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RESEARCH AND DEVELOPMENT OF ANTENNAS FOR ROCKETS AND SATELLITES--ETC(U)
MAR 78 A WATERMAN, D G HENRY F19628-75-C-0072

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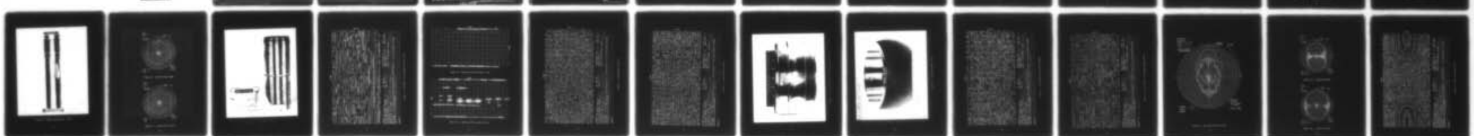

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# RESEARCH AND DEVELOPMENT OF ANTENNAS FOR ROCKETS AND SATELLITES

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Final Report For Period February 1975 - January 1978

March 1978

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

| | | |
|---|---|---|
| Stripline | Beacon | Sphere Antennas |
| Antenna | S-band | Aries Antennas |
| Array | C-band | Corporate Feed |
| Telemetry | X-band | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Physical Science Laboratory, New Mexico State University has conducted research and development studies of antenna designs under contract to the Air Force Geophysics Laboratory. The studies included development of telemetry, beacon and command antennas in various frequency bands. Different mechanical configurations for rockets and satellites were investigated under direction of the contract monitor.

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## 1.0 INTRODUCTION

This report is a summary of various scientific investigations and technical projects pursued from 1975 to 1978. More detailed information on each of the subjects is available by obtaining a copy of the indicated reference. The authors wish to thank J. E. Litton, R. Lanphere and other members of the Physical Science Laboratory (PSL) electromagnetics section who contributed to the work reported herein.

## 2.0 STRIPLINE CONFIGURATIONS

### 2.1 Models 55.507 and 55.508[1-3, 14]

PSL developed both of these antenna arrays to be flush mounted on a nine inch diameter vehicle. They are physically interchangeable and share a common S-band telemetry design, however they each have a different beacon frequency. Model 55.507 has a C-band beacon array, while model 55.508 uses an S-band beacon design.

The C-band beacon array is composed of four linear elements mounted 90° apart and fed in phase. There are two radiating elements for each polarization, and they are 180° apart. Typical roll plane patterns at a frequency of 5.8 GHz are shown in Figures 1a and 1b.

The S-band beacon array is composed of two orthogonal linear elements mounted 180° apart and fed in phase. A roll plane pattern at a frequency of 2.89 GHz is shown in Figure 2.

The S-band telemetry antenna is a ten element linear array. The radiating elements are fed in phase with a constant impedance corporate feed structure. Impedance matching and equal power division is achieved by this symmetrically fed network using parallel combinations and line lengths to obtain the desired results. This decreases the necessity for extremely close tolerance line widths in the circuit design. Figure 3 is a view of this unit on a flight payload. The effects of the spike antennas may be seen by comparing the roll plane patterns shown in Figures 4a and 4b.

### 2.2 Model 55.455[4-10]

This array was developed for the Arcas vehicle which is 4.5 inches in diameter. Aerodynamic and mechanical considerations precluded any antenna structure being either on the outer surface or flush mounted on this vehicle. An additional payload section with a flush mounted unit was also considered unacceptable. The resulting design was an array mounted on a cylinder which was then placed inside the vehicle. It was necessary to machine the vehicle skin to provide five windows for the elements to radiate through. Figure 5 shows the completed unit, and Figure 6 is a copy of the radiation contour plot for this configuration.

### 2.3 Model 55.511[4-8, 11, 15]

This system was designed for use in a ten inch sphere. Originally PSL developed a 12 element S-band TM array (model 55.509) for this diameter sphere in 1972. In 1976 a C-band array was added to the sphere without increasing the area set aside for the original antenna design. Our first attempt was to slightly compress the original S-band design and maintain the 12 element capability. This became model 55.510S and its' radiation pattern was unaltered.

The C-band beacon portion (model 55.510C) was developed using two linear orthogonal elements placed 180° apart and fed in phase. The final design was only 2.7 cm wide but it still had to be mounted on top of the S-band array because of a lack of space. Although both units exhibited good radiation characteristics the mounting configuration and subsequent potting techniques were barely adequate.

Further redesign led to an S-band TM tradeoff. The S-band array was made smaller by reducing the number of radiating elements to eight. This resulted in some radiation pattern degradation but the mechanical advantage made the tradeoff acceptable. For comparison purposes, two simplified versions of the TM radiation contour plots are shown in Figures 7a and 7b. Both patterns are at a frequency of 2.25 GHz, and the cross hatched areas are 10 to 14 dB below isotropic while the shaded areas are 14 dB or more below isotropic.

Radiation contour plots for the C-band beacon are shown in Figures 8 and 9. The entire system now known as model 55.511 is shown in Figure 10. The flight condition is shown in Figure 11. In the launch configuration, the shere is installed within a metal nose cone. To ensure correct systems operation, the nose cone has had four aperatures machined into it. This allows both the telemetry and beacon to be tested in the pre-launch mode, and the TM and radar ground stations to lock on to the signal prior to sphere ejection during the mission.

### 2.4 Model 55.385[3-6, 9-12]

This array was fabricated for the Aries vehicle. It was designed to be mounted on a ring whose outer diameter is 37.25 inches. The antenna was fabricated in six pieces and then harnessed together using coax cables and power dividers. Each of the six modules had eight radiating elements. The array was 2.75 inches wide and was installed under a 0.25 inch thick aluminum heat shield. The heat shield installation requires approximately 20 feet of EMI gasket material. There are two complete arrays for each vehicle, one for the Sensor Module (SM) and one for the Target Engine Module (TEM). Full scale radiation contour plots were taken on a mock up with and without a nose cone. Figure 12 is a radiation contour plot with the nose cone. This simulates the SM with the doors closed. Figure 13 is a radiation contour plot without the nose cone, and this is the condition for the TEM.

After arrival of the sensor module, the roll plane pattern comparison tests were done with the SM doors opened and closed. Although the effect of the doors is visible on the patterns, it was felt that the degradation was minimal and would not adversely effect the system. Originally the system was to operate for three TM links and therefore, tests were conducted at three different frequencies. A fourth link was added by using a single 8 element module designated as model 55.385T. It was fabricated with tapered edges, and was screwed to the outer skin. There was no heat shield and the TM coverage was limited to a small portion of the vehicle. Since this link was only for housekeeping data the coverage was considered adequate.

### 2.5 Model 55.380[10-12]

This array was developed for two different programs. Both the Spice vehicle and the Irbs vehicle are 38 inches in diameter. The antenna array is flush mounted and uses six modules for a total of 48 radiating elements. A gain pattern of the first flight array on a mock up is shown in Figure 14. During the next report period, we plan to complete the tests for these programs. A radiation data set on a flight payload will be taken at the antenna range, and we will test some of the RF components in the PSL vacuum chamber.

## 3.0 BAMM[8]

A system of five separate S-band telemetry stubs and three different command antenna systems were developed for a parachute payload. These units were used on the BAMM project and functioned as expected.

## 4.0 ARIES

### 4.1 C-band Investigation[4, 6, 13]

Extensive tests were conducted on several C-band components supplied to PSL. All of the testing was done on a 37.25 inch diameter mock up. Data was taken using an array of two, three and four elements. The best overall coverage was obtained from an array of two elements. Sample patterns were taken at frequencies of 5.8 and 5.72 GHz. Complete data sets were run at a frequency of 5.76 GHz. The roll plane patterns for a two element array are shown in Figures 15a and 15b.

### 4.2 X-band Development[5, 9, 11]

Model 39.003, an open-ended, dielectric filled waveguide, was developed for this project. There were two units installed on opposite side of the target engine module. A coax switch in the TEM operated by command would then select the appropriate antenna for tracking. This arrangement provided an additional 3 dB gain for the system. A radiation contour plot for an axially mounted slot is shown in Figure 16.

### 4.3 Command System[9, 11]

A standard pair of PSL model 4.003 quadraloop antennas mounted 180° apart was used for the command system. A radiation contour plot for this diameter vehicle is shown in Figure 17.

### 4.4 X-band Tracker[10, 11]

A tracking system developed by the Cubic Corporation was tested at the PSL antenna range on two separate occasions. The unit was tested the first time in May 1977. At that time the sensor module had no other instruments installed. PSL provided operational personnel and recorded data for representatives of AFGL and Cubic. The second test was in early November 1977. PSL provided support only and no data was recorded. Representatives of AFGL and Cubic were on hand to observe the tests. The vehicle was in its pre-launch configuration with almost all of its instruments installed.

## 5.0 ANTENNAS SHIPPED[1-12]

During the report period PSL fabricated, tested and shipped 57 pairs of standard antennas. In addition to these quadraloops, spikes and valentines, there were 12 other units such as stubs and waveguide antennas. PSL also developed 39 stripline arrays composed of 73 pieces.

## 6.0 CONCLUSION

The topics discussed in this report cover the highlights of the efforts from 1975 to 1978. Ongoing projects include the Aries and the Spice, Irbs programs. Future developments include studies relating to antenna bandwidth, radiation coverage and physical size.

