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A LOW COST DIPOLE TELEMETRY ANTENNA FOR SMALL SOUNDING ROCKETS

by

John Mar

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ABSTRACT

The design of a low cost dipole telemetry antenna, suitable for external mounting on small sounding rockets, is described. The antenna consists of flexible wire rope which is protected against burnoff from aerodynamic heating by a simple ablative sleeve located at the antenna and rocket body juncture. Features of the antenna are compared with designs of more conventional form.

1. INTRODUCTION

This report describes a novel approach to the design of an omnidirectional, electrically efficient, mechanically simple, and aerodynamically stable low cost telemetry antenna suitable for use on small spin stabilized tube-launched or rail-launched rocket vehicles such as those used for scientific atmospheric sounding experiments. The category small in the present context means approximately a 5-inch diameter rocket with 30 second burn time, and burnout velocity between Mach 4 and 5 at altitudes of around 70,000 ft. Such rockets generally are capable of carrying about 15 lbs. of payload instrumentation to an altitude of 60 miles.

In the following section, telemetry antenna design approaches commonly used at present, and their shortcomings, are briefly reviewed and compared to the proposed design.

2. APPROACH AND LIMITATIONS

Present antenna designs for telemetry transmission consist of fixed blade (Fig. 1 and 2) and quadraloop (Fig. 3) configurations (1) (2) (3) (4). These designs suffer from a number of limitations which are best described in the following list:

(i) It is difficult to optimize on electrical design without compromising aerodynamic and mechanical design such as length and relative configuration to rocket body. For example, it is generally desirable to make antenna lengths no shorter than a quarter wavelength in order to ensure reasonable matching of the admittance. A quarter wavelength antenna for 220-260 MHz (common telemetry band for rockets) would correspond to lengths of 11 1/2 to 13 1/2 inches. On a 5-inch rocket, such lengths would probably not be suitable because of the relatively large lift and drag force increase.

(ii) Since the antenna elements act as fixed lifting surfaces, considerable care must be taken in their design to ensure aerodynamic compatibility with the vehicle.

(iii) The fabrication of these antennas requires very careful machining and the use of alloys able to resist high temperatures.

(iv) Because the antennas are rigid, the maximum permissible length that can be used for a tube-launched rocket, such as an Arcas sounding rocket, is seriously restricted by the available clearance in the bore of the launcher (Fig. 4).

(v) Because it would not be practical to alter the physical lengths of the antenna once installed on a vehicle, final electrical trimming of the antenna system is limited to internal adjustments of the matching network.

(vi) Because blade and "quadraloop"[1] systems are not inherently good omni-directional radiators, careful ground calibrations of the radiation patterns must be performed prior to flight.

3. PROPOSED DIPOLE DESIGN

The proposed design consists simply of a flexible dipole or crossed dipole antenna made from 7 wire and 7 strand, 3/32 in. diameter stainless steel aircraft control cable. Hardwood interlocking sleeve segments fitted over the root region of the whips are used to provide the necessary ablative protection against aerodynamic heating during flight (Figs. 5, 6).

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[1] Coined name referring to quarter wavelength (see Ref. 4).

Protection against aerodynamic heating is necessary only at the root since the high heat condition of stagnation flow is confined to regions of the whip which are normal to the flow field. The aerodynamic heating on the remaining portion of the whip is relieved because of large sweepback angle caused by drag in flight. Since stagnation temperature is roughly proportional to the square of the Mach number, an element of antenna swept back at angle θ gains a reduction in stagnation velocity proportional to $\cos^2\theta$ (Fig. 7).

For the antenna, the free stream stagnation temperature To_∞ is (5):

$$To_\infty = T_\infty \left(1 + \frac{\gamma - 1}{2} M_{n\infty}^{2}\right)$$

where T_∞ = free stream static temperature

γ = Cp/Cv ratio of specific heats

M_∞ = free stream Mach Number

$M_{n\infty} = M_\infty \cos\theta$

θ = angle between antenna element and relative velocity vector

C_p = specific heat of air at constant pressure

C_v = specific heat of air at constant volume

The apparent advantages of such a design may be summarized as follows:

(i) The proposed antenna is extremely simple to design, construct, and install in comparison to that presently used.

