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DEFINITION STUDY OF THE SHUTTLE IMAGING RADAR-A (SIR-A) ANTENNA ON THE SECOND SPACE SHUTTLE MISSION (OFT-2)

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SUMMARY

The study resulted in the definition of an antenna configuration fixed-mounted high in the payload bay on the hybrid OFT-2 pallet which is compatible with Orbiter interface requirements. Tests showed that the combination of the selected panels and the designed corporate feed will meet the SIR-A performance requirement of 33 dB gain. The effects of Orbiter structure proximity on performance were determined by scale model tests to be negligible. The potential for improved performance during subsequent reflights includes a multiple-beam capability and dual polarization.

1.0 INTRODUCTION

A study was conducted to define the concept and preliminary design of the SIR-A antenna. Operational Flight Test Number 2 (OFT-2) is the first mission to include scientific experiments in the payload bay and SIR-A is the highest priority experiment approved for flight. It is presently scheduled for flight during the second half of 1979.

The primary consideration of the study was to provide the concepts for the antenna, supporting structure, and corporate feed at the lowest possible cost, while meeting the performance requirements and Orbiter interface requirements. The antenna was constrained to fit in the area forward of the Development Flight Instrumentation (DFI) without protruding from the payload bay envelope. The antenna points to the north side of the orbital track while the Orbiter flies with the payload bay opening facing the earth. This orientation is intended to thermally qualify the Orbiter to fly in this attitude for long durations. Results of the study included definition of the location in the payload bay, selection of antenna panels, design and selection of the corporate feed, design of supporting structure, and performance projections. The study has been followed by a program of detailed design, manufacturing, and test of the system.

2.0 CONFIGURATION

The SIR-A antenna design relies heavily upon previous SEASAT technology and the utilization of standard components in an effort to minimize cost and risk factors while optimizing system performance. Seven honeycomb microstrip antenna panels, identical to the panel developed and tested for the SEASAT Engineering Model Unit (EMU), are arrayed to form a 9.38m x 2.08m planar, longitudinally polarized, radiating surface. A unique coaxial corporate feed distributes power to each panel in-phase, but with a stepped amplitude taper such that the center three panels each radiate one-sixth of the total power and the outer four panels each one-eighth. Power to each radiating patch on the panel is carried by a microstrip feedline network etched on the face of the panel.

The antenna panels and corporate feed, as shown in Figure 1, are mechanically supported and aligned to a planar surface by a fixed strongback truss. An installation truss, with adjustable fittings to the OFT-2 spacelab-hybrid pallet, supports the antenna/strongback in a fixed high-in-the-payload bay location and allows vernier adjustment of the antenna boresight pointing angle to 47 degrees from nadir.

Initial truss concepts were constructed with graphite epoxy material, but reduction in the pallet-mounted, structural fundamental frequency requirements has permitted the use of less costly, aluminum trusswork. With either material, thermal and mechanical distortions of the truss structure are sufficiently small to cause the array to deviate less than ± 0.635cm from a planar surface during on-orbit operations. Multilayer aluminized mylar on the trusswork and teflon-impregnated quartz cloth on the radiating panels provide passive thermal control. The multilayer insulation is covered with the quartz cloth to reduce the surface reflectivity, thus avoiding potential glare to the crew.

3.0 ANTENNA PANELS

The 1.34m x 2.08m EMU panel combines microstrip array techniques with a unique fiberglass honeycomb construction [1] to yield an efficient, lightweight, monolithic antenna. All radiating elements and feedlines are precision photo-etched on a copper laminate and supported above a bonded copper ground plane by the honeycomb structure, thus significantly reducing dielectric losses. The complete EMU array is illustrated in Figure 2, with nominal measured performance for individual panels tabulated below. Low development and manufacturing costs, rugged construction, and adequate performance made the EMU design particularly attractive for application to the SIR-A antenna. Only minor attachment fitting modifications have been made in this SEASAT design for the SIR-A program.