## REFERENCES


1. Quarterly Progress Report Number 1, February 1975 - April 1975.
2. Quarterly Progress Report Number 2, May 1975 - July 1975.
3. Quarterly Progress Report Number 3, August 1975 - October 1975.
4. Quarterly Progress Report Number 4, November 1975 - January 1976.
5. Quarterly Progress Report Number 5, February 1976 - April 1976.
6. Quarterly Progress Report Number 6, May 1976 - July 1976.
7. Quarterly Progress Report Number 7, August 1976 - October 1976.
8. Quarterly Progress Report Number 8, November 1976 - January 1977.
9. Quarterly Progress Report Number 9, February 1977 - April 1977.
10. Quarterly Progress Report Number 10, May 1977 - July 1977.
11. Quarterly Progress Report Number 11, August 1977 - October 1977.
12. Quarterly Progress Report Number 12, November 1977 - January 1978.
13. Letter Report, C-band Beacon Antennas, January 1976.
14. Scientific Report Number 1, AFGL-TR-76-0066, February 1976.
15. Scientific Report Number 2, AFGL-TR-77-0064, February 1977.

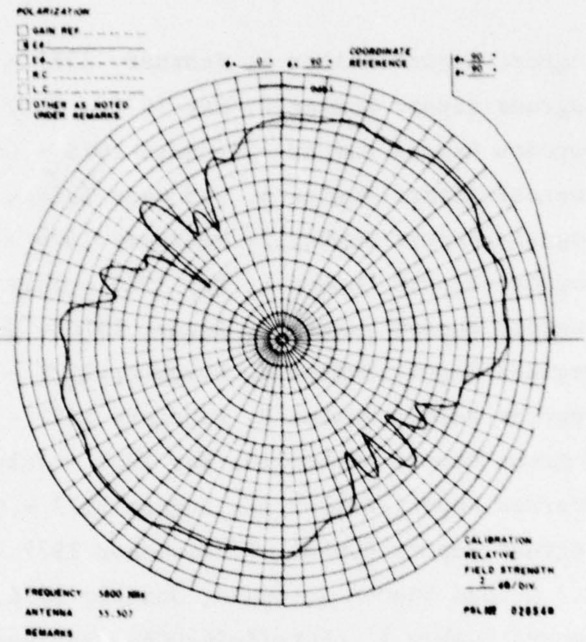



Figure 1a. C-band Beacon Roll Plane

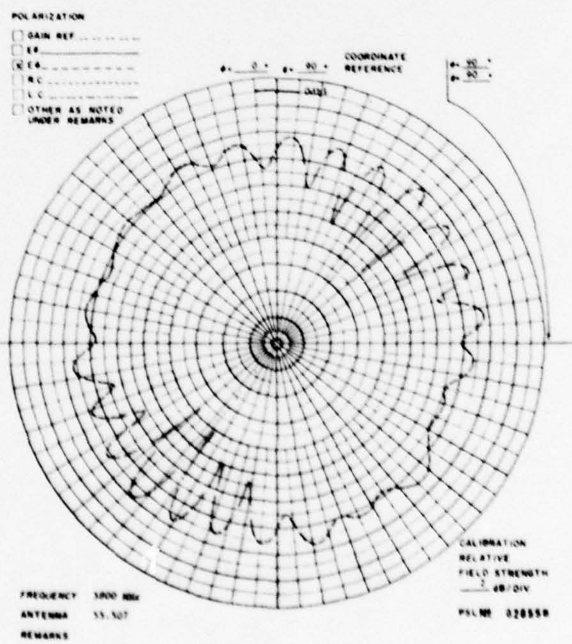



Figure 1b. C-band Beacon Roll Plane

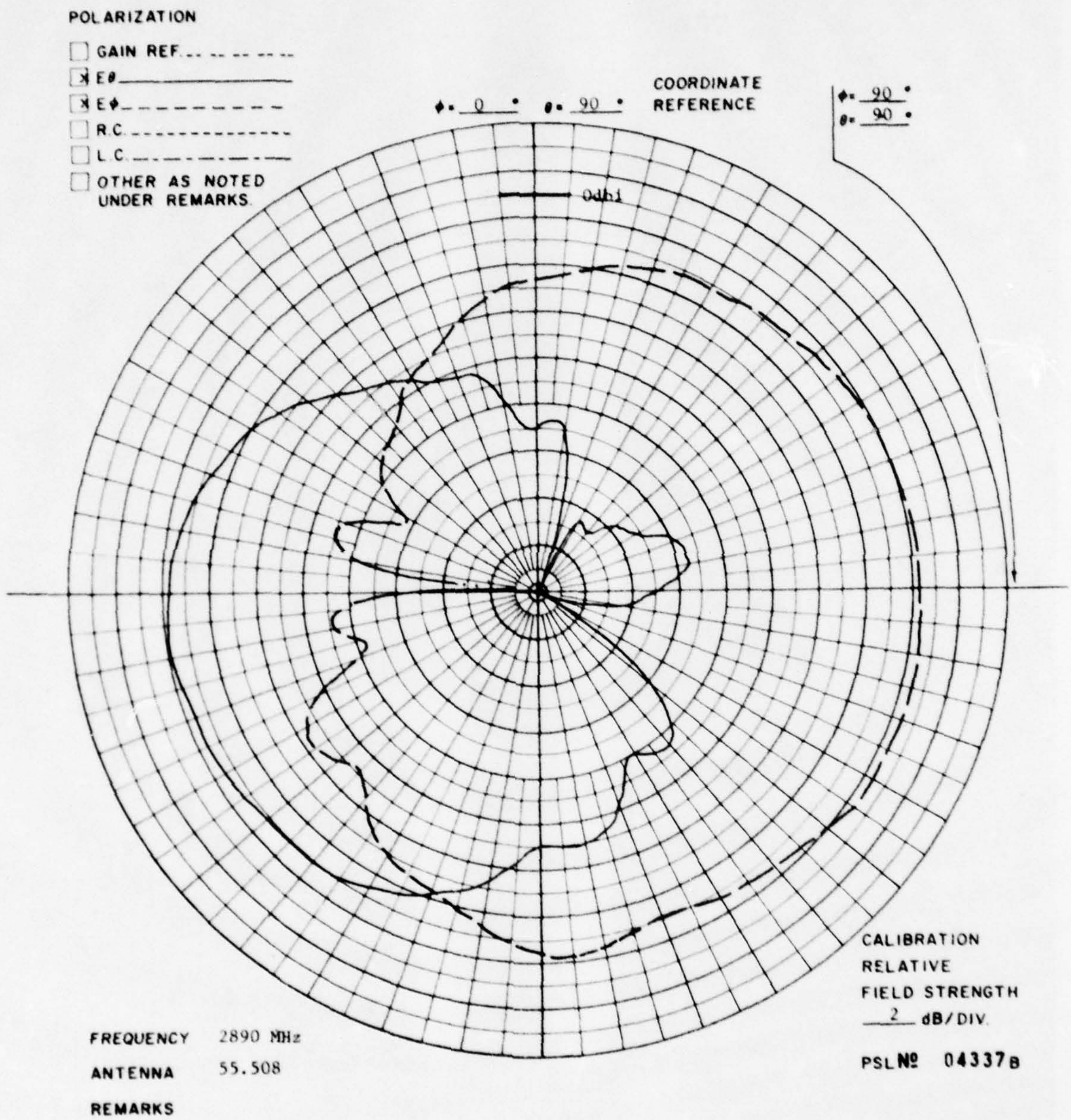



Figure 2. S-band Beacon Roll Plane

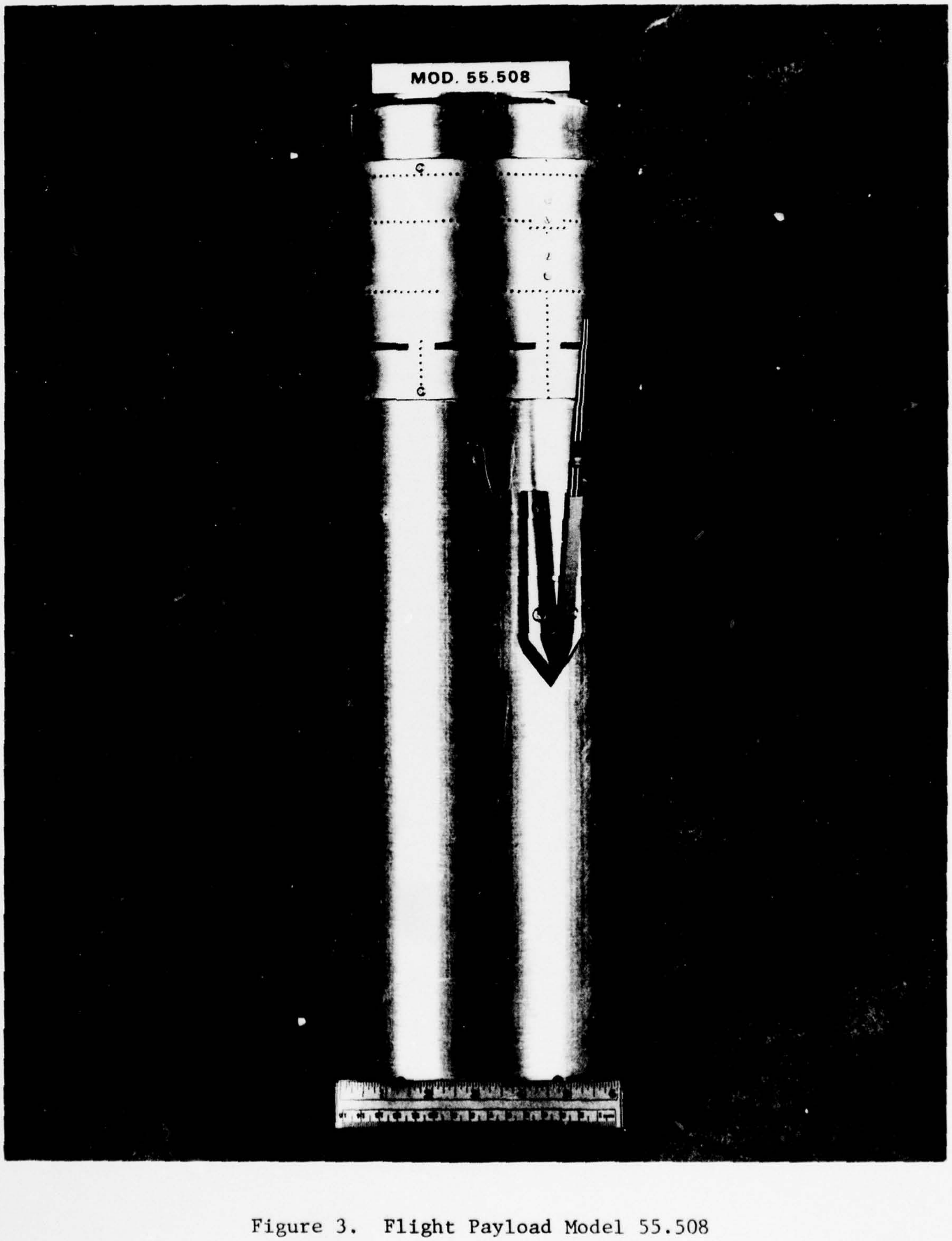



Figure 3. Flight Payload Model 55.508

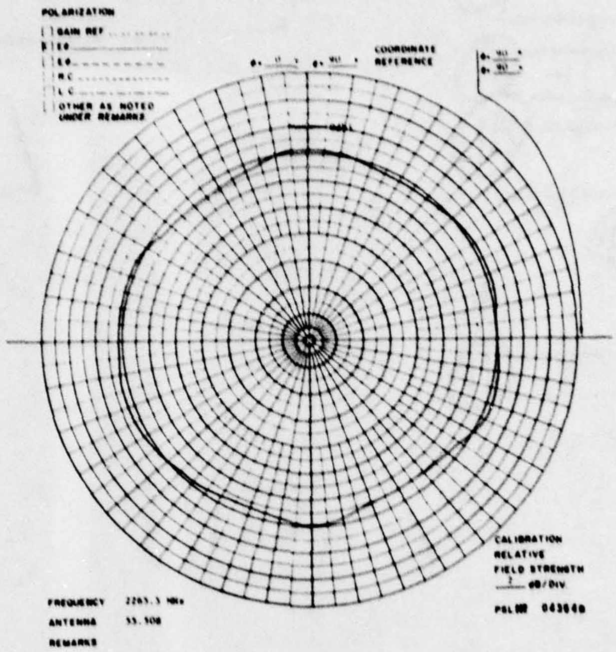



Figure 4a. S-band TM Roll Plane

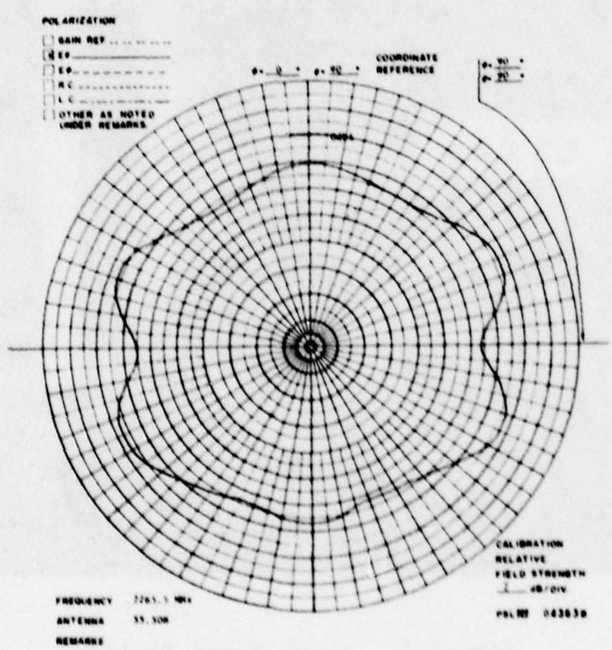



Figure 4b. S-band TM Roll Plane

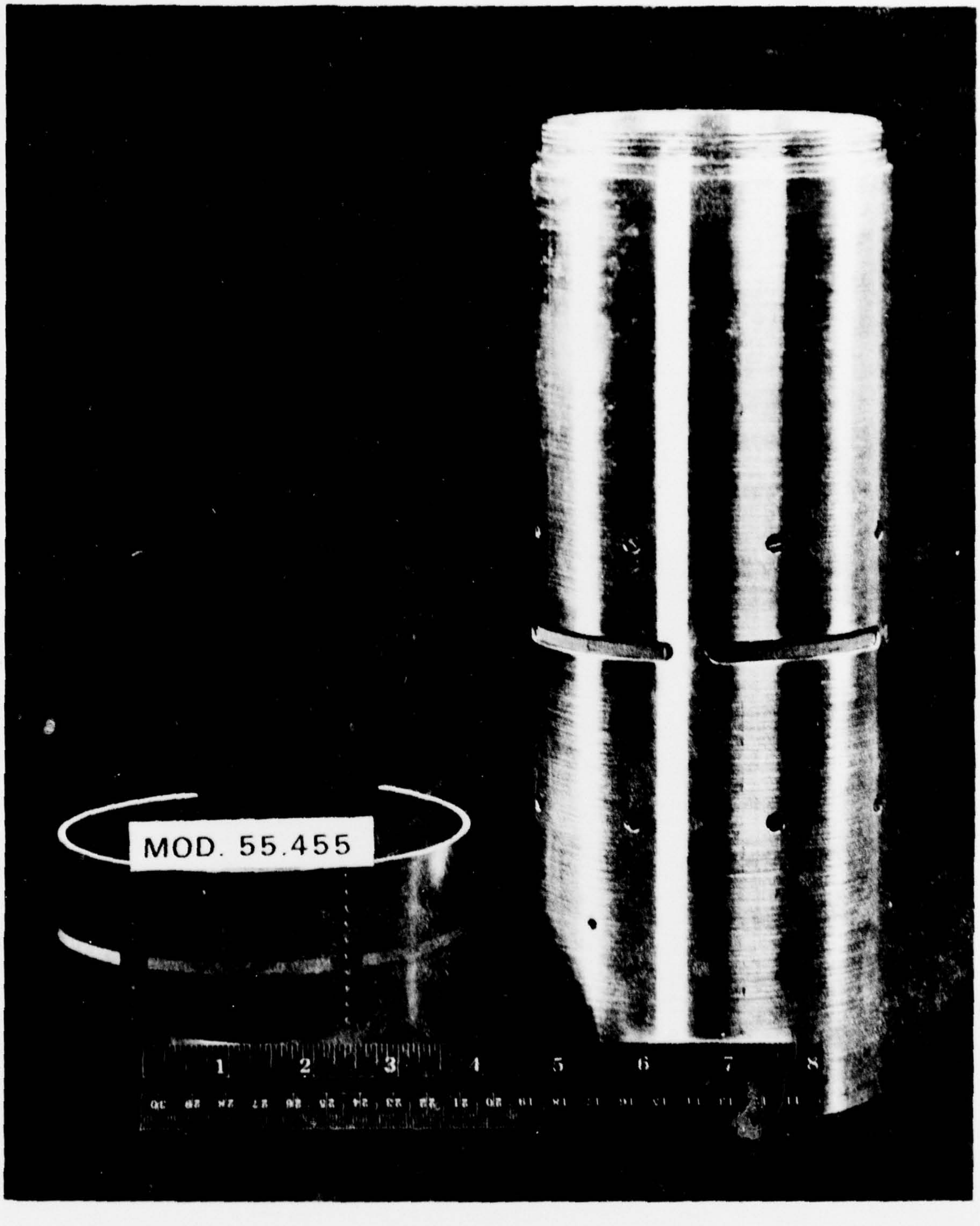
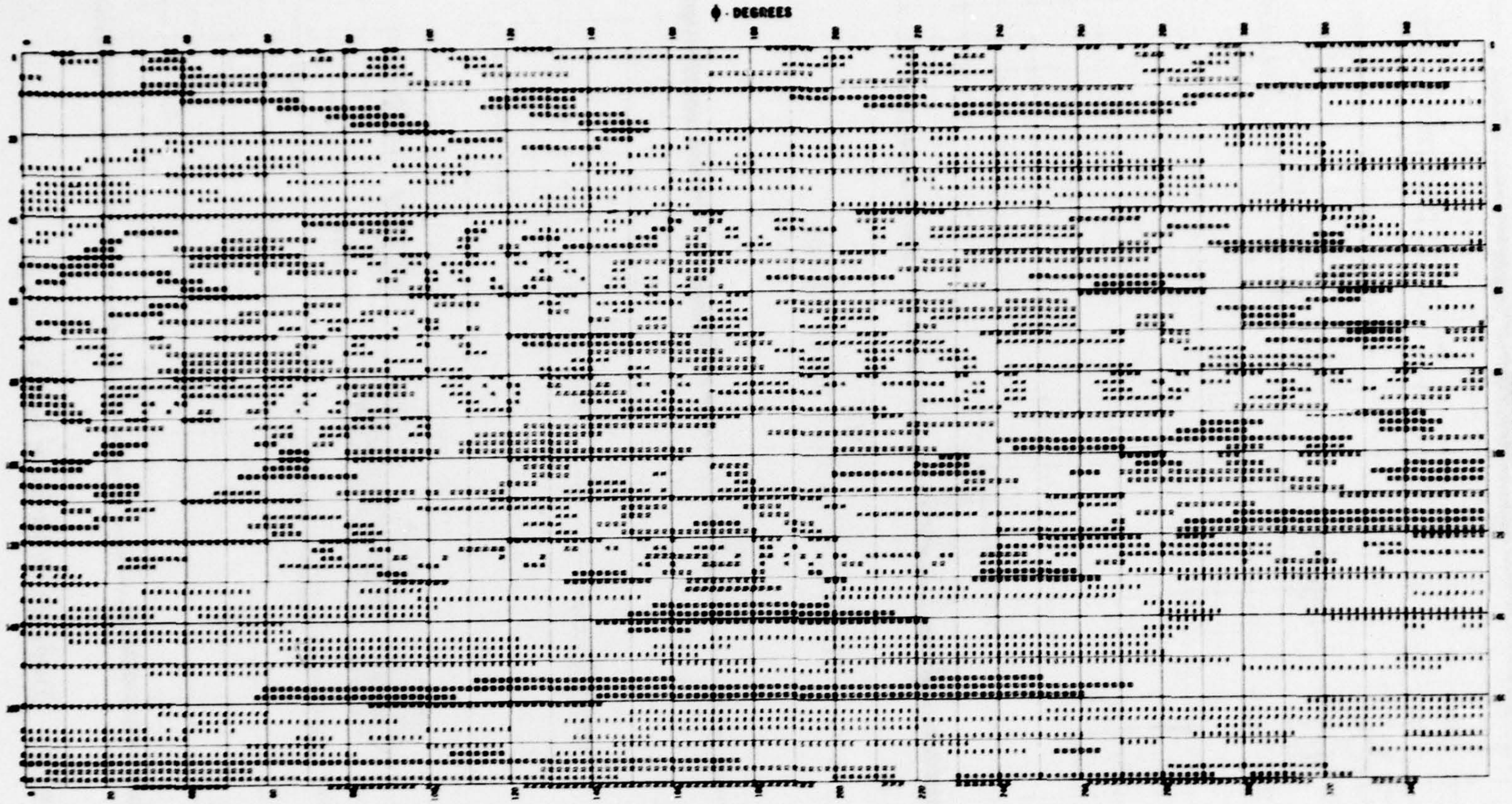