(ii) The flexibility afforded by the wire rope antenna permits its use on tube-launched vehicles without difficulty.

(iii) Because the flexible cables contribute very little lift and drag, the aerodynamic characteristics of the basic vehicle should be little changed.

(iv) When used on a spinning vehicle, the centrifugal force causes the antenna whip to extend outward as the drag forces decrease at maximum altitude (since atmospheric density and hence drag decreases with altitude). This provides for a more efficient dipole configuration when range is greatest.

(v) Because the radiating element is wire rope, electrical trimming of the antenna may be easily carried out by simply cutting the whips to length.

(vi) Protection against aerodynamic heating is easily accomplished by fitting segmented interlocking sleeves of walnut hardwood over the root region of the antenna. The hardwood sleeves provide a convenient and mechanically rugged form of ablative heat protection, which is simple to manufacture and install.

(vii) Because the proposed design is flexible as well as rugged, it would not be easily damaged during ground handling operations.

(viii) The proposed antenna is much cheaper to build than any other system presently in use.

(ix) The crossed dipole configuration gives the best omnidirectional pattern achievable for an antenna.

(x) The weight of the proposed antenna design is much less than the quadraloop and blade type.

4. FLIGHT PERFORMANCE

A telemetry antenna of the proposed design was installed on an Arcas rocket launched from Cold Lake, Alberta, in August 1962. The probe was launched in connection with the upper atmosphere research program conducted by the Defence Research Telecommunications Establishment (DRTE).

The rocket payload was recovered on parachute descent and the condition of the antennas examined. The performance of the antennas and their ablative hardwood sleeves were as predicted (Fig. 8 and 9).

5. CONCLUSIONS

A simple externally mounted dipole antenna, constructed of stainless steel cable or flexible piano wire, may be designed for use on small sounding rockets. Protection against destruction of antennas by aerodynamic heating is accomplished by placing interlocking segments of hardwood around the root region of the antenna whips as an ablative material. Such an antenna was successfully flown on an Arcas rocket and was found to perform satisfactorily.

In comparison to antenna designs presently used on small rockets, the antenna described in this report is extremely simple, lightweight, and low in cost to construct.

6. REFERENCES

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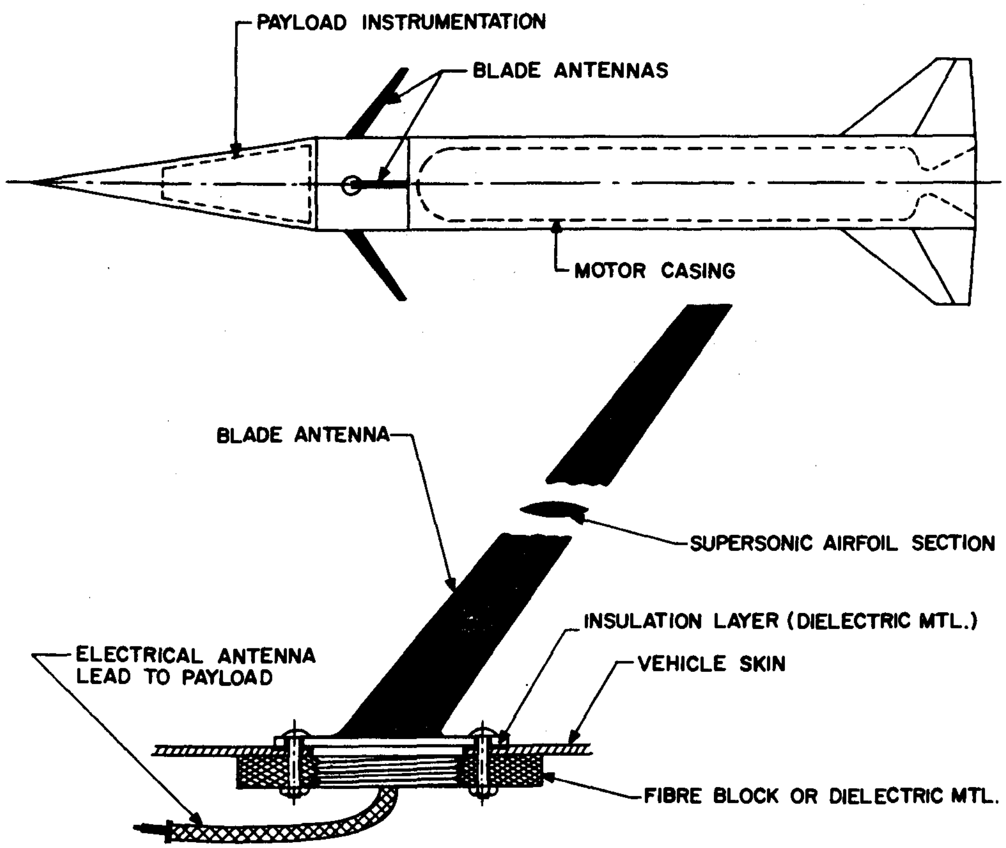

