abstracts of the

Thirteenth Annual

SYMPOSIUM

USAF ANTENNA RESEARCH and DEVELOPMENT PROGRAM

Sponsored by

AIR FORCE AVIONICS LABORATORY
WRIGHT PATTERSON AIR FORCE BASE, OHIO.

In cooperation with the

UNIVERSITY of ILLINOIS.

October 14, 15, 16, 17, 18, 1963.

Robert Allerton Park, Monticello, Illinois.

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B-70 ANTENNA SYSTEM

by

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Paper presented at the Thirteenth Annual Symposium on USAF Antenna Research and Development.

INTRODUCTION

The antenna system development for the B-70 was faced with many new and unique problem areas, although electrical performance requirements were somewhat conventional. Military specification requirements formed, for the most part, the basic antenna requirements. The broad thermal spectrum to which B-70 antennas would be exposed was probably the most significant single factor contributing to the need for a state-of-the-art advancement in the antenna area. The high-temperature exposure time of many hours created a high-temperature antenna requirement much different from those based on missile applications which relied on the thermal inertia of the particular part. Although antennas designed for much higher peak temperature conditions were available or at least within the state-of-the-art, the high-temperature soak times of the B-70 could not be tolerated. Crippling loads, in excess of any expected structural or aerodynamic loads, imposed on an antenna assembly of dissimilar materials exposed to this long-duration heat soak, ruled out many of the so-called high-temperature designs. These factors coupled with the low-temperature conditions of letdown and landing necessitated an antenna development program.

The design philosophy of the development program varied during the program based on data refinements in the area of thermal and aerodynamic environments and on a continuing Value Engineering approach which attempted to match performance requirements with the actual mission and air vehicle economic considerations. For example, the original effort was directed toward the development of completely flush-type antennas. This was redirected to the development of external types in some applications based on a value-to-the-mission type of analysis. The requirement for an automatic tuning HF coupler was changed to a passive preselected frequency approach on the basis of mission requirement economics. (This coupler design was reported at the Antenna Symposium of 1960 by J. K. Aiton of North American Aviation Inc, Los Angeles Division.) This refinement of requirements and subsequent change in philosophy is discussed below.

REQUIRED FUNCTIONS

The basic electromagnetic radiating functions required on the B-70 are the conventional requirements of a manned system, namely, communications, and navigation and landing aids.

The communications system consisted initially of both UHF and HF requirements. Upon further analyses of the XB-70 mission, the HF requirement resolved into one of making provisions only for HF, and further HF development per se was deferred.

The navigation aids system consists of the TACAN equipment and the air-to-ground beacon transponder (IFF). Both of these equipments operate in the L-band region of the spectrum.

The landing aids system requirement includes the Glide Slope, Localizer, and Marker Beacon functions.

TECHNICAL APPROACH

The development programs for the antenna elements were formulated and refined to their final status by a continuing Value Engineering analysis of each phase of the development program. The results of this analysis showed that the areas of testing and reporting were the predominant areas in which cost and time savings could be realized without jeopardizing the electrical or mechanical quality of the final part.

Also, during this phase of the program, it was concluded that the antenna should be designed to assume the vehicle structural loads in lieu of having the vehicle structure accommodate for the structural discontinuity caused by the antenna. Thus, the development program was directed toward this objective. Structural analyses of antenna materials were made in parallel with the environment, type, and location analyses. The location of the antennas on the vehicle, as shown in figure 1, was the result of considering the individual and the combined areas of electrical performance and the thermal, aerodynamic, and structural environments. The ultimate location and design was the result of this composite analysis. All of this information was compiled and detailed on individual design control drawings and in specifications for completion of the development by NAA or a subcontractor.

ANTENNA TYPES

UHF ANTENNA SYSTEM

The UHF communications antenna system includes two antennas. One antenna is located on the top fuselage centerline and the other on the lower centerline as shown in figure 1. These antennas are cycled by a C-2193 A/A switch to provide the required antenna pattern coverage.