Figure 5. Arcas Model 55.455




CONTRACT NO: F 19628-75-C-0072 PSL FUND NO: 13201 RANGE REQUEST NO: 2347 DATE: 8 June 1977

PATTERN MEASUREMENT FREQUENCY: 2.2515 GHz PSL PHOTO NO: N/A ANTENNA MODEL NO: 55:455 MODEL SCALE: 1:1

POLARIZATION COMPONENT RECORDED: Eθ ARRAY NO: N/A ARRAY PHASING: N/A

GAIN REFERENCE ANTENNA: TYPE AND S/N: SGH 1.7 GAIN OF THE REFERENCE ANTENNA: + 16 dB

DESCRIPTION OF TEST ANTENNA: Five element stripline array for 4.5 inch diameter vehicle.

DESCRIPTION OF VEHICLE MOCKUP: Arcas flight section two feet long. Antenna mounted internally and centered.

THE NUMBER 10 IN THE POWER CONTOUR GRAPH CORRESPONDS TO - 16 dB WITH RESPECT TO THE GAIN REFERENCE ANTENNA.

DESCRIPTION OF THE GAIN MEASUREMENT: Reference PSL gain pattern no. 102028

REMARKS:

Figure 6. Arcas Model 55.455 Radiation Contour Plot

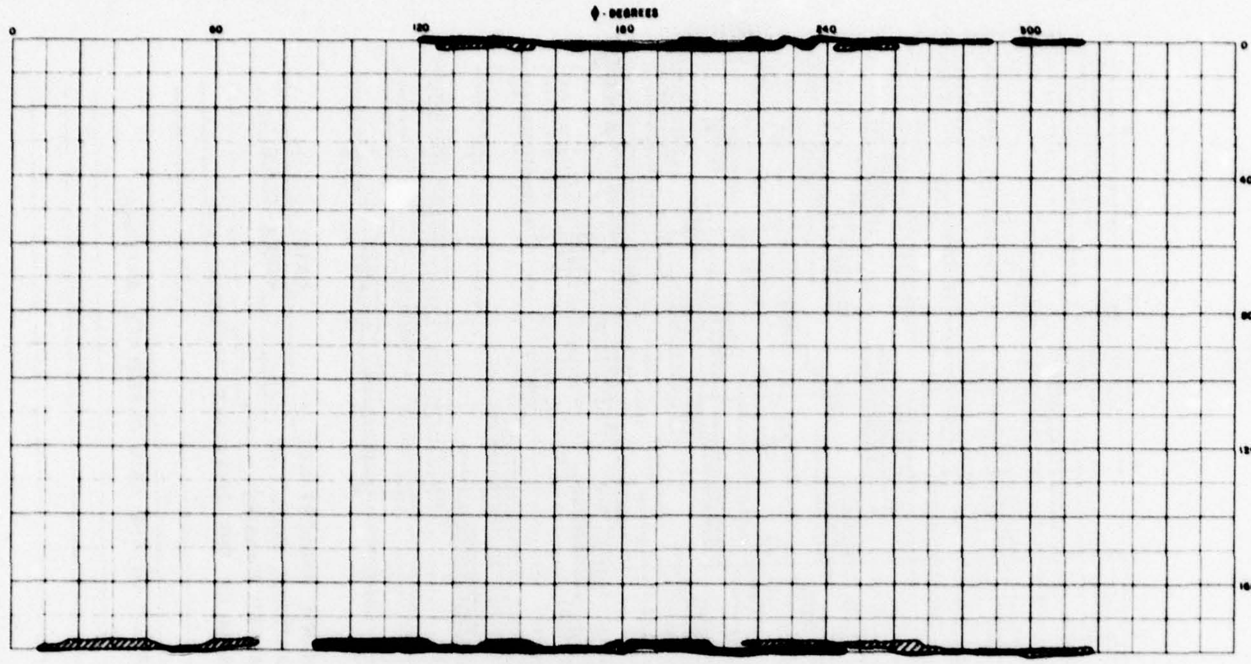



Figure 7a. Simplified TM Plot Model 55.509

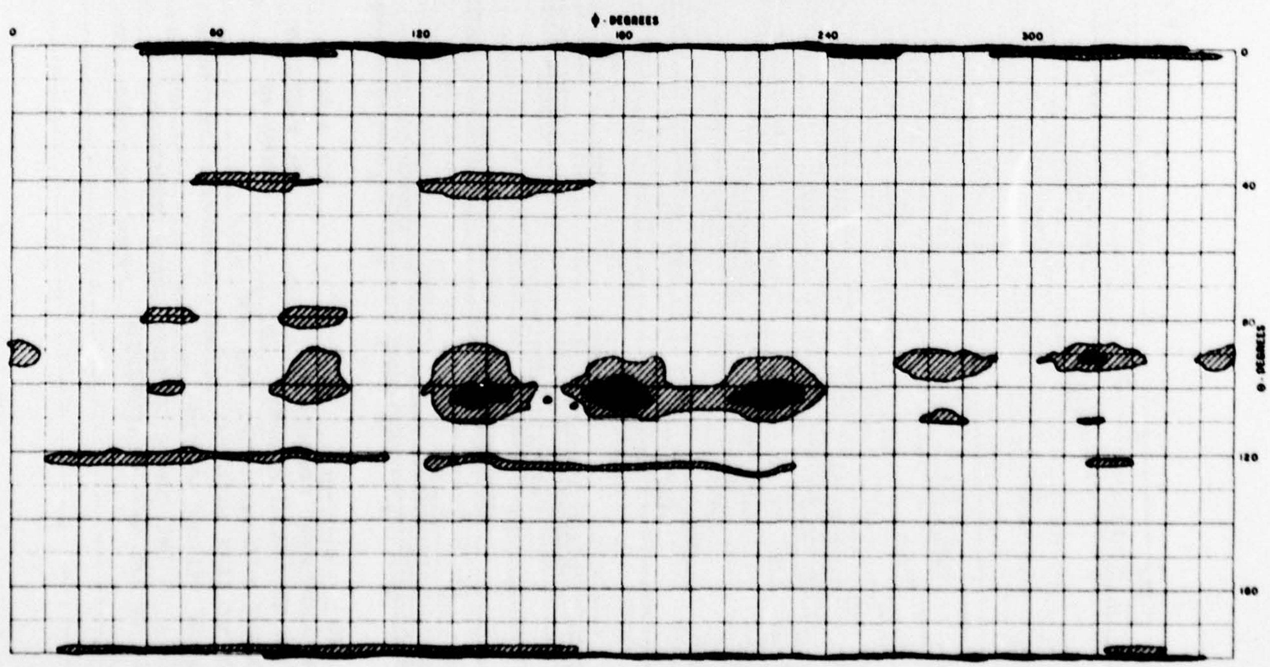
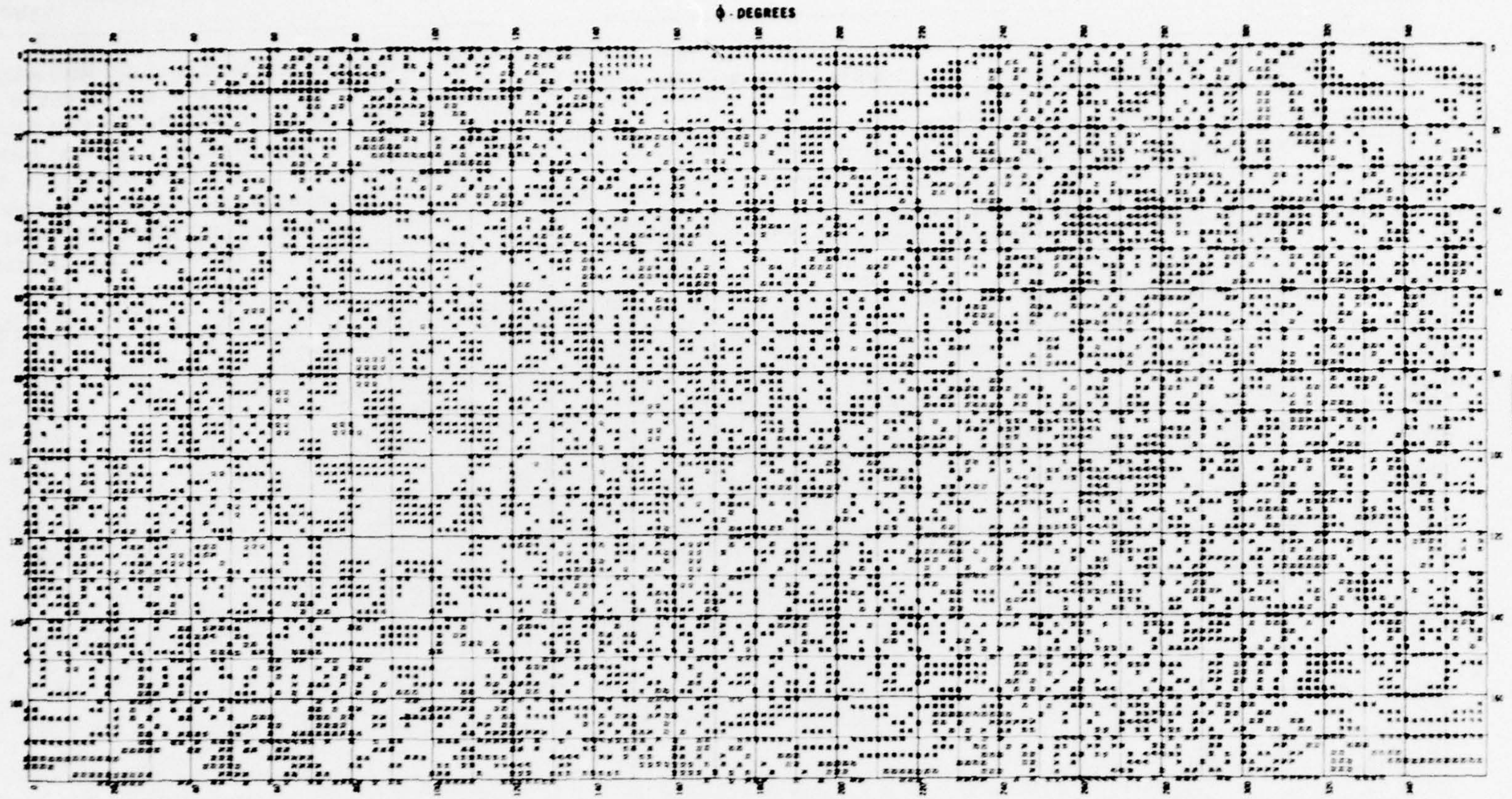



