physical measurements of the material, are given in Table 6.

UNCLASSIFIED

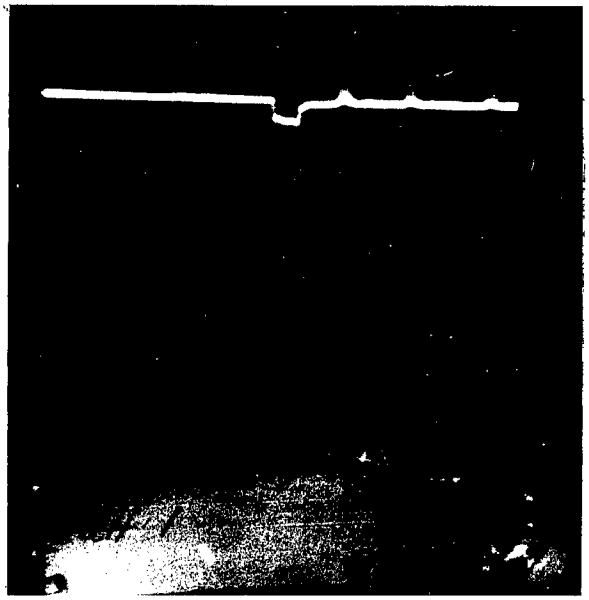

Figure 6 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type C
Echo 3. Standard material

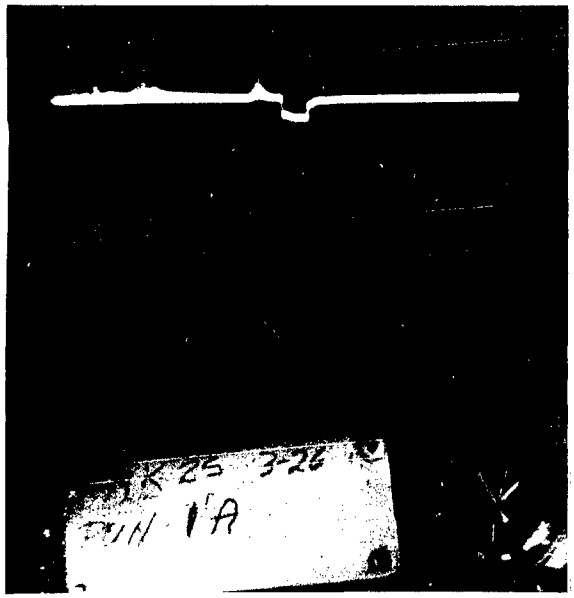

Figure 7 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type C
Echo 3. Standard material
Echo 4. AD Aircraft

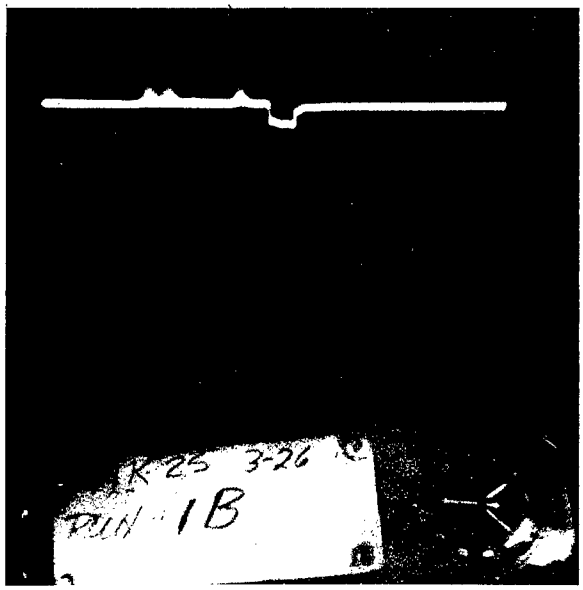

Figure 8 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type C
Echo 3. AD Aircraft