As previously mentioned, a flush-mounted annular slot type of antenna was considered initially for this application, but upon further refinement of requirements, high-temperature, high-speed blade type antennas were selected. The antenna considered was a slot-excited, one-piece blade being developed for the Navy by Transco Products of Venice, California. The Navy antenna was fabricated from a high-temperature aluminum alloy. Although this material would provide adequate strength and stand the thermal environment, the difference in coefficients of expansion between this material and the B-70 skin material would impose failure stresses on the antenna. The material for the B-70 antenna was, therefore, specified to be stainless steel. This material change unveiled problems of sealing the antenna at the mating of the slot dielectric and the stainless steel in order that it would meet the military specification seal-test requirements. This problem will be discussed further. The XB-70 antenna resulting from this program is shown in figure 2.

NAVIGATION AIDS ANTENNA SYSTEM

Both the TACAN and air-to-ground beacon transponder (IFF) systems operate in the L-band region and, therefore, can use identical antennas. As originally planned, the antenna system for these equipments was to be an integrated, two-antenna system incorporating an antenna selector (C-2193), a lobing switch (SA-498 A/A), and two F-339/A filters. NAA/LAD experience on the T-39 Sabreliner flight-test program and Air Force and industry experience subsequently indicated that the attenuation and loss of adjacent channels caused by the filters was not tolerable during service conditions. Therefore, the integrated antenna system concept was deleted and separate antennas were planned for each function. The antennas are located on the upper and lower fuselage centerlines as shown in figure 1.