Fig. 1. Conventional blade antenna.

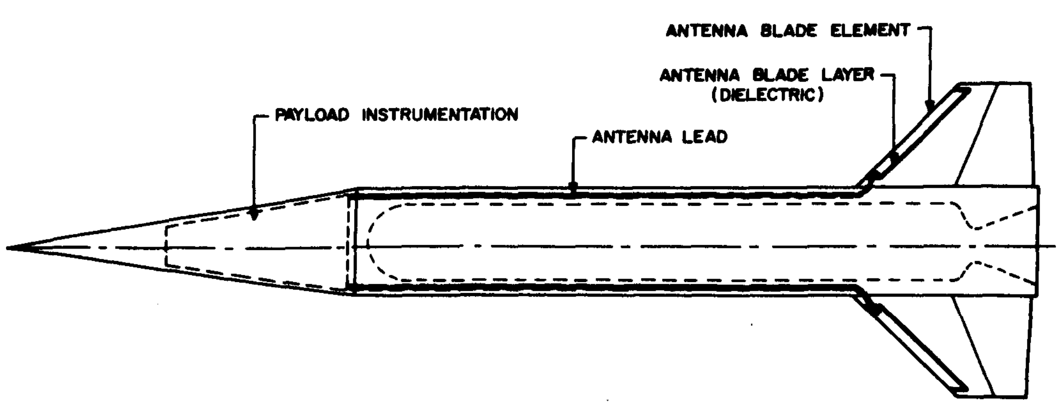

Fig. 2. Blade antenna on fin leading edge.