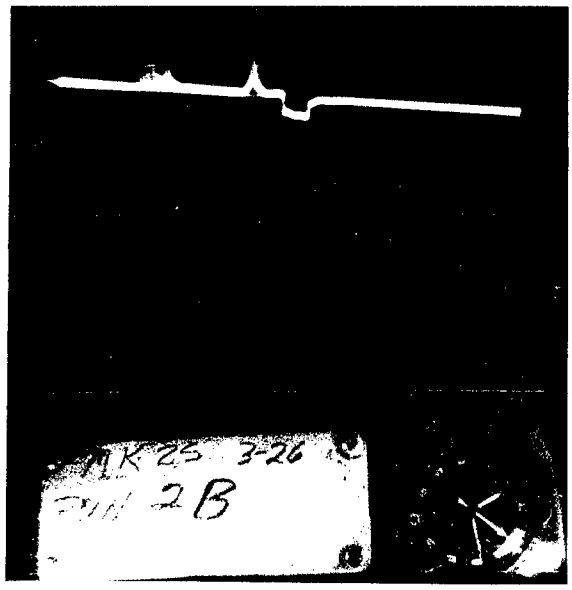

Figure 9 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type B
Echo 3. AD Aircraft

UNCLASSIFIED

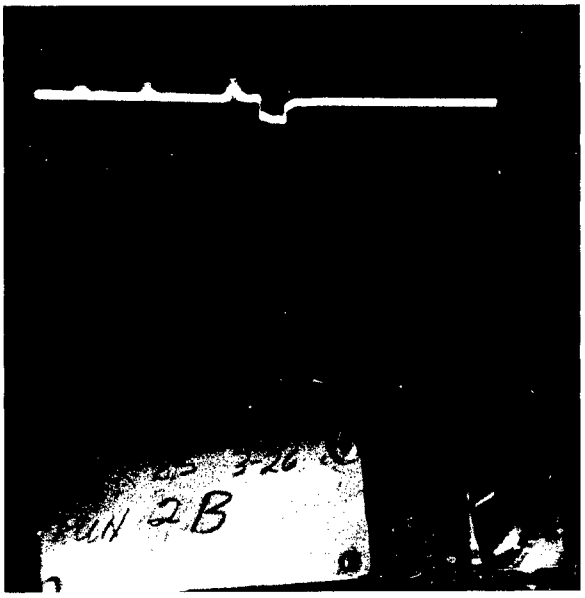

Figure 10 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type B
Echo 3. Standard material

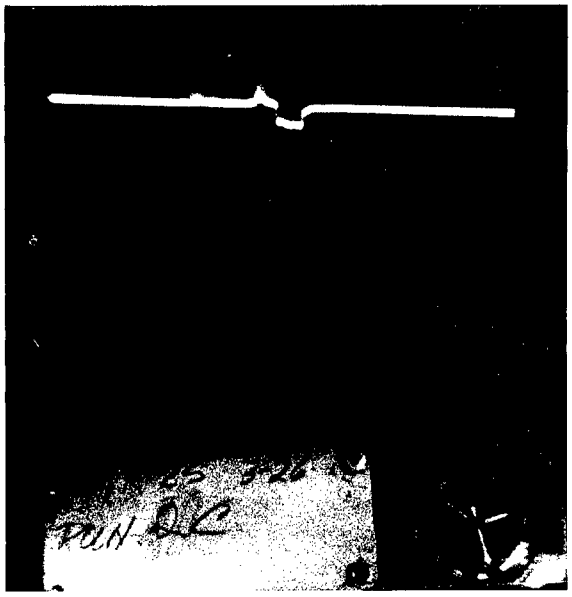

Figure 11 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type B
Echo 3. AD Aircraft

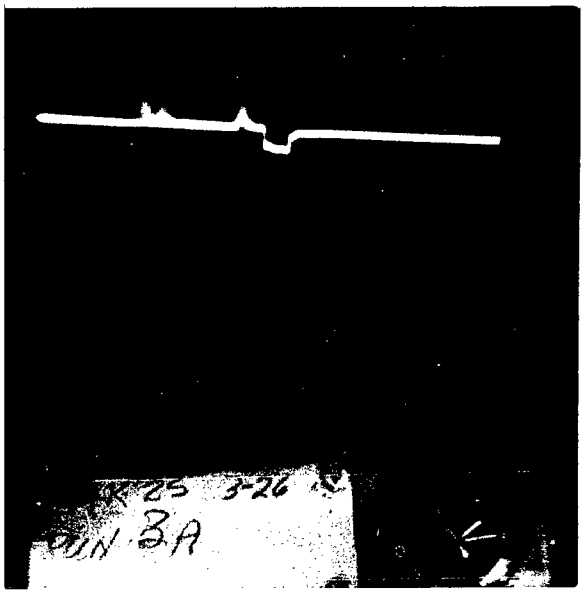

Figure 12 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type A
Echo 3. AD Aircraft