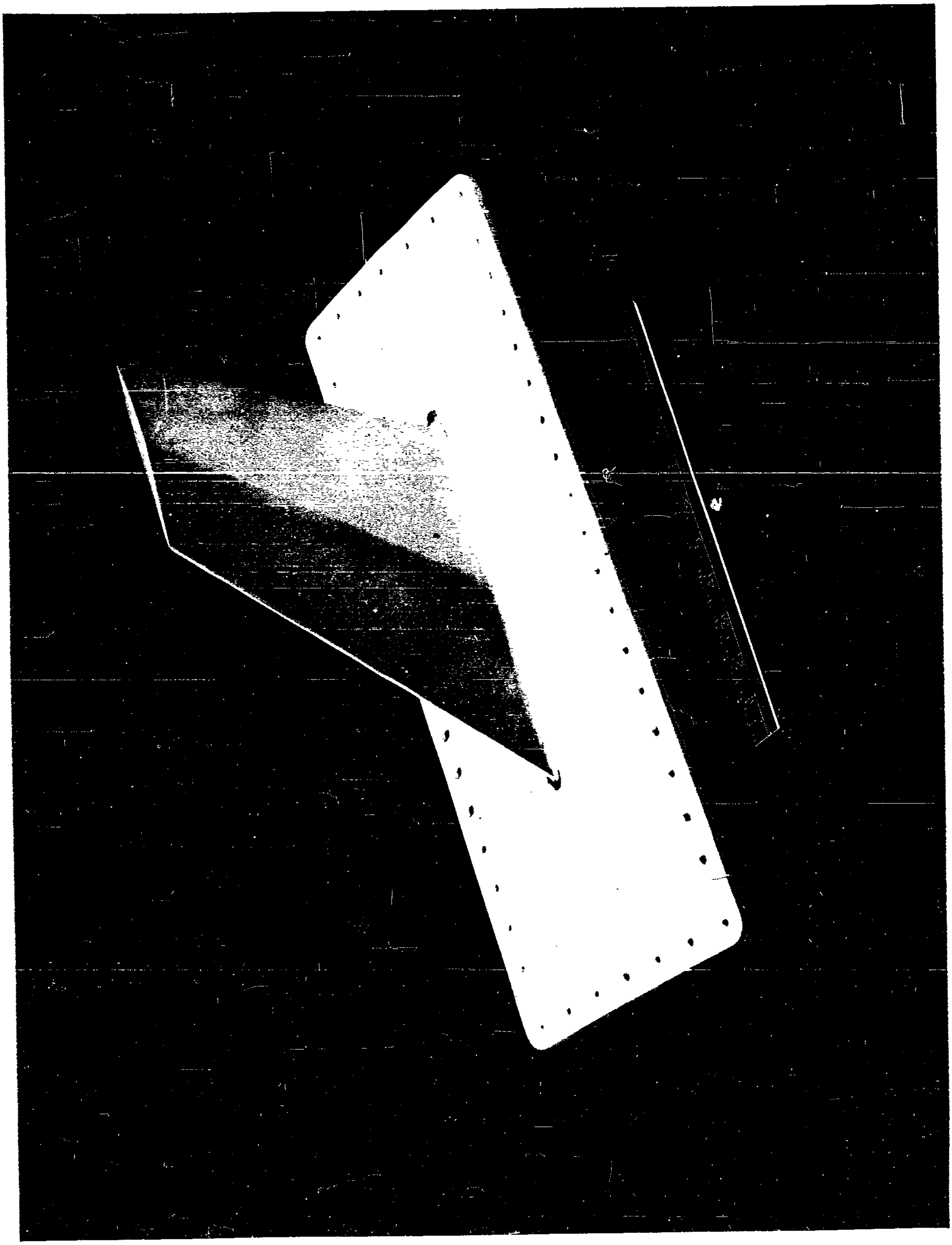

Figure 2. UHF Antenna

The electrical performance requirements for these antennas were similar to those required of the standard AT-740 and AT-741 antennas. Meeting these requirements under the environmental conditions of temperature and altitude of the B-70 did pose some problem, however. As in the instance of the UHF antenna design approach, a flush-type annular slot antenna design was initially considered. However, here also, later analyses indicated a low profile slot excited blade (similar to the UHF antenna) being developed for the Navy approached the B-70 requirements. In this application also, the high-temperature aluminum was replaced by stainless steel. The pressure leak problem experienced with the UHF antenna did not present itself here however, presumably because of the slight difference in mechanical attachment caused by the size relationship to the mounting radius of curvature.

Environmental tests to validate the antenna performance showed that voltage breakdown, observed at the blade tips and across the dielectric filled slots, occurred at power levels, temperatures, and pressure altitudes much in excess of those required in the B-70 application. These tests qualified both the UHF and the L-band blade antennas.

The resulting antenna, shown in figure 3, incorporates a test probe for system checkout. Transmission lines from the probes are routed to a test panel in the vehicle electronic equipment bay.

LANDING AIDS ANTENNA SYSTEM

This system includes antennas for Marker Beacon, Glide Slope, and Localizer functions.

Because the Marker Beacon antenna is a narrow band tuned cavity, it was recognized that some problems in design for the extreme thermal band requirement of the B-70 would be realized if conventional cavity dimensions were imposed. A cavity volume of approximately four times that of the standard AT-134 antenna was permitted to accommodate a larger antenna element and offset the dielectric losses expected from a thick, structurally sound, dielectric cover.

The compensation required to keep the antenna tuned over the thermal band width and the sealing of the dielectric cover presented significant developmental problems. However, mechanical rather than electrical difficulties proved to be the more difficult to solve.

A thermal compensating, printed circuit capacitive element keeps the antenna within a 2.5:1 VSWR at 75 mc ±300 kc throughout a temperature range of -65°F to +500°F.

Two significant problems were associated with the dielectric cover: that of sealing the cover itself, and that of sealing the cover to the cavity case. Several dielectric laminate companies tried to solve the problem of cover leakage. Although sound thin laminates could be easily achieved, thicker, structurally acceptable laminates, wicked and/or became porous as sections were temperature cycled. Finally, a structurally acceptable dielectric cover was fabricated by Laminar of Gardena, California, using a proprietary resin to high-pressure laminate a Specification MIL-R-9300 material. This cover darkened after repeated temperature cycling and, therefore, did effect the antenna performance to a minor degree because of this carbonization, but the cover did not leak during or after