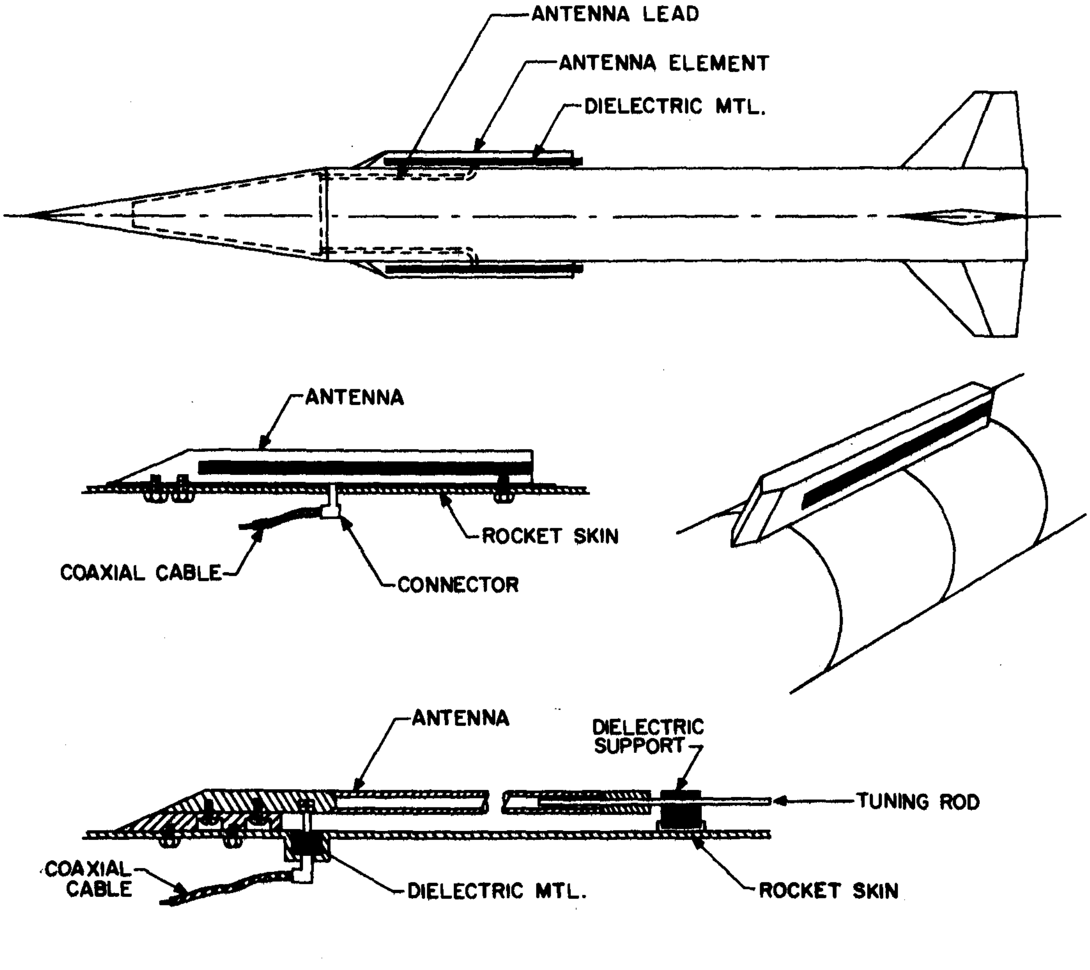

Fig. 3. Typical quadraloop antenna.