Figure 7b. Simplified TM Plot Model 55.511




CONTRACT NO: F 19628-75-C-0072 PSL FUND NO: 13201 RANGE REQUEST NO: 2332 DATE: February 17, 1977

PATTERN MEASUREMENT FREQUENCY: 5.72 GHz PSL PHOTO NO: N/A ANTENNA MODEL NO: 55.510C MODEL SCALE: 1:1

POLARIZATION COMPONENT RECORDED: Eθ ARRAY NO: N/A ARRAY PHASING: N/A

GAIN REFERENCE ANTENNA: TYPE AND S/N: SGH 3.9 GAIN OF THE REFERENCE ANTENNA: +19dB

DESCRIPTION OF TEST ANTENNA: Two element C-band Beacon, one element for each polarization.

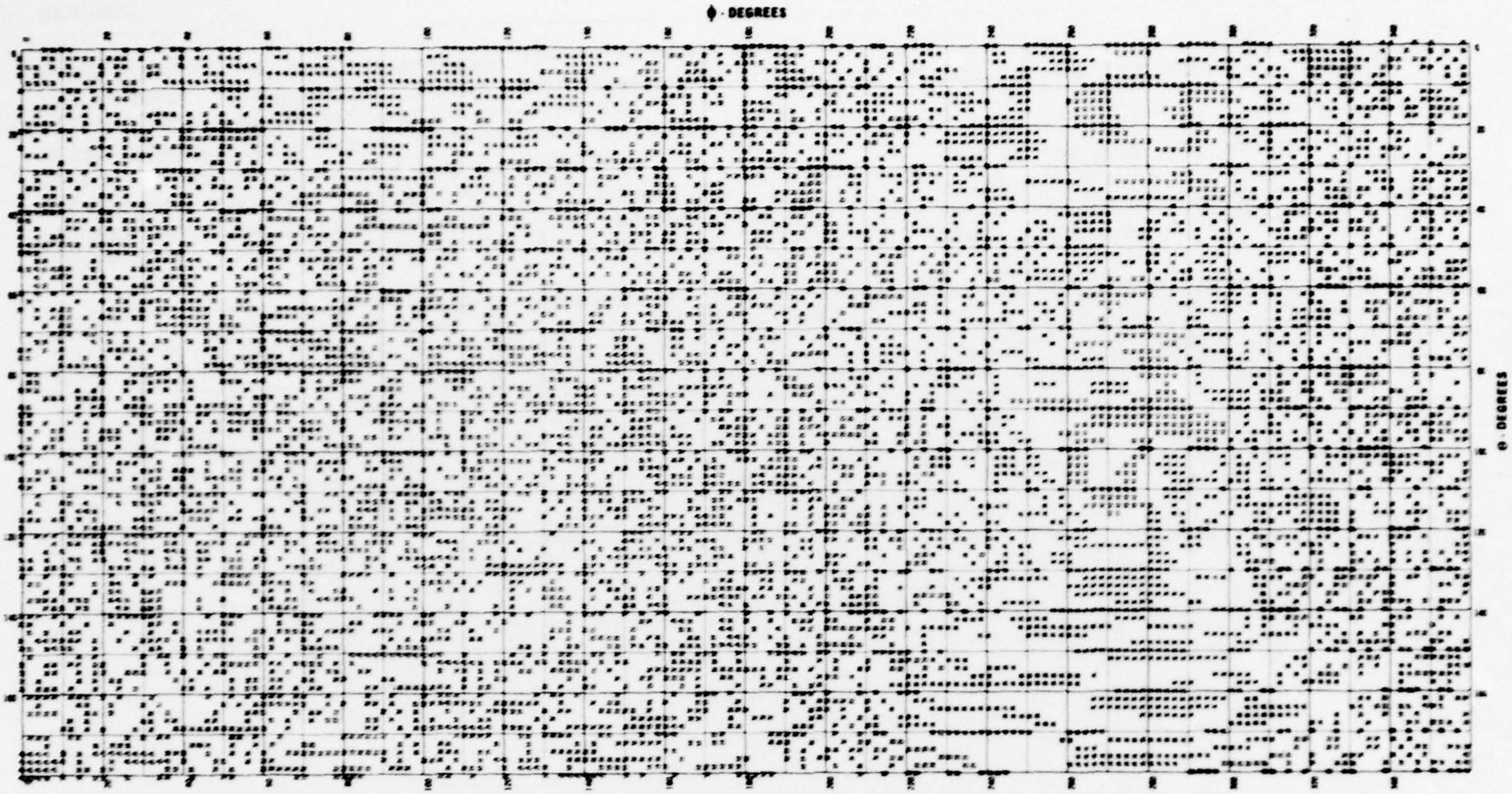
DESCRIPTION OF VEHICLE MOCKUP: 10.12 inch sphere flight unit

THE NUMBER 10 IN THE POWER CONTOUR GRAPH CORRESPONDS TO -19 dB WITH RESPECT TO THE GAIN REFERENCE ANTENNA

DESCRIPTION OF THE GAIN MEASUREMENT: Reference PSL gain pattern No. 092218

REMARKS:

Figure 8. C-band Model 55.510C Eθ




CONTRACT NO: F 19628-75-C-0072 PSL FUND NO: 13201 RANGE REQUEST NO: 2332 DATE: February 17, 1977

PATTERN MEASUREMENT FREQUENCY: 5.72 GHz PSL PHOTO NO: N/A ANTENNA MODEL NO: 55.510C MODEL SCALE: 1:1

POLARIZATION COMPONENT RECORDED: Eϕ ARRAY NO: N/A ARRAY PHASING: N/A

GAIN REFERENCE ANTENNA: TYPE AND S/N: SGR 3.9 GAIN OF THE REFERENCE ANTENNA: +19dB

DESCRIPTION OF TEST ANTENNA: Two element C-band Beacon; one element for each polarization.

DESCRIPTION OF VEHICLE MOCKUP: 10.12 inch sphere flight unit

THE NUMBER 10 IN THE POWER CONTOUR GRAPH CORRESPONDS TO -19 dB WITH RESPECT TO THE GAIN REFERENCE ANTENNA

DESCRIPTION OF THE GAIN MEASUREMENT: Reference PSL gain pattern No. 092218

REMARKS:

Figure 9. C-band Model 55.510C Eϕ

Figure 10. S-band and C-band 10 inch Sphere Model 55.511

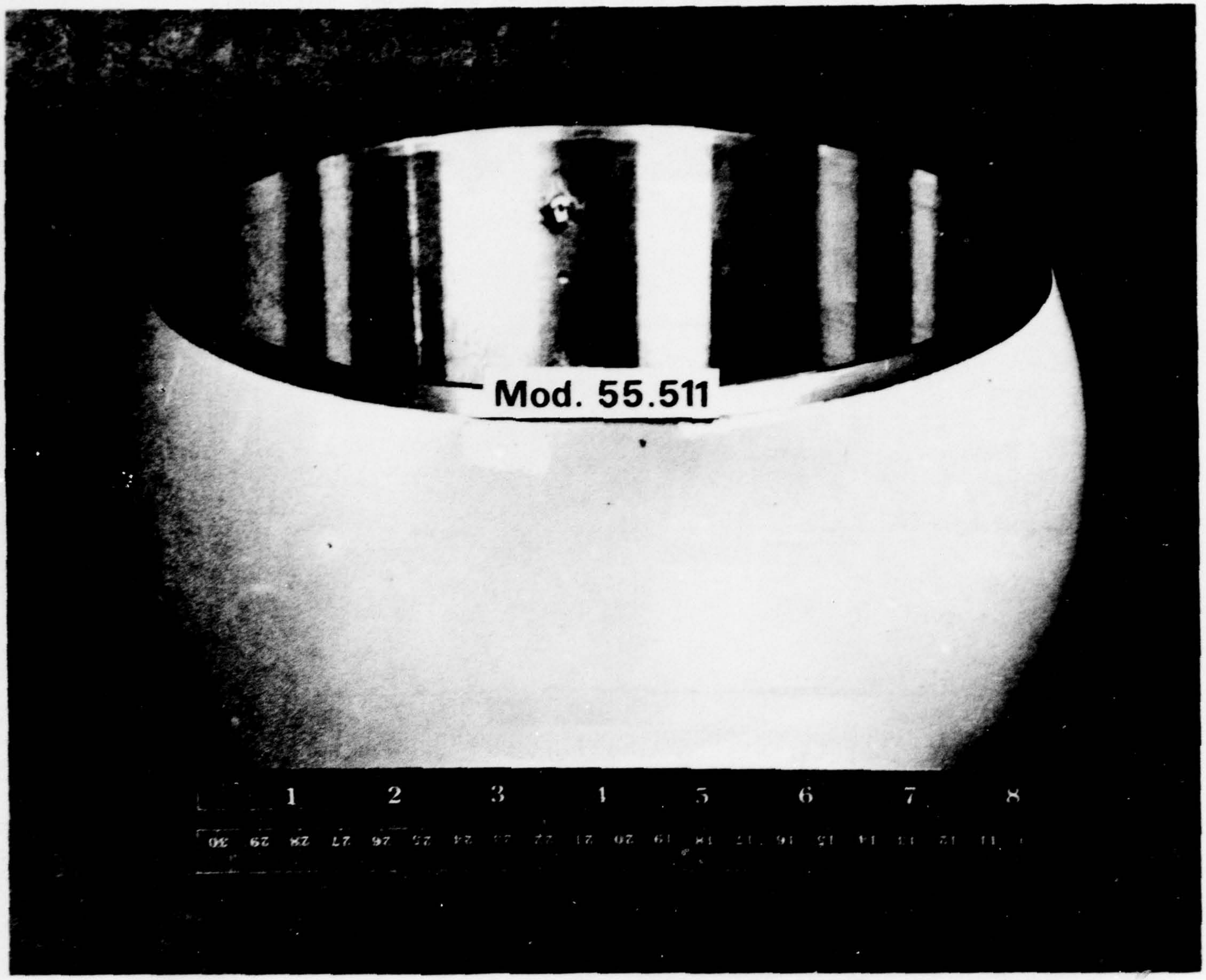
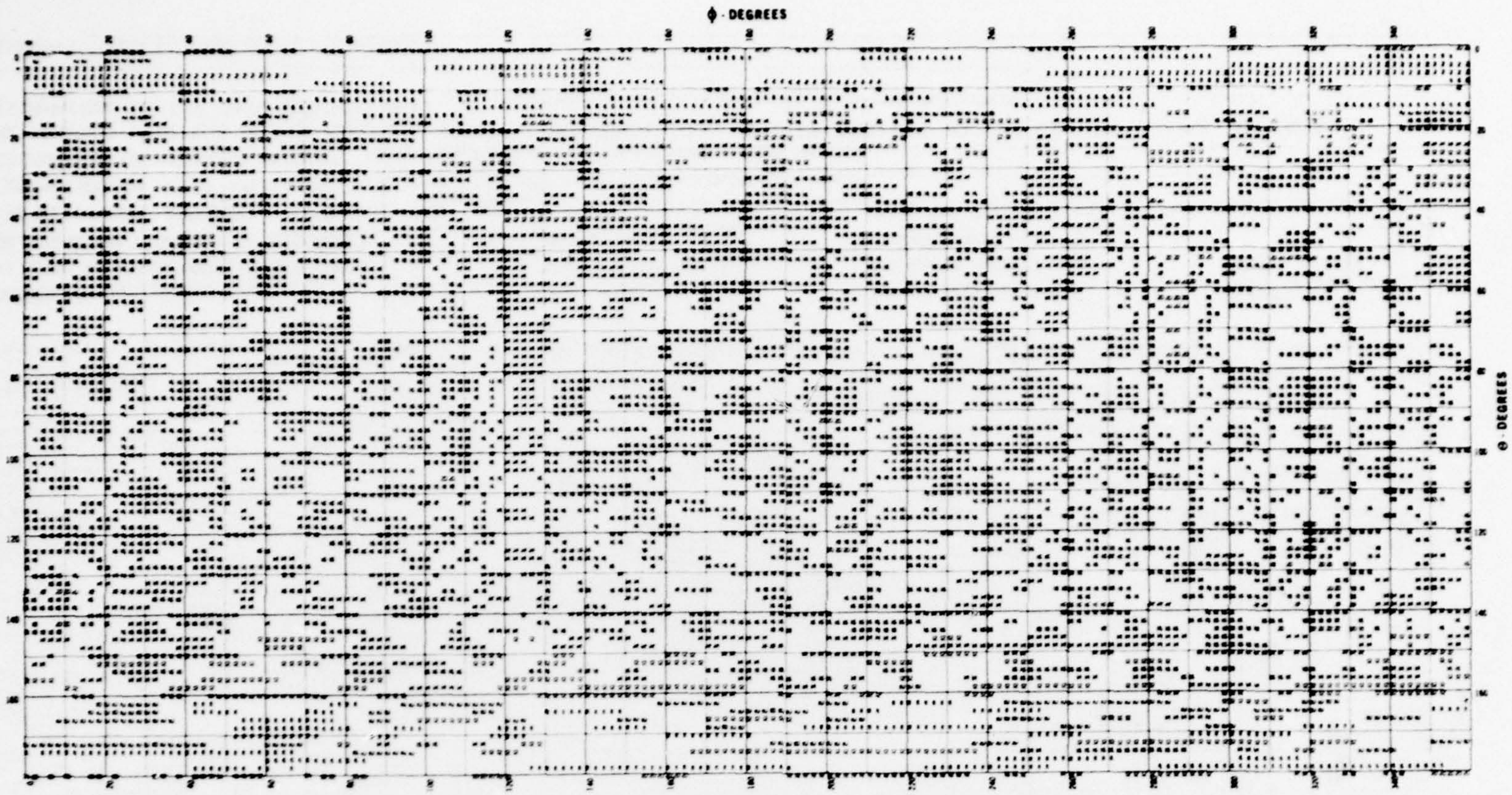