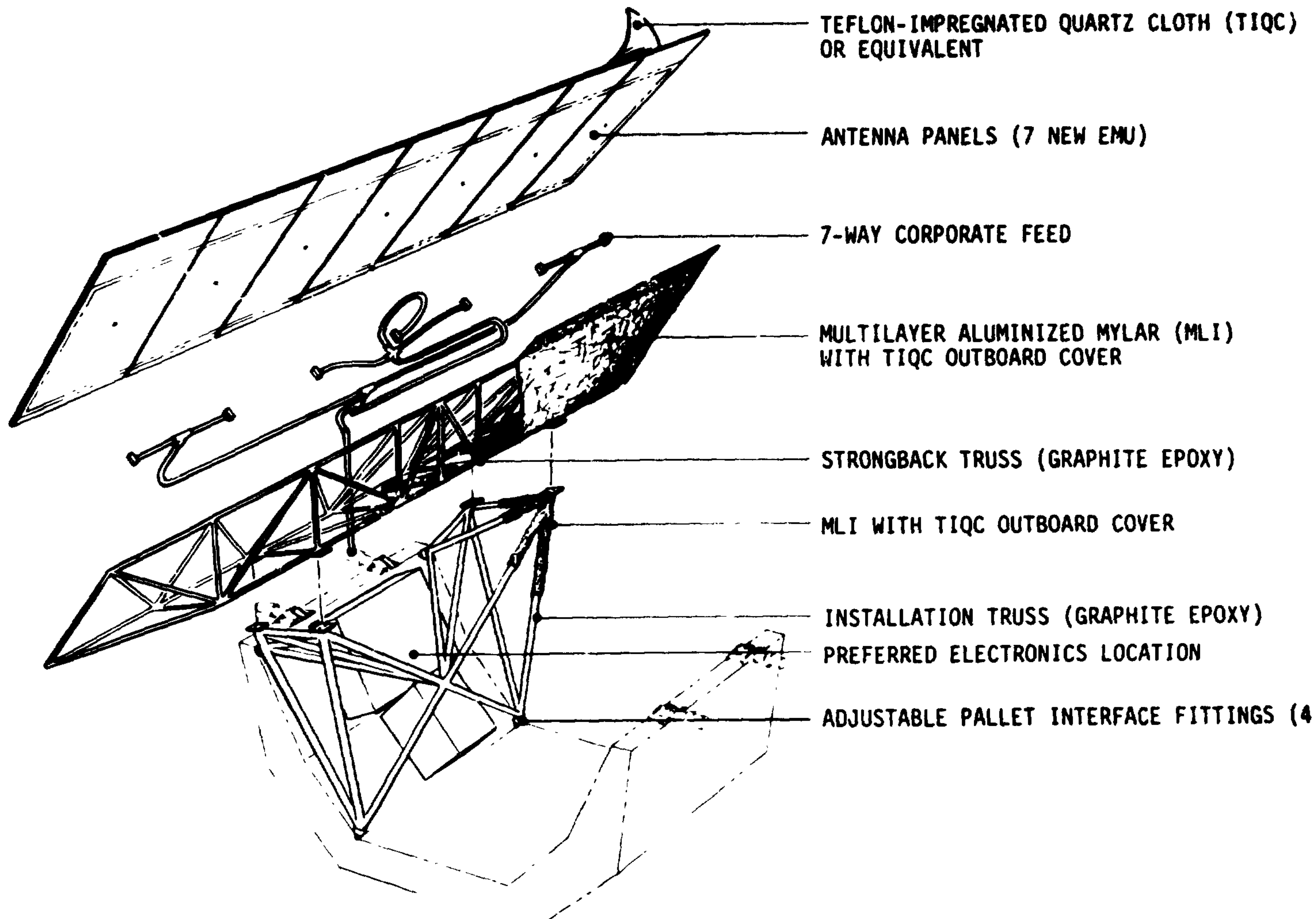

FIGURE 1

SIR-A BASELINE CONFIGURATION

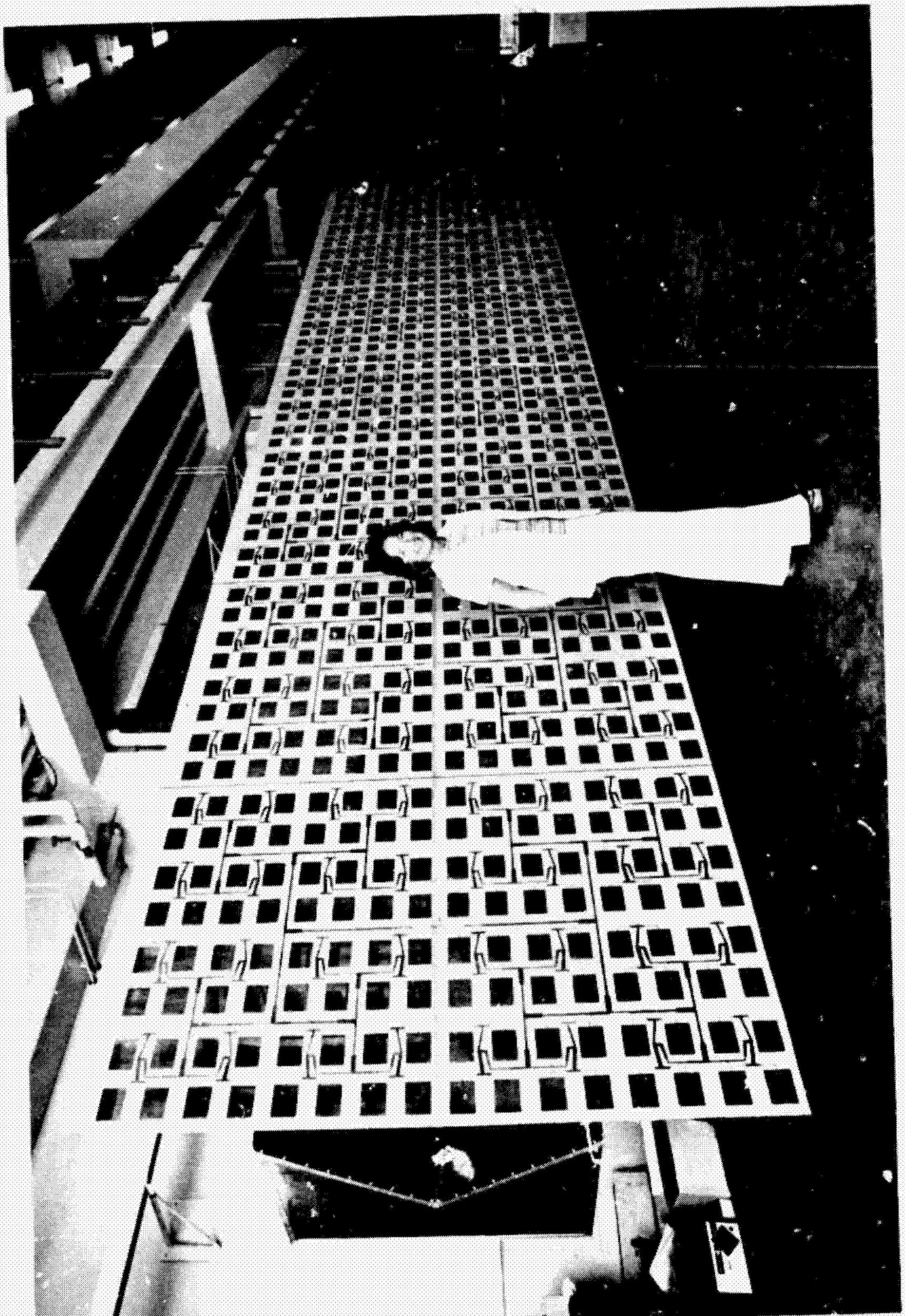

FIGURE 2

SEASAT EMU ARRAY

TABLE 1

EMU PANEL CHARACTERISTICS

PARAMETER	PERFORMANCE
Gain	25.9 dB
Sidelobes	
E-Plane	<-12.5 dB
H-Plane	<-16.0 dB
Beamwidth	
E-Plane	9.1°
H-Plane	6.2°
VSWR	< 1.3:1

4.0 CORPORATE FEED

A seven-way corporate feed, composed of standard air-loaded coaxial line and reactive power dividers, efficiently distributes power to the array panels and implements the required phase and amplitude distribution. As depicted in Figure 3, the power divider configuration theoretically yields a "natural" amplitude taper across the array. If required, minor power distribution variations due to load mismatches in the reactive network can be compensated by modifying the power split of the first reactive divider, the only nonstandard electrical component. Equal phase illumination is ensured by trimming similar lines to equivalent electrical lengths and critically phasing the 127 inch line shown in Figure 3, such that the electrical length from input to panel terminations is equivalent for all ports. Multipactor breakdown considerations dictate the use of TNC-type connectors and dielectrically loaded power dividers. A 3 dB multipactor margin is maintained throughout the system. Based on vendor data, system insertion is calculated as less than 0.7 dB.

A prototype SIR-A feed system composed of Andrews H5550 7/8" coaxial cable with N-type connectors and Microlab D2TN power dividers was constructed and tested during this study in order to establish confidence in the proposed design. The feed exhibited good control over the amplitude distribution and total system insertion loss was 0.3 dB with input VSWR less than 1.15 < 1. Theoretical insertion loss for the prototype system was 0.2? dB.

5.0 SYSTEM PERFORMANCE

Projected nominal performance of the SIR-A antenna is shown in Table 2. When the array of seven EMU panels is uniformly illuminated, the E-Plane beamwidth (–8 dB) is

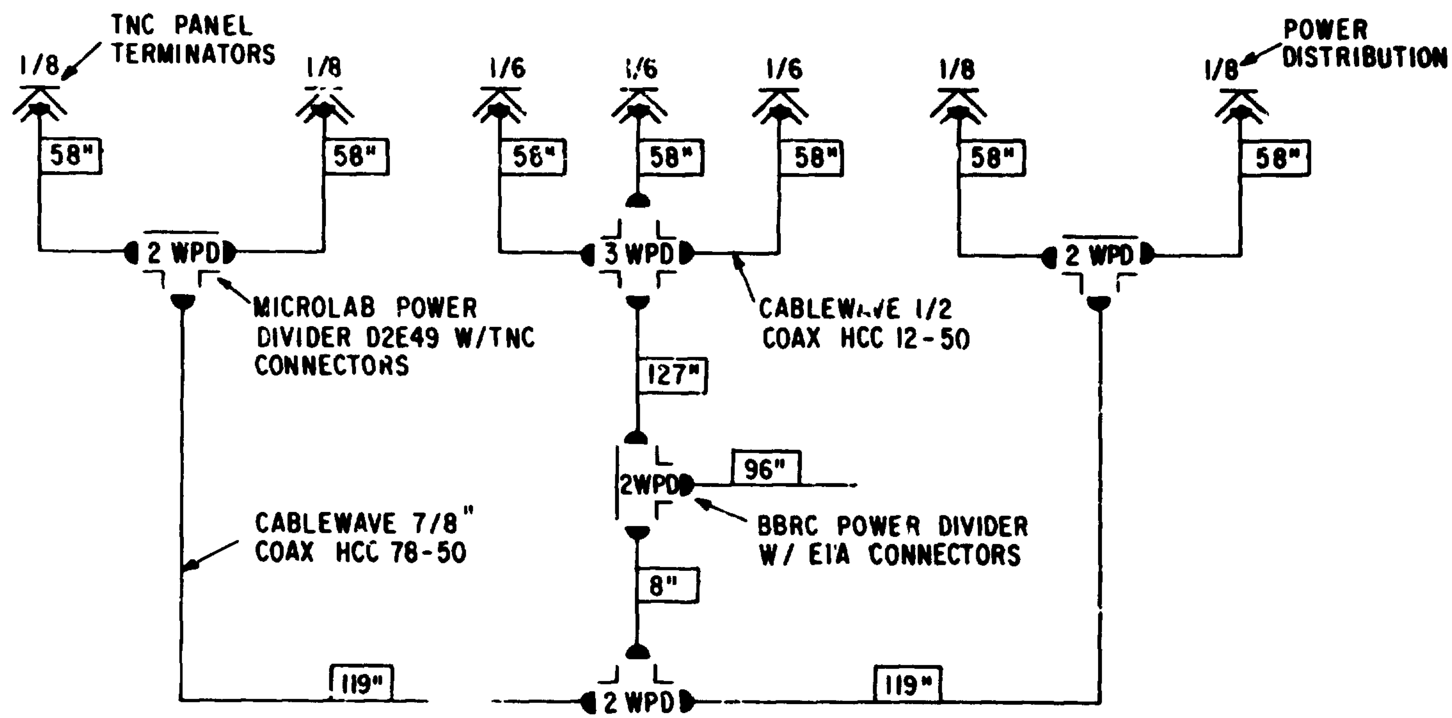

FIGURE 3
SIR-A CORPORATE FEED

theoretically 1.99 degrees with 13 dB sidelobes, but the amplitude taper implemented by the corporate feed increases this beamwidth to 2.07 degrees and potentially reduces sidelobes to -15.2 dB. Array distortions, and particularly phase and amplitude errors in the feed, will cause deviations from these nominal values [2].

The panel gain (25.9 dBi), plus the seven-element array factor gain of 8.45 dB, yields a theoretical 34.35 dBi gain for the SIR-A antenna array; however, several nominal directivity and efficiency losses must be considered (Table 2).

TABLE 2

DIRECTIVITY AND EFFICIENCY LOSSES

E-Plane Taper	-0.02
Feed Network	-0.70
Mechanical Distortions	-0.08
Feed Phase and Amplitude Errors	-0.13
Thermal Blanket	-0.05
Frequency and Temperature Effects	-0.2
NET LOSS	-1.18

Thus, the nominal projected gain of the seven-panel SIR-A antenna array is 33.17 dBi.

Due to the proximity of the SIR-A antenna to potential reflecting surfaces within the Shuttle payload bay, a 1/10 scale model radiation pattern test at 12.75 GHz was conducted to assess the impact of the Shuttle structural surfaces on the SIR-A antenna performance. The test configuration is depicted in Figure 4. This figure shows the antenna in a scale model payload bay with the DFI pallet installed. The Orbiter radiator panel on the side of the bay is also mocked up. Radiation patterns with the antenna mounted high in the bay, as in Figure 1, indicated no measurable beamwidth variation from free space conditions and only a minor increase (0.8 dB) in one H-Plane sidelobe. Shuttle structural surfaces will not adversely affect SIR-A performance.

6.0 POTENTIAL FOR IMPROVEMENT

Because the SIR-A experiment remains inside the Shuttle vehicle and returns to earth, the potential for evolution in system configuration during subsequent reflights is possible. Probable reflights, as yet unscheduled, will provide greater ground coverage than is possible during the 5-day OFT-2 Mission. Improvements in performance could be achieved, with small additional costs, by adding an H-Plane multiple-beam capability to the antenna. Dual polarization could also be added with some

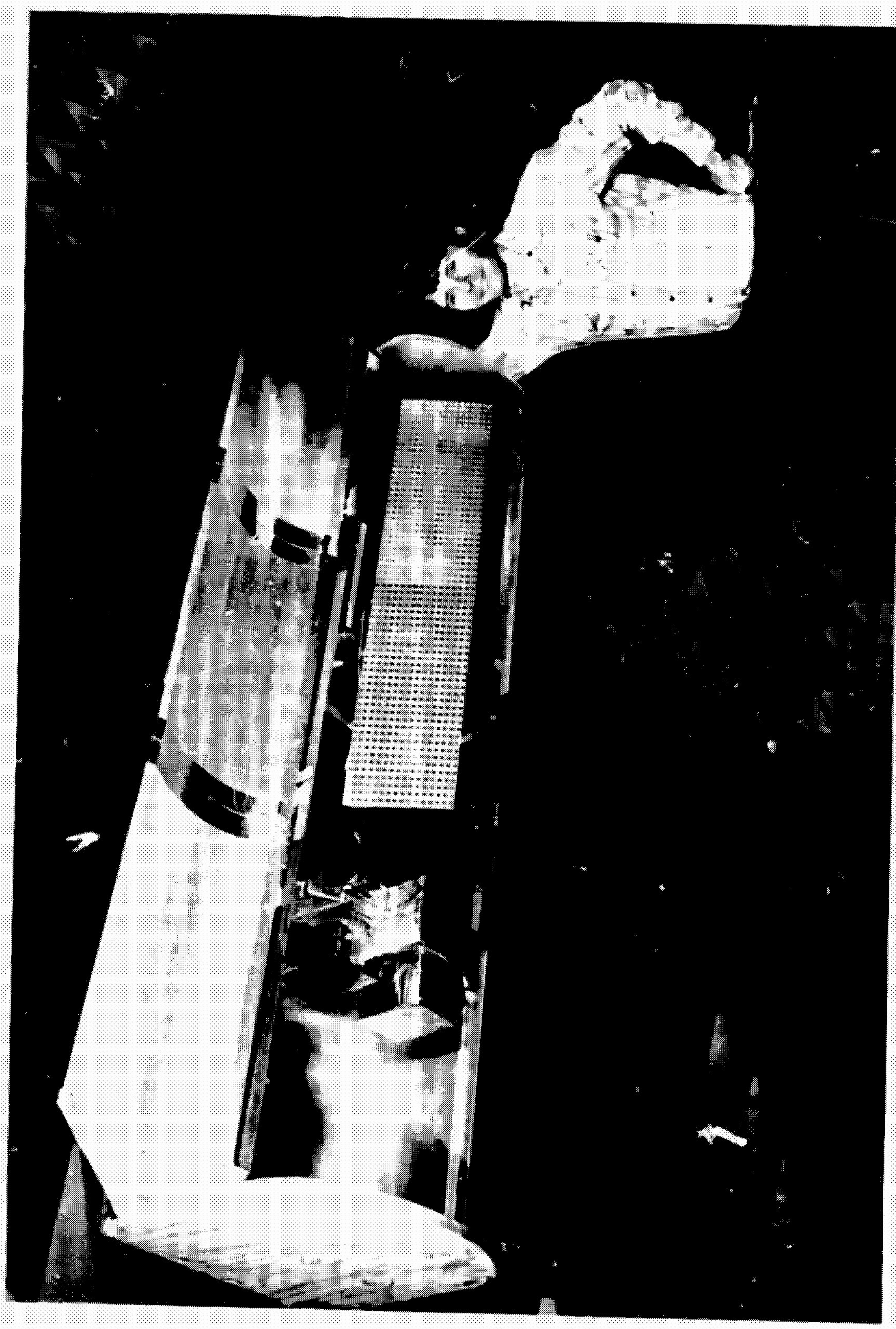

FIGURE 4

1/10 SCALE OPERATIVE MOCK-UP OF THE PROPOSED SIR-A ANTENNA IN THE SHUTTLE BAY modification to the antenna circuit artw~r~ and transmitter. The antenna could have an on-orbit pointing adjustment capabili ncorporated. Another improvement would be to fold the antenna so that it occupies approximately the width of one Spacelab pallet during launch and descent, and deploys over the aft payload bay doors during operation. This change would reduce the length of payload bay occupied, without affecting Orbiter thermal radiator performance, thus allowing a larger variety and number of additional other payloads to share the mission. In order to accomplish this, a foldable feed system, as implemented on the SEASAT SAR antenna and a DoD SAR antenna, would be required. Such changes would result in additional scientific data and provide evolutionary improvement.

7.0 REFERENCES

[1] Brejcha A. G., Keeler L. G., Sanford G. G., "The SEASAT-A Synthetic Aperture Radar Antenna," Synthetic Aperture Radar Technology Conference - 1978.

[2] Huisjen M. A., "Prediction of Antenna Array Performance from Subarray Measurements," Synthetic Aperture Radar Technology Conference - 1978.