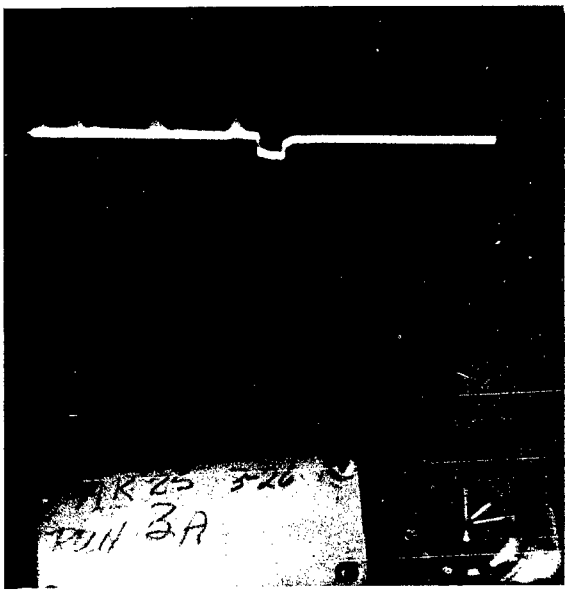

Figure 13 - Flight test echoes
Echo 1. Standard material
Echo 2. Minnesota Mining type A
Echo 3. Standard material
Echo 4. AD Aircraft

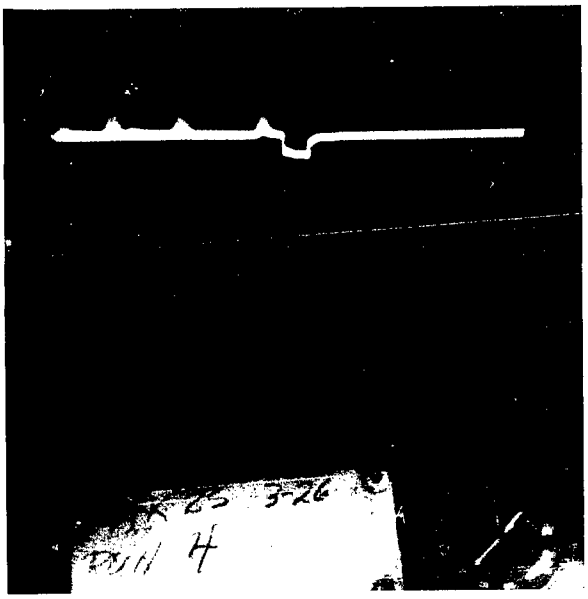

Figure 14 - Flight test echoes
Echo 1. Standard material
Echo 2. Suchy
Echo 3. Standard material
Echo 4. AD Aircraft

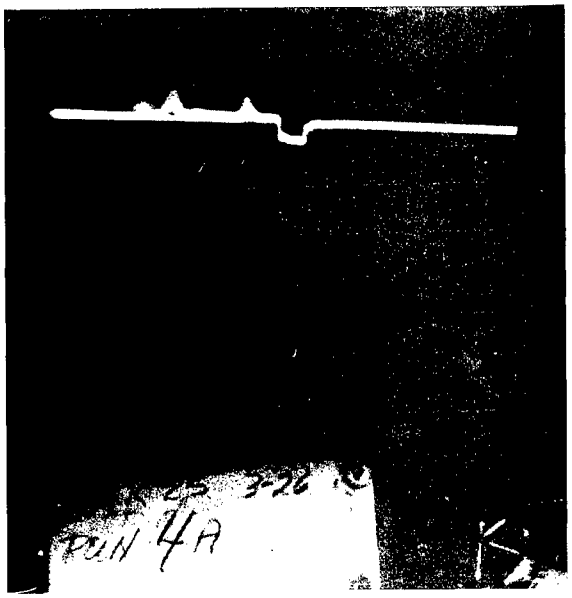

Figure 15 - Flight test echoes
Echo 1. Standard material
Echo 2. Suchy
Echo 3. AD Aircraft