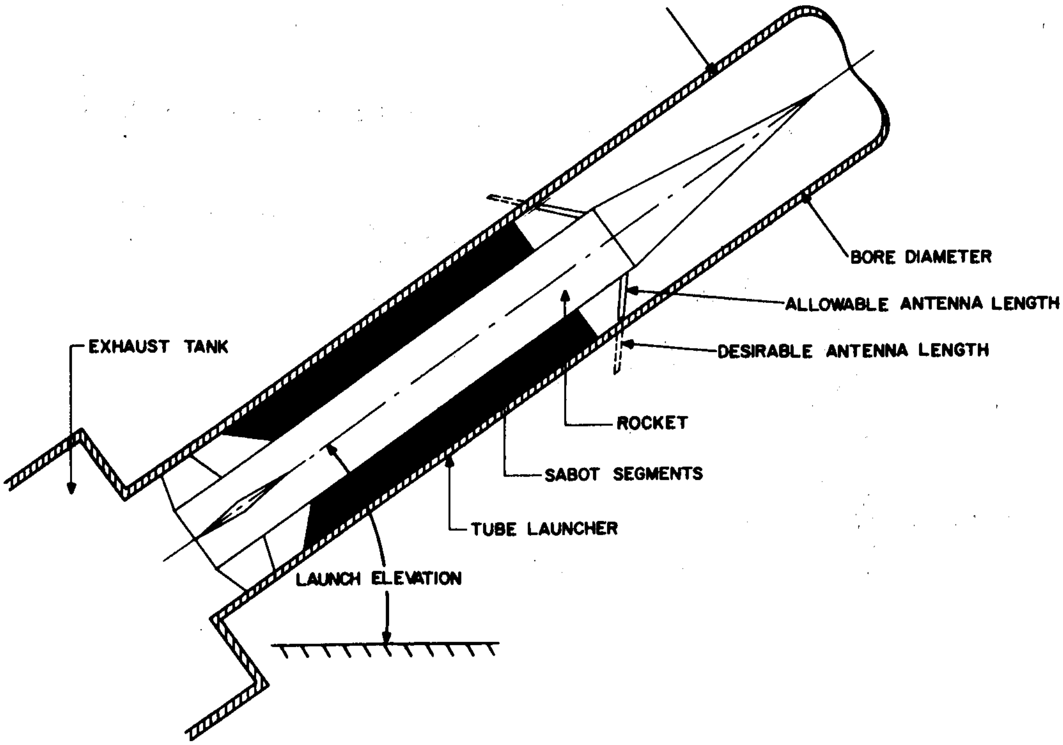

Fig. 4. Schematic of tube-launched rocket arrangement.

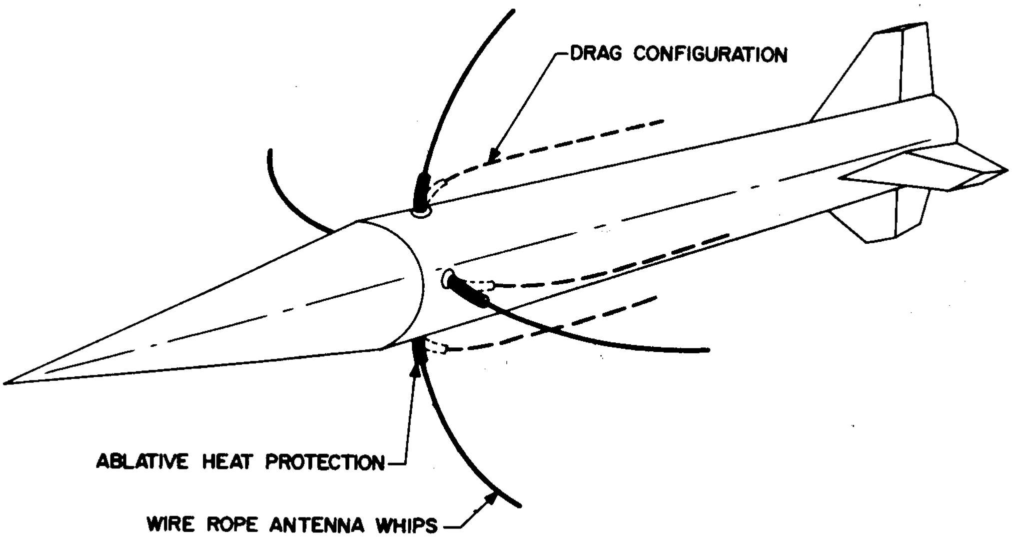

Fig. 5. Sketch of proposed dipole telemetry antenna on rocket.