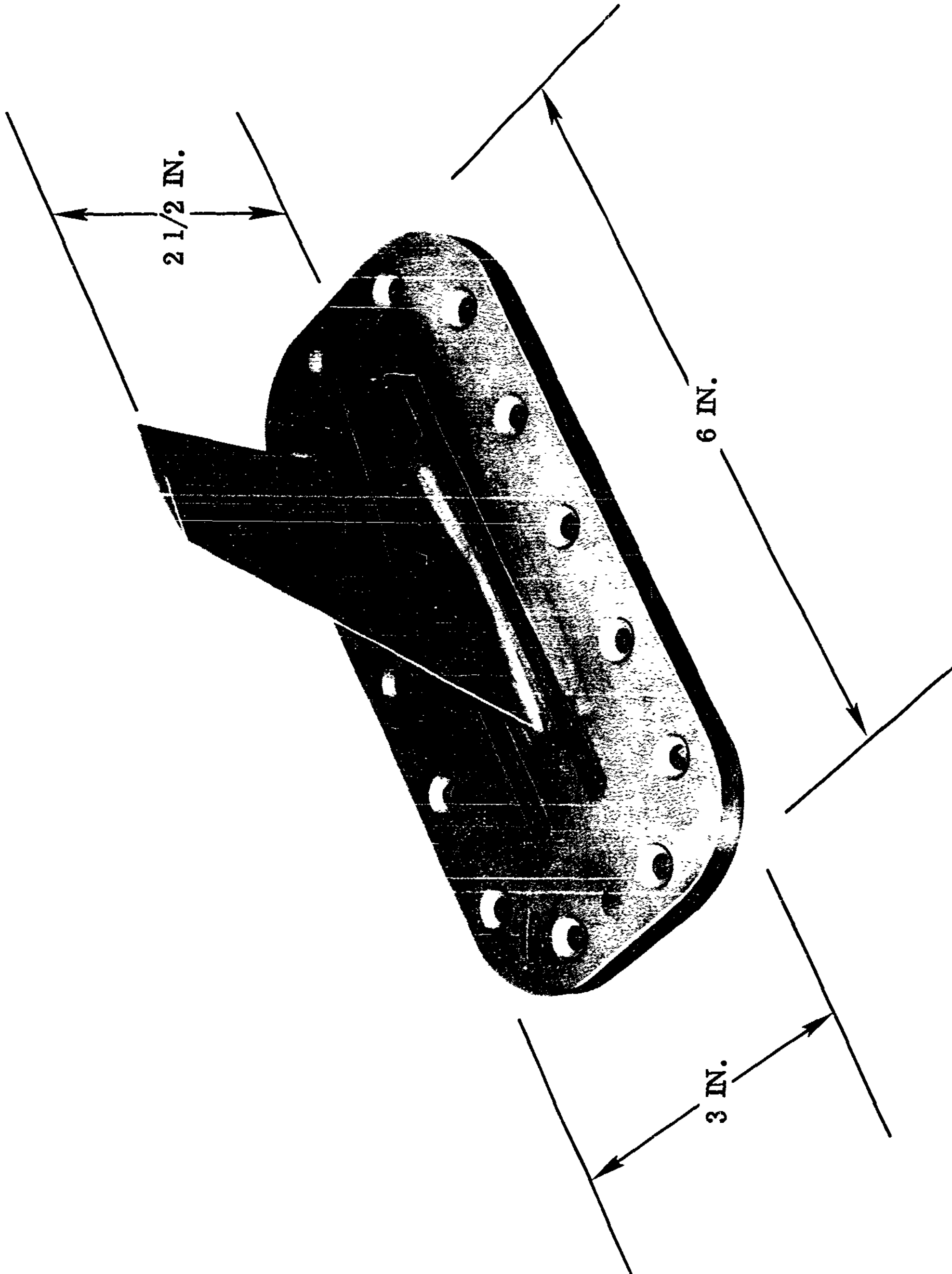

Figure 3. L Band Antenna

environmental exposure. The material was later accepted for this cover as well as the UHF slot windows.

In a joint effort, Transco Products and NAA/LAD investigated many techniques of bonding the cover to the cavity case after mechanical fasteners were found unacceptable because of their damaging effect on the laminate. Room-temperature vulcanizing compounds (RTV) and various film adhesives were investigated, with varying results. After considerable experimentation and testing, an AF-31 film adhesive, qualified to Specification MIL-A-5090, was used to bond the dielectric cover to the Marker Beacon case. This provided both a structurally sound adhesive bond throughout the temperature range and a leakproof seal. This film adhesive was not applicable on the UHF antenna because of bonding surface discontinuities. However, a technique was developed using a RTV compound which was successful in sealing the UHF antenna.

The Marker Beacon antenna finally developed is shown in figure 4, and is located as shown in figure 1. Although the gain of this antenna is low because of the composite effect of the element, high-temperature foam filler, dielectric cover, and cavity size, it does meet the performance requirements.

The harmonic relationship of the operating frequencies for the Glide Slope and Localizer equipments permitted the design of a single antenna. A bent dipole, balanced with a broadband coax balun, bonded to the inside surface of the nose radome was designed by NAA. A diplexer which separates the glide slope and localizer signals and provides isolation between the equipments is located in the electronic equipment bay.