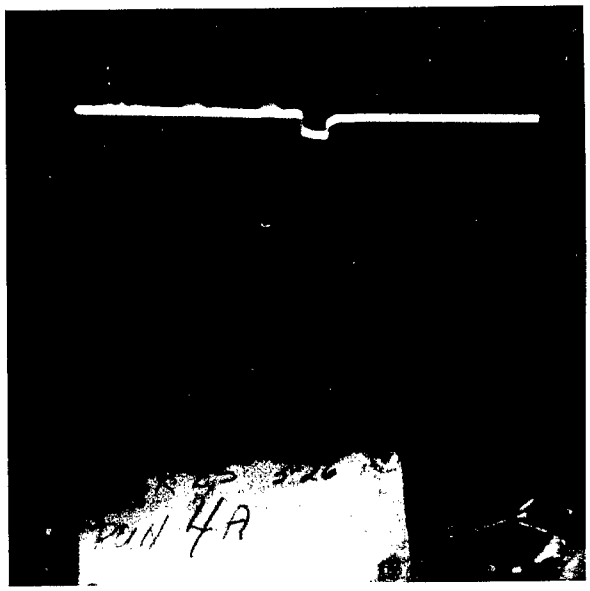

Figure 16 - Flight test echoes
Echo 1. Standard material
Echo 2. Suchy
Echo 3. Standard material

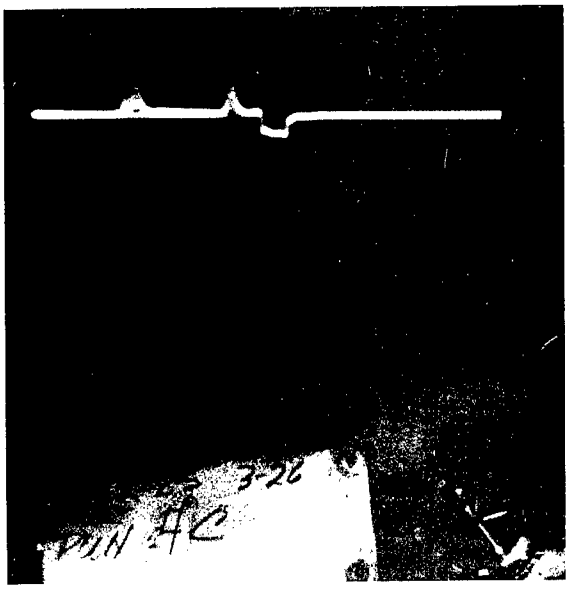

Figure 17 - Flight test echoes
Echo 1. Standard material
Echo 2. Suchy
Echo 3. AD Aircraft

UNCLASSIFIED

TABLE 5
Number of Dipoles Equivalent to 0.036″
Aluminum-Foil Dipole

Dipole Type	Flight Test (ratio)	Reflectometer Test (ratio)
Minnesota Mining A	5.3	2.2
Minnesota Mining B	8.0	5.7
Minnesota Mining C	6.7	6.8
Suchy	2.8	3.5

TABLE 6
Physical Characteristics of Packages of Dipoles
Equivalent to a B-29 Aircraft

Dipole Type	Number of Dipoles (millions)	Weight of Package (grams)	Volume of Package (in.^{3})
RR12A/U	0.75	500	27
Minnesota Mining A	4	300	31 to 32
Minnesota Mining B	6	210	27 to 28
Minnesota Mining C	5	110	12 to 13
Suchy	2.5	300	28 to 29

CONCLUSIONS

The Minnesota Mining and Manufacturing type C dipole is the most promising of the new materials tested, since it is the only type which gives reductions in both space and weight while producing an echo which should be equivalent to that of the standard RR12A/U. This type of dipole requires five million dipoles, or 6.7 times the number of dipoles used in the RR12A/U package, to produce the same size echo, but this number of dipoles weighs only one-fifth as much and should occupy only one-half the space of the standard package. During the tests, it was noted that the Minnesota Mining type C dipoles had a tendency to curl. If this tendency can be eliminated while maintaining the present size and weight, a considerable increase in the efficiency of this dipole may be expected. A further increase in efficiency could be obtained by using a heavier conductive coating.

The Minnesota Mining and Manufacturing type C material in its present form offers substantial weight and space savings over the conventional type RR12A/U. The large number of dipoles needed to produce an echo equivalent to that of the RR12A/U suggests that future development will increase the reductions in the weight and volume of the package necessary to produce the required echo.

* * *

NAVY-DPPO PRNC. WASH., D.C