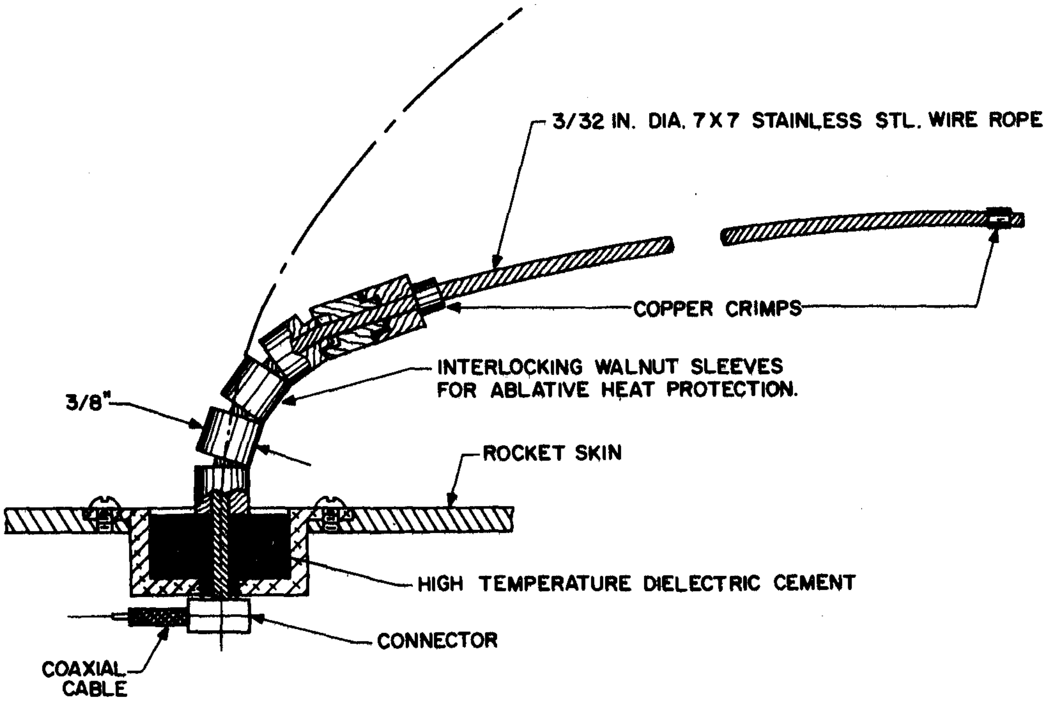

Fig. 6. Assembly diagram of proposed antenna whip.

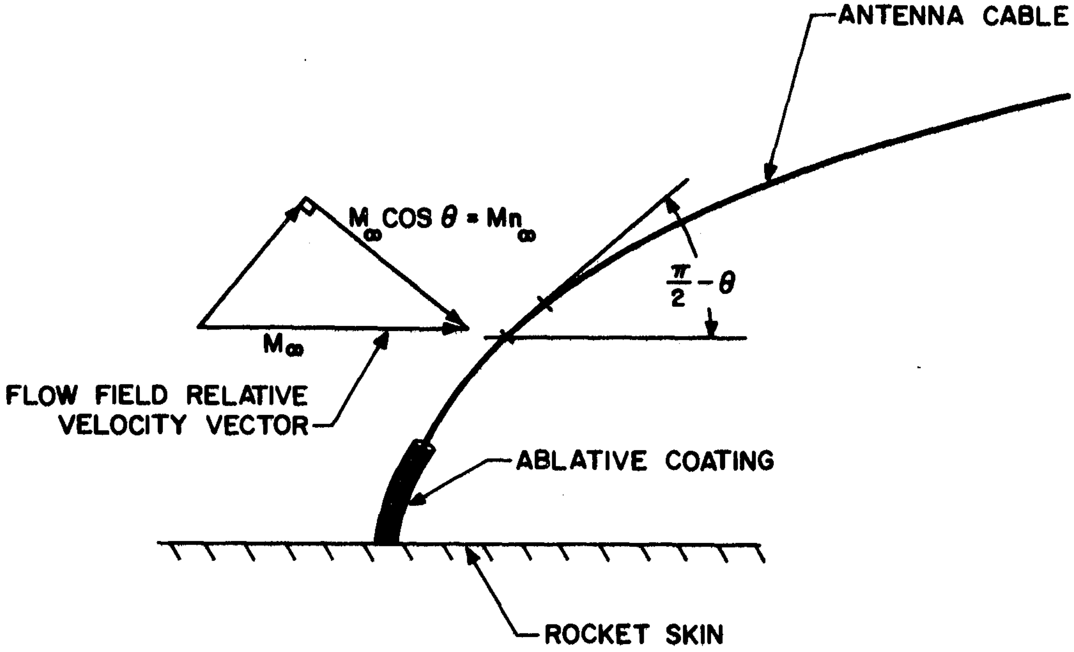

Fig. 7. Effect of sweepback angle on antenna relative flow velocity.

