(NASA-CR-147673) SHUTTLE ORBITER C-BAND BEACON ANTENNA LOCATION STUDY (McDonnell-Douglas Corp.) 111 p HC $5.50 CSCL 22A

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MCDONNELL DOUGLAS
CORPORAT

SHUTTLE ORBITER
C-BAND BEACON ANTENNA
LOCATION STUDY

1.2-DN-B0203-003 MAY 30, 1975

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

SYSTEMS ENGINEERING ANALYSIS

This Design Note is Submitted to NASA Under Task Order
No. B0203, Contract NAS 9-13970.

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1.0 SUMMARY

The purpose of this study is to make a recommendation for the location of the Space Shuttle C-Band Beacon Antenna(s) to be used during Approach and Landing Tests. The study has included an Orbiter-to-ground radar look angle evaluation, a vehicle shadowing evaluation and extensive 1/10-scale antenna pattern measurements. Locations were limited to the cutouts for the S-Band Quads and Hemis to minimize skin perturbation. The results show that a single C-Band Antenna located in the lower Hemi cutout will provide optimum coverage and eliminate the need for switching and the undesirable interferometer effects of two antennas.

2.0 INTRODUCTION

The purpose of this report is to evaluate the C-Band Beacon Antenna location for Approach and Landing Tests at Edwards AFB, California for the Space Shuttle Program. Candidate antenna locations were limited to the cutouts for the S-Band Hemis and Quads to minimize perturbations to the Shuttle Orbiter skin. Detailed consideration is given to the Orbiter-to-ground radar look angles as related to antenna pattern coverage at each location. Antenna patterns are presented to simulate both the free flight and captive configurations with the Orbiter mated to a Boeing 747. Vehicle shadowing as well as extensive measured pattern data is presented for each applicable location and configuration. Finally, a recommendation is made for the location of the C-Band Beacon Antenna(s) based on measured data and look angle information.

3.0 DISCUSSION

This section contains pertinent background information, Orbiter-to-ground radar look angles, vehicle shadowing effects and antenna pattern data.

3.1 Background Information

A C-Band Beacon Transponder Motorola type DPN-66 will be utilized on the Shuttle Orbiter during the Approach and Landing Tests at Edwards AFB, California to accurately locate the Orbiter during each flight. Current plans show the transponder connected to two antennas through a combination switch/power divider (Tee). When the beacon is receiving on 5660 MHz the two antennas are connected in parallel and when the beacon is transmitting on 5585 MHz only one antenna is used depending on the ground command. A two pulse code is used by the ground to select one antenna and a three pulse code is used to select the other antenna. The presently planned antenna locations include the lower left and upper right S-Band Quad cutouts (References A, B and C). The antennas will be Vega Precision type 845-CX-2 tear shaped monopoles. A block diagram of the C-Band Beacon System is shown in Figure 1. An antenna pattern of the C-Band Beacon Antenna on a 6-inch diameter ground plane is shown in Figure 2 at a frequency of 5600 MHZ and general antenna specifications are given in Figure 3.

3.2 Orbiter-to-Ground Radar Look Angles

Present planning entails 11 free flights with the Orbiter separating from the Boeing 747. Five flights will involve landing on runway 17 and six flights are associated with runway 22. Ground tracks of two reference flights are given in Figure 4 (Reference D) along with the location of the FPS-16 ground radar on hill R-4 (Reference E). The hill has an altitude of 2625 feet