The antenna has less than a 2.5 to 1 VSWR in both frequency bands, and the pattern, although narrower in azimuth than military specification requirements, satisfies the requirement for the high performance B-70. The antenna is an integral part of the nose cavity and because of the cavity effect, the pattern was narrowed and forced downward. A photograph of this antenna on the XB-70A dielectric nose fairing is shown in figure 5.

SUMMARY

In conclusion, it can be said that the environmental conditions of the B-70 was the basis for the need of an antenna development effort. A program that analyzed the structural, thermal, aerodynamic, and electrical performance requirements to obtain a practical and economic balance of these requirements mitigated the magnitude of development effort required. A survey of state-of-the-art developments proved successful in several areas where existing technology was upgraded to produce a design which met the new XB-70 requirements. Use of both testing and analysis in combination allowed a reduction in the over-all test program.

The approach taken on this program has proved to be successful at NAA/LAD and is worthy of consideration for application on future programs.

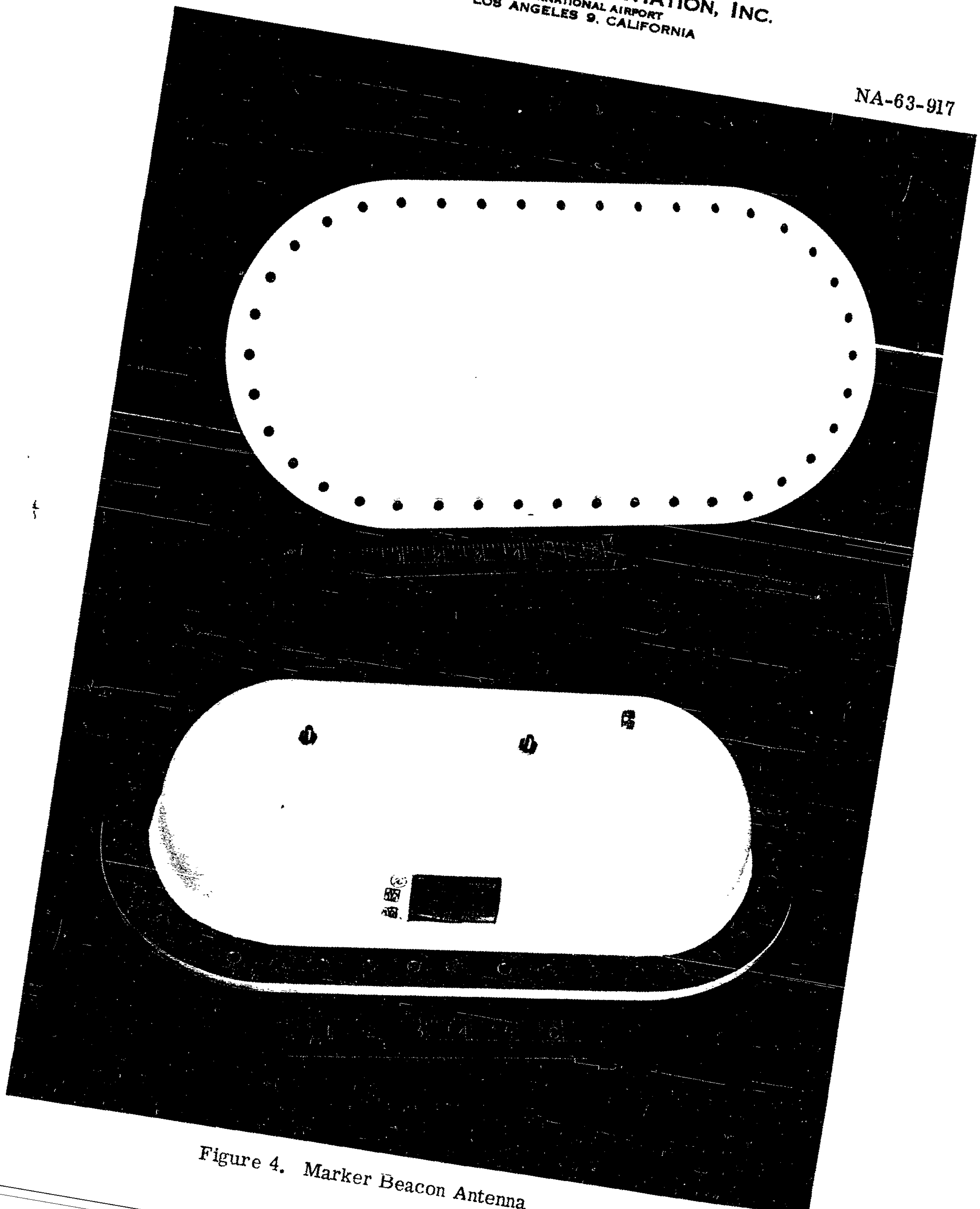

Figure 4. Marker Beacon Antenna

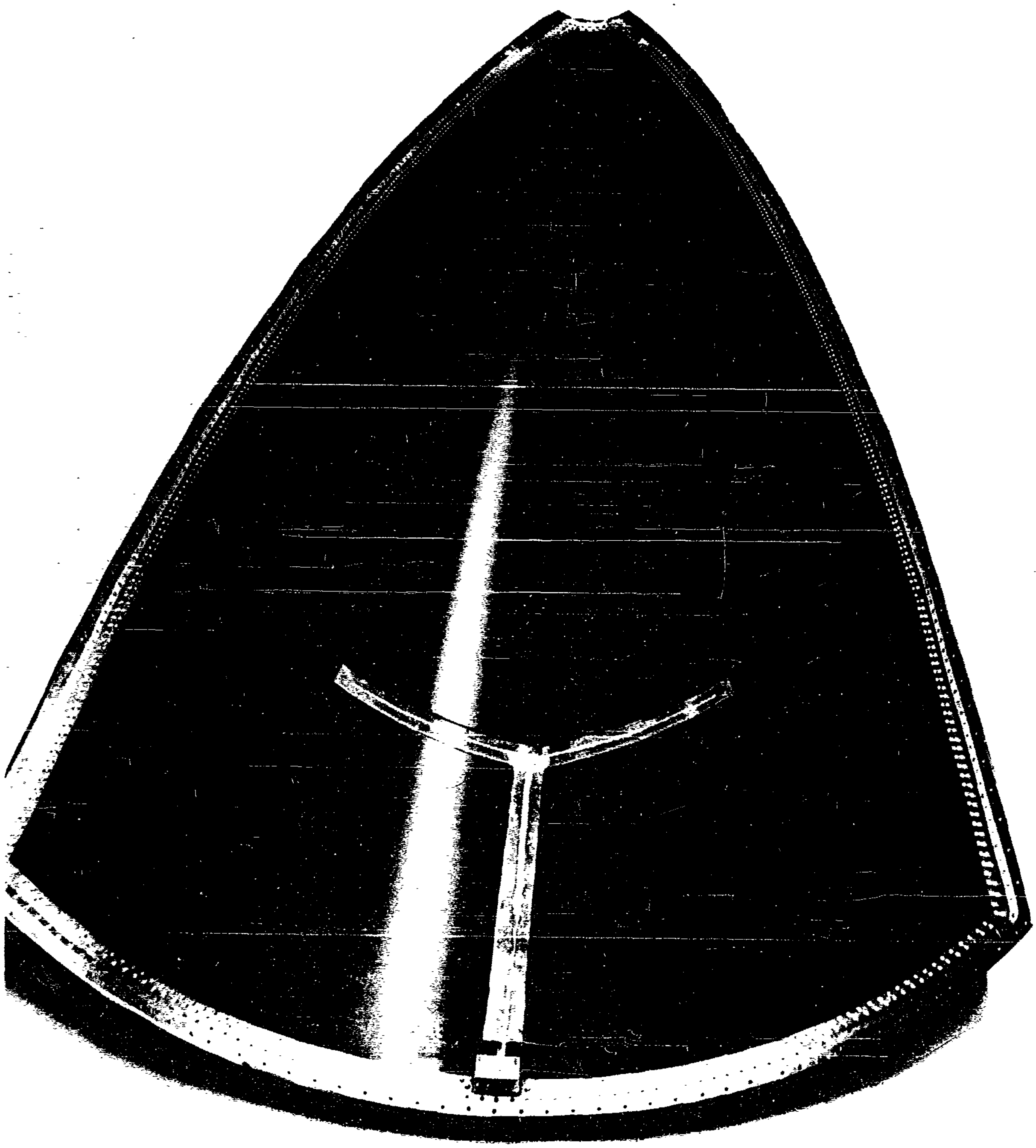

Figure 5. Glide Slope - Localizer Antenna