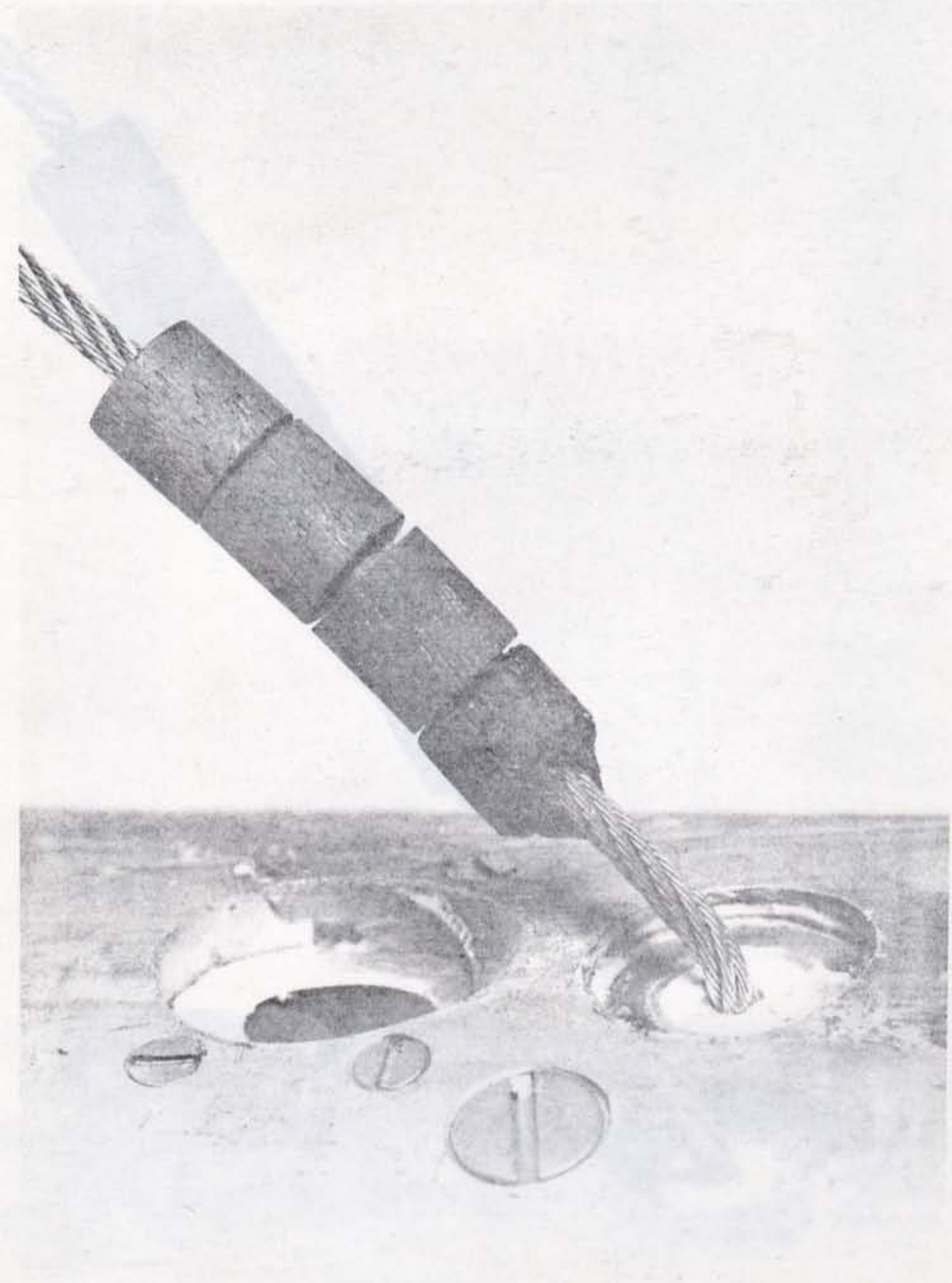

Fig. 8. Flight performance of ablative protection on a recovered antenna sample.