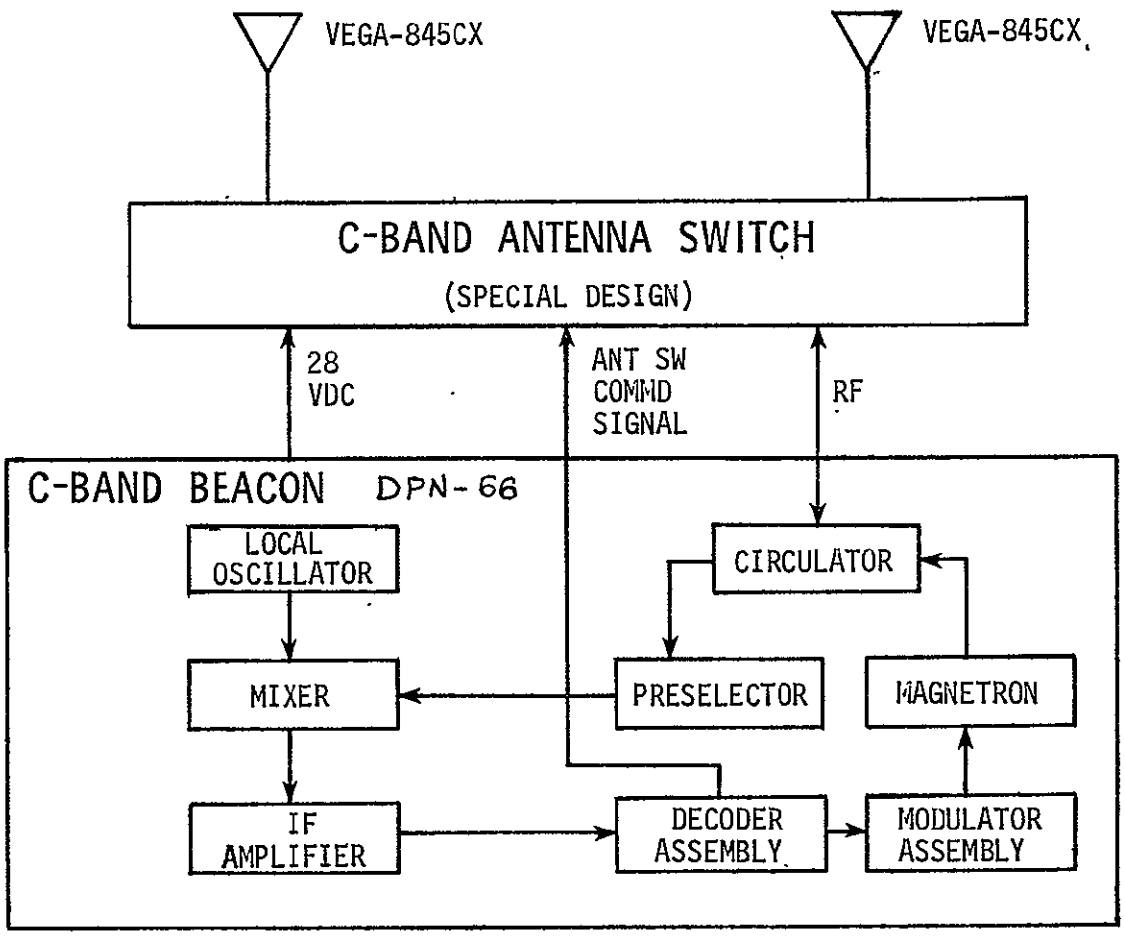


FIGURE 1. C-BAND BEACON SYSTEM

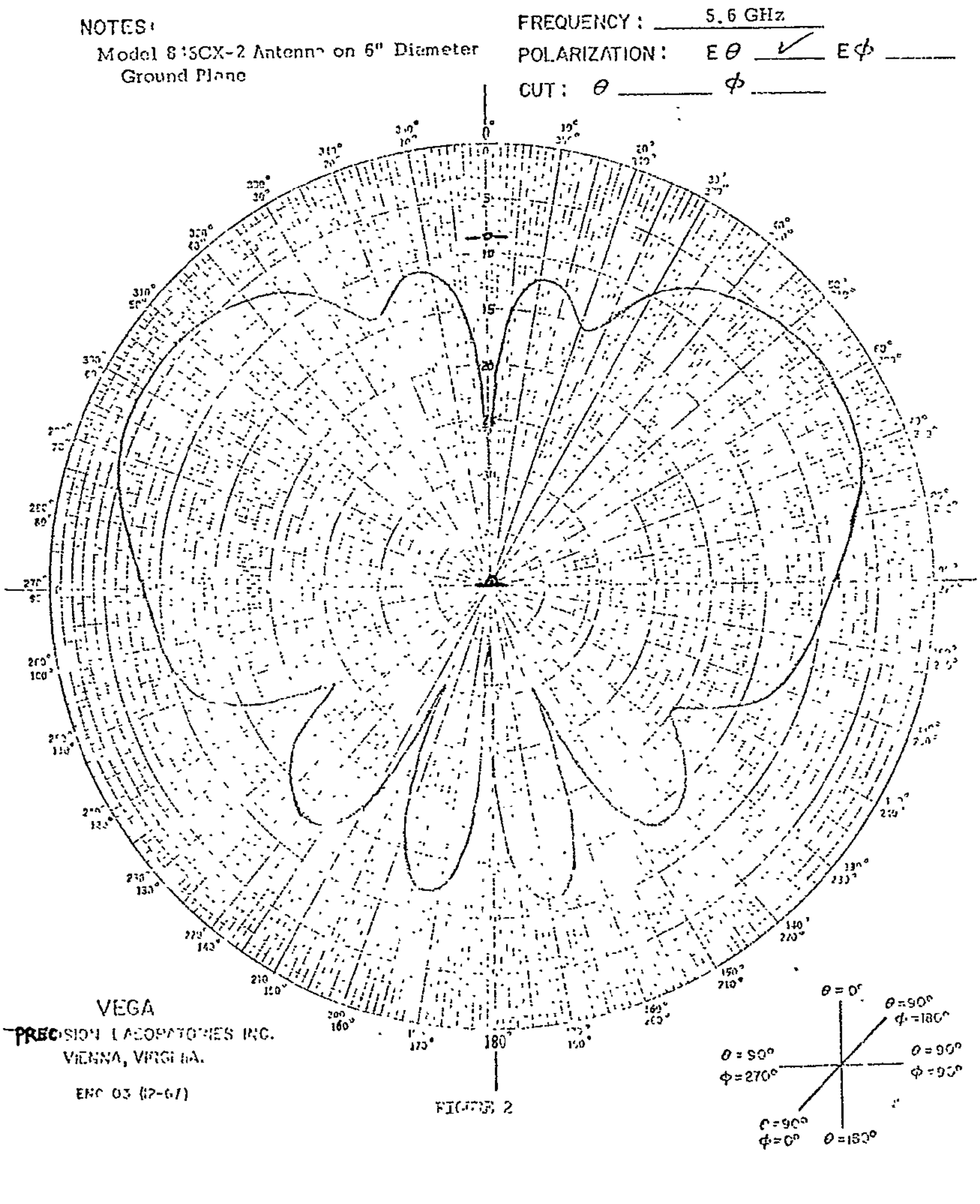
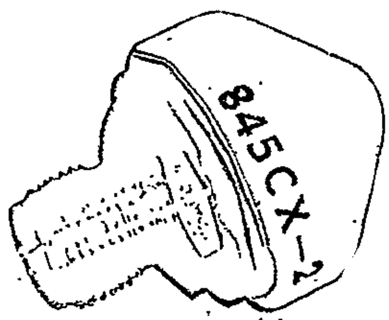


Figure 2. C-Band Beacon Antenna Pattern (Full Scale)

STUB ANTENNA
C AND X-BAND
845CX-2



The Model 845CX-2 Stub Antenna was developed for airborne application in association with either C-Band or X-Band transponders. The antenna is a vertical polarized omnidirectional antenna enclosed within a radome. The antenna is characterized by its compactness and is extremely lightweight while still maintaining the electrical and environmental characteristics required by this type of antenna. The height of the radome is approximately three-quarters of an inch and the diameter of the radome is approximately one inch.

The skin of the vehicle serves as the ground plane for the antenna due to the simplified mounting technique. Mounting of the antenna is accomplished via a "D" hole (.505 diameter x .480 flat) through the vehicle skin. It is then secured to the vehicle with a locking nut.

SPECIFICATIONS

FREQUENCY RANGE	5.4 – 9.6 GHz
VSWR	≤2 0:1
IMPEDANCE	50 ohms
AZIMUTH BEAMWIDTH	Omnidirectional
ELEVATION BEAMWIDTH	That of λ/4 stub
POLARIZATION	Vertical (linear)
POWER	1.5 KW Peak
CONNECTOR	TNC (Female)
WEIGHT	0.5 ounces
SEALING	O-Ring

Figure 3. General C-Band Beacon Antenna Specification