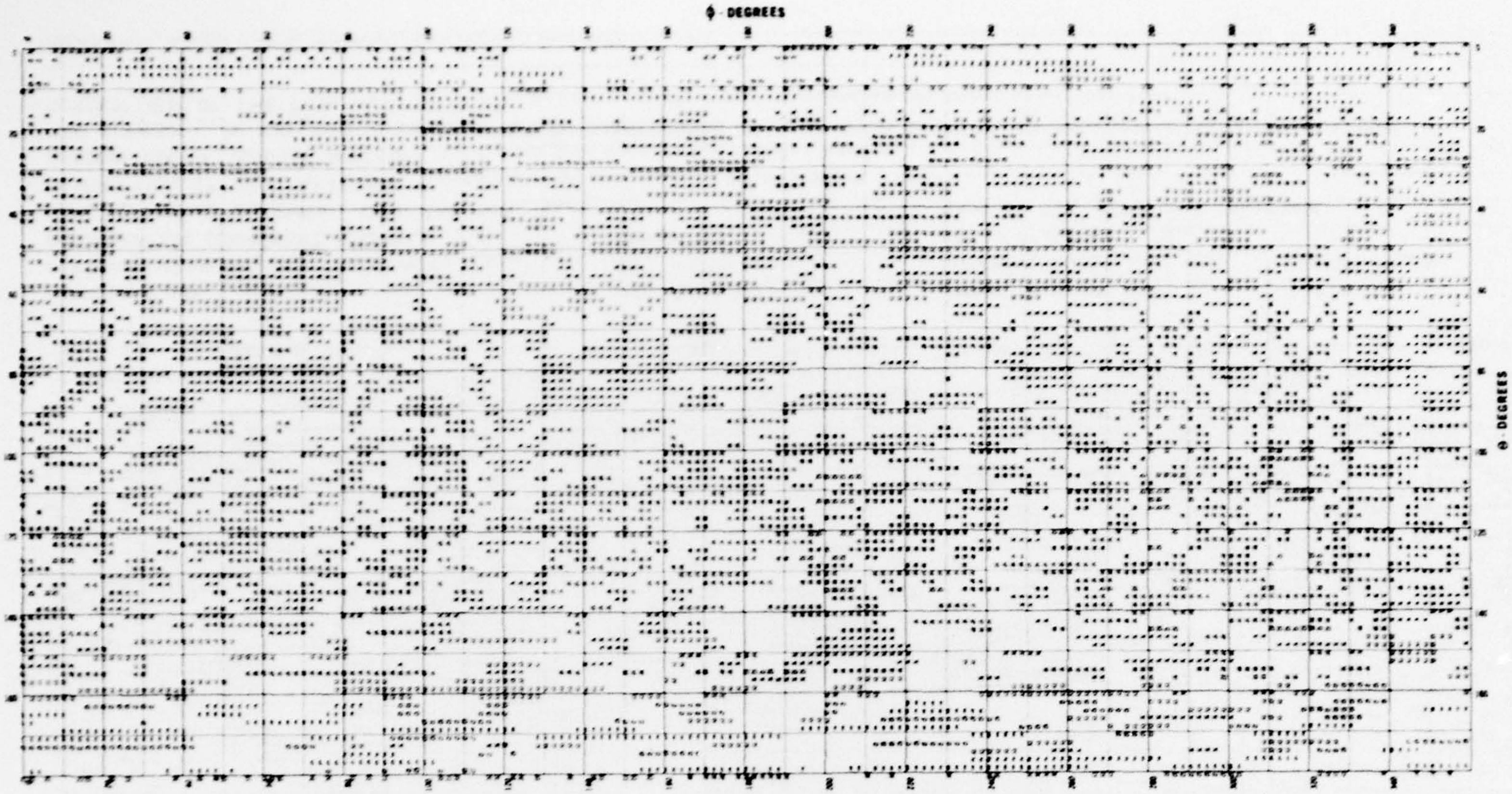

Figure 11. Flight Unit Model 55.511




CONTRACT NO: F19628-75-C-0072 PSL FUND NO: 13201 RANGE REQUEST NO: 2337 DATE: 5 May 77
PATTERN MEASUREMENT FREQUENCY: 2.25 GHz PSL PHOTO NO: N/A ANTENNA MODEL NO: 55.385 MODEL SCALE: 1:1
POLARIZATION COMPONENT RECORDED: EÐ ARRAY NO: N/A ARRAY PHASING: In phase
GAIN REFERENCE ANTENNA: TYPE AND S/N: SGR 1.7 GAIN OF THE REFERENCE ANTENNA: +16 dB
DESCRIPTION OF TEST ANTENNA: Six sub arrays in flight condition i.e. heat shields and EMI gasket installed.
DESCRIPTION OF VEHICLE MOCKUP: Four foot long, 38 inch diameter mockup with antenna at extreme end.
THE NUMBER 10 IN THE POWER CONTOUR GRAPH CORRESPONDS TO -16 dB WITH RESPECT TO THE GAIN REFERENCE ANTENNA
DESCRIPTION OF THE GAIN MEASUREMENT: The lowest serial number sub array was designated as ϕ = 0°. Reference PSL Gain Pattern No. 10057B.

REMARKS: Nose Cone approximately three feet long, simulation of Sensor Module doors closed.

Figure 12. Aries Model 55.385 Sensor Module




CONTRACT NO: F19628-75-C-0072 PSL FUND NO: 13201 RANGE REQUEST NO: 2337 DATE: 5 May 7

PATTERN MEASUREMENT FREQUENCY: 2.25 GHz PSL PHOTO NO: N/A ANTENNA MODEL NO: 55.385 MODEL SCALE: [illegible]

POLARIZATION COMPONENT RECORDED: [illegible] ARRAY NO: N/A ARRAY PHASING: In phase

GAIN REFERENCE ANTENNA: TYPE AND S/N: SGR 1.7 GAIN OF THE REFERENCE ANTENNA: +16 dB

DESCRIPTION OF TEST ANTENNA: Six sub arrays in flight condition i.e. heat shields and EMI gasket installed.

DESCRIPTION OF VEHICLE MOCKUP: Four foot long, 38 inch diameter mockup with antenna at extreme end.

THE NUMBER 10 IN THE POWER CONTOUR GRAPH CORRESPONDS TO -16 dB WITH RESPECT TO THE GAIN REFERENCE ANTENNA

DESCRIPTION OF THE GAIN MEASUREMENT: The lowest serial number array was designated as ϕ = 0°. Reference PSL Gain Pattern No. 10071B

REMARKS: No Nose Cone, simulation of Target Engine Module.