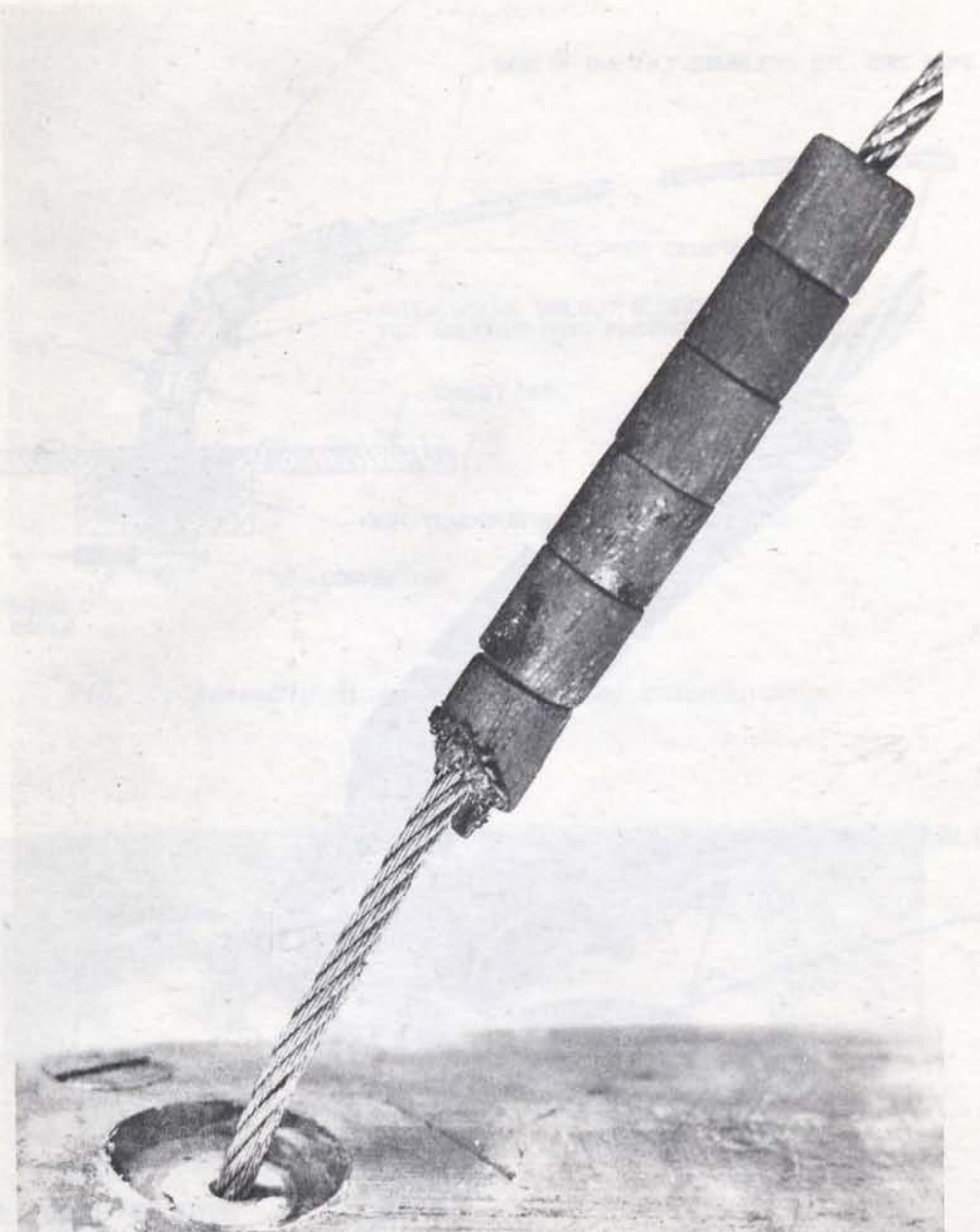

Fig. 9. Flight performance of ablative protection on a second recovered antenna sample.

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