Figure 13. Aries Model 55.385 Target Engine Module

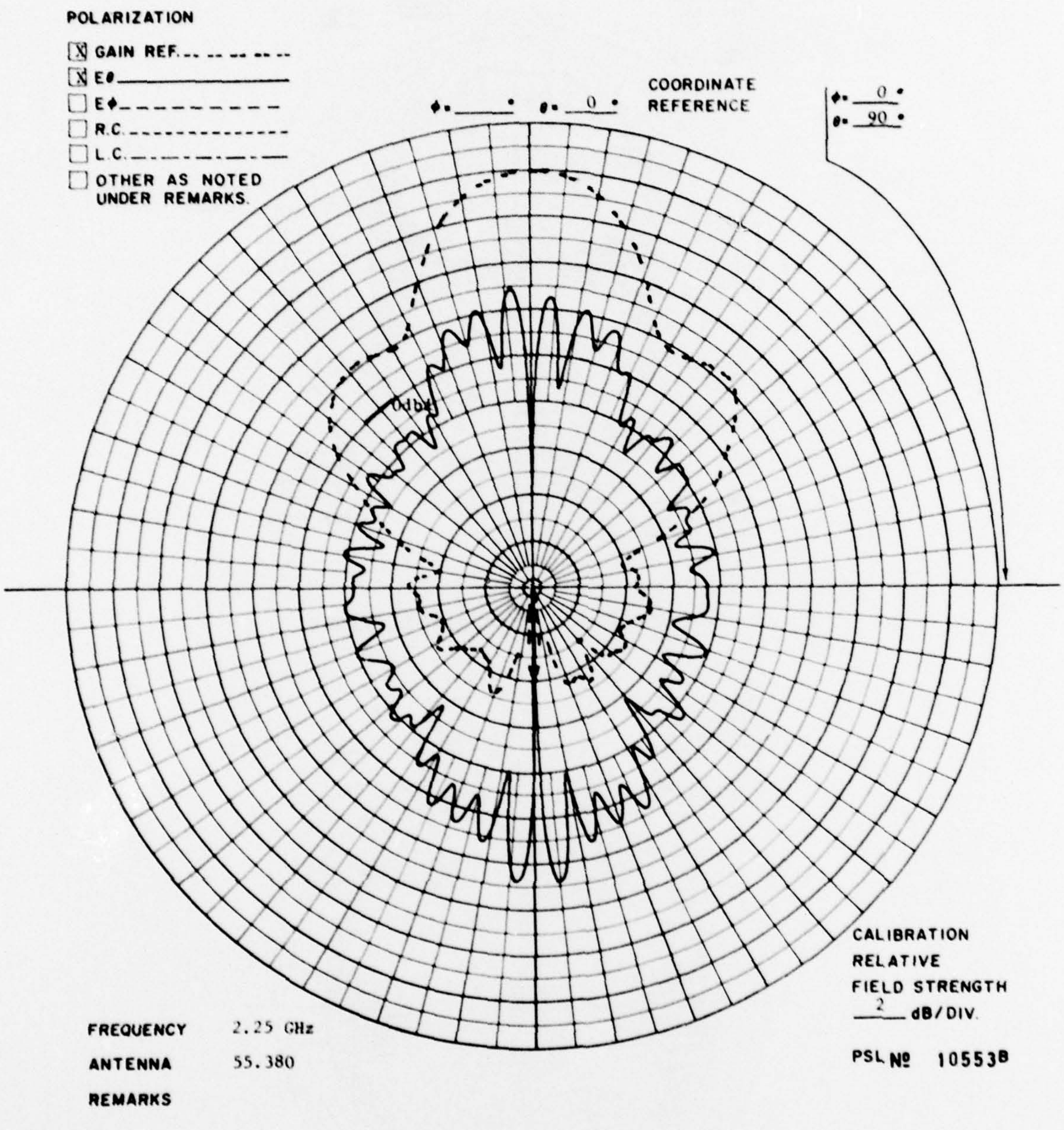



Figure 14. Gain Reference Mod 55.380

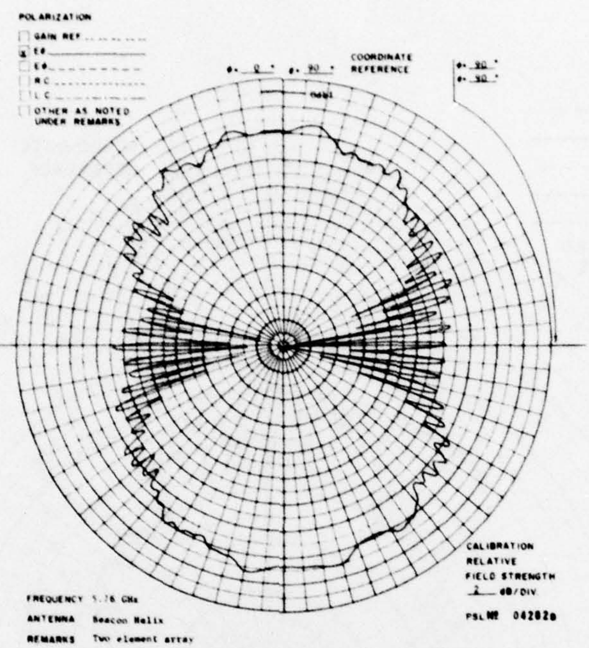



Figure 15a. C-band Roll Plane

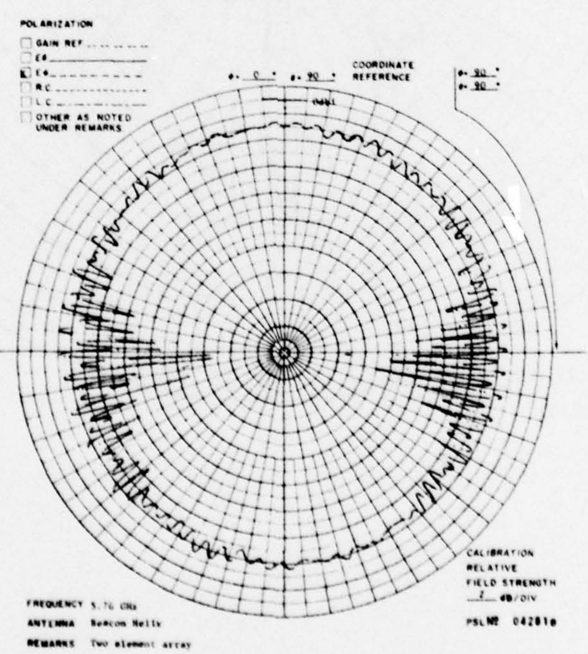
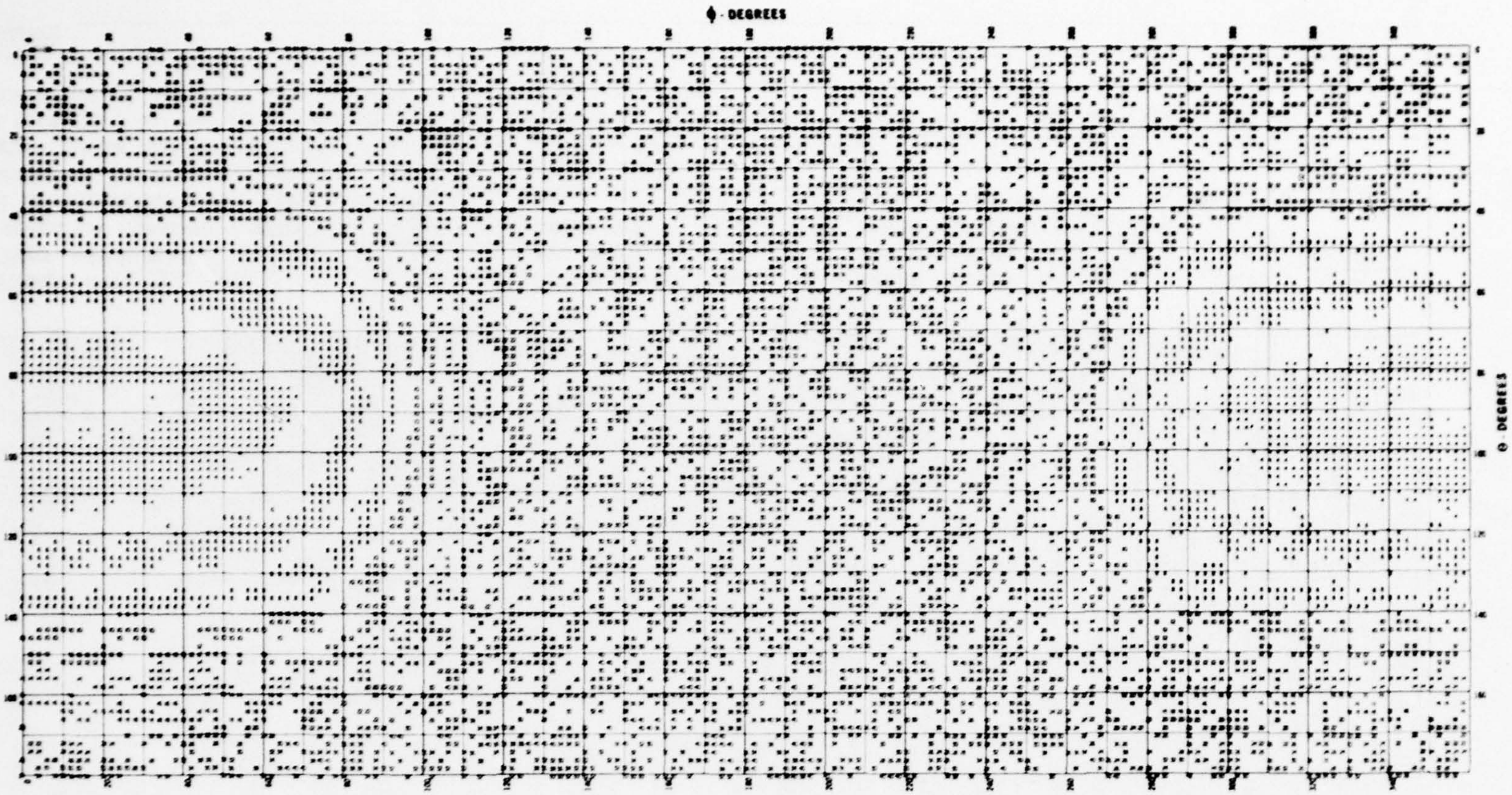


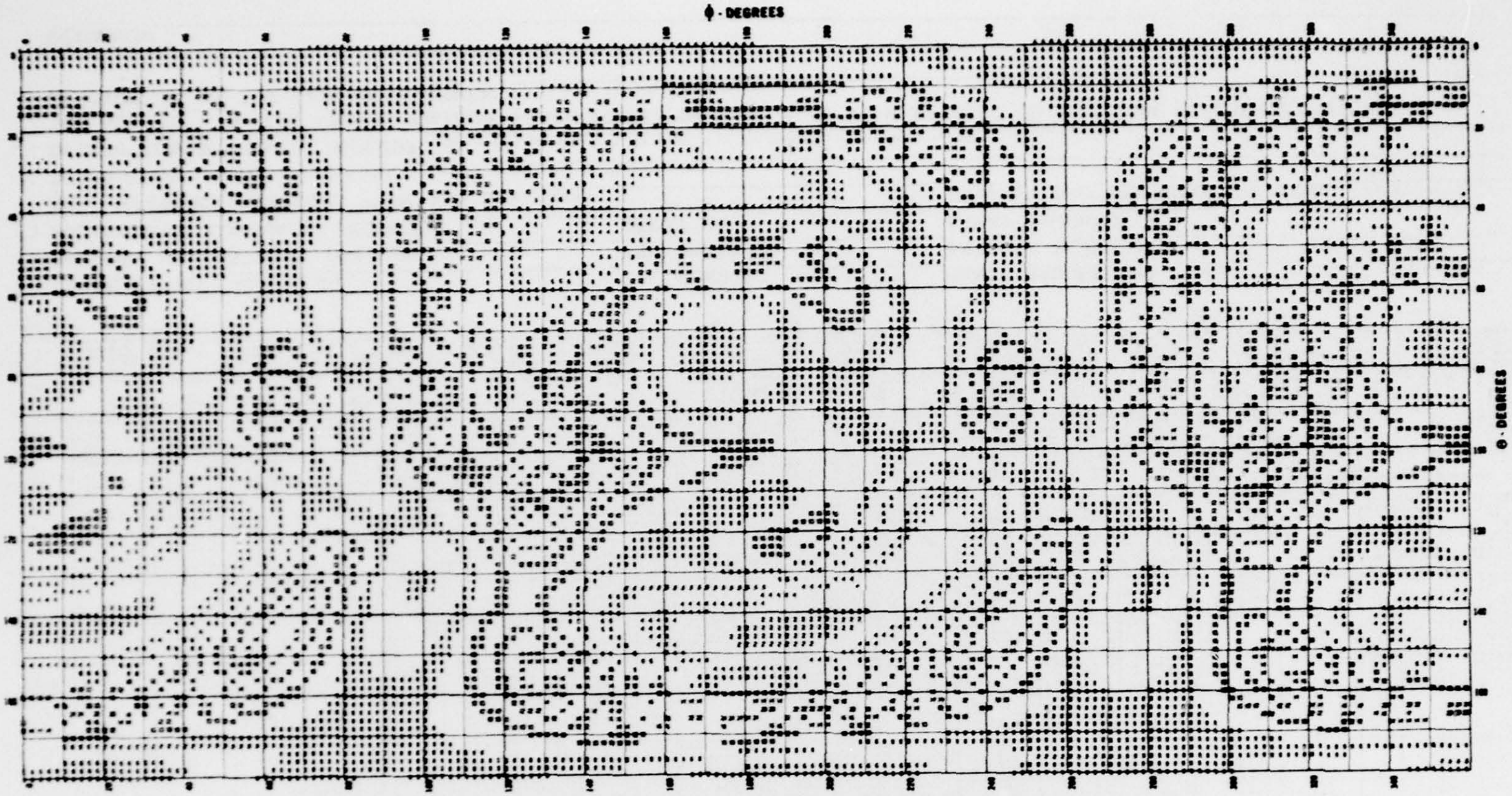

Figure 15b. C-band Roll Plane




CONTRACT NO: F19628-75-C-0072 PSL FUND NO: 13201 RANGE REQUEST NO: 2406 DATE: 28 October 1977
PATTERN MEASUREMENT FREQUENCY: 9.7 GHz PSL PHOTO NO: N/A ANTENNA MODEL NO: 39.003 MODEL SCALE: 1:1
POLARIZATION COMPONENT RECORDED: Eθ ARRAY NO: N/A ARRAY PHASING: N/A
GAIN REFERENCE ANTENNA: TYPE AND S/N: SGH 8.2 GAIN OF THE REFERENCE ANTENNA: +22 dB
DESCRIPTION OF TEST ANTENNA: A single element model 39.003 mounted axially.
DESCRIPTION OF VEHICLE MOCKUP: The antenna was mounted in the center of a four foot long 38 inch diameter vehicle.
THE NUMBER 4 IN THE POWER CONTOUR GRAPH CORRESPONDS TO -22 dB WITH RESPECT TO THE GAIN REFERENCE ANTENNA
DESCRIPTION OF THE GAIN MEASUREMENT: Reference PSL gain pattern No. 10600B

REMARKS:

Figure 16. Axial Slot Model 39.003




CONTRACT NO: F19628-75-C-0072 PSL FUND NO: 13201 RANGE REQUEST NO: 2407 DATE: 25 Oct 1977

PATTERN MEASUREMENT FREQUENCY: 409 MHz PSL PHOTO NO: N/A ANTENNA MODEL NO: 4.003 MODEL SCALE: 1:1

POLARIZATION COMPONENT RECORDED: LC ARRAY NO: N/A ARRAY PHASING: 180° out of Phase

GAIN REFERENCE ANTENNA: TYPE AND S/N: Corner Reflector GAIN OF THE REFERENCE ANTENNA: +10 dB

DESCRIPTION OF TEST ANTENNA: One pair of model 4.003 antennas mounted 180° apart

DESCRIPTION OF VEHICLE MOCKUP: Antennas mounted in the center of a four foot long 38 inch diameter vehicle

THE NUMBER 10 IN THE POWER CONTOUR GRAPH CORRESPONDS TO -6 dB WITH RESPECT TO THE GAIN REFERENCE ANTENNA.

DESCRIPTION OF THE GAIN MEASUREMENT: Reference PSL gain pattern no. 10544B

REMARKS:

Figure 17. Command Model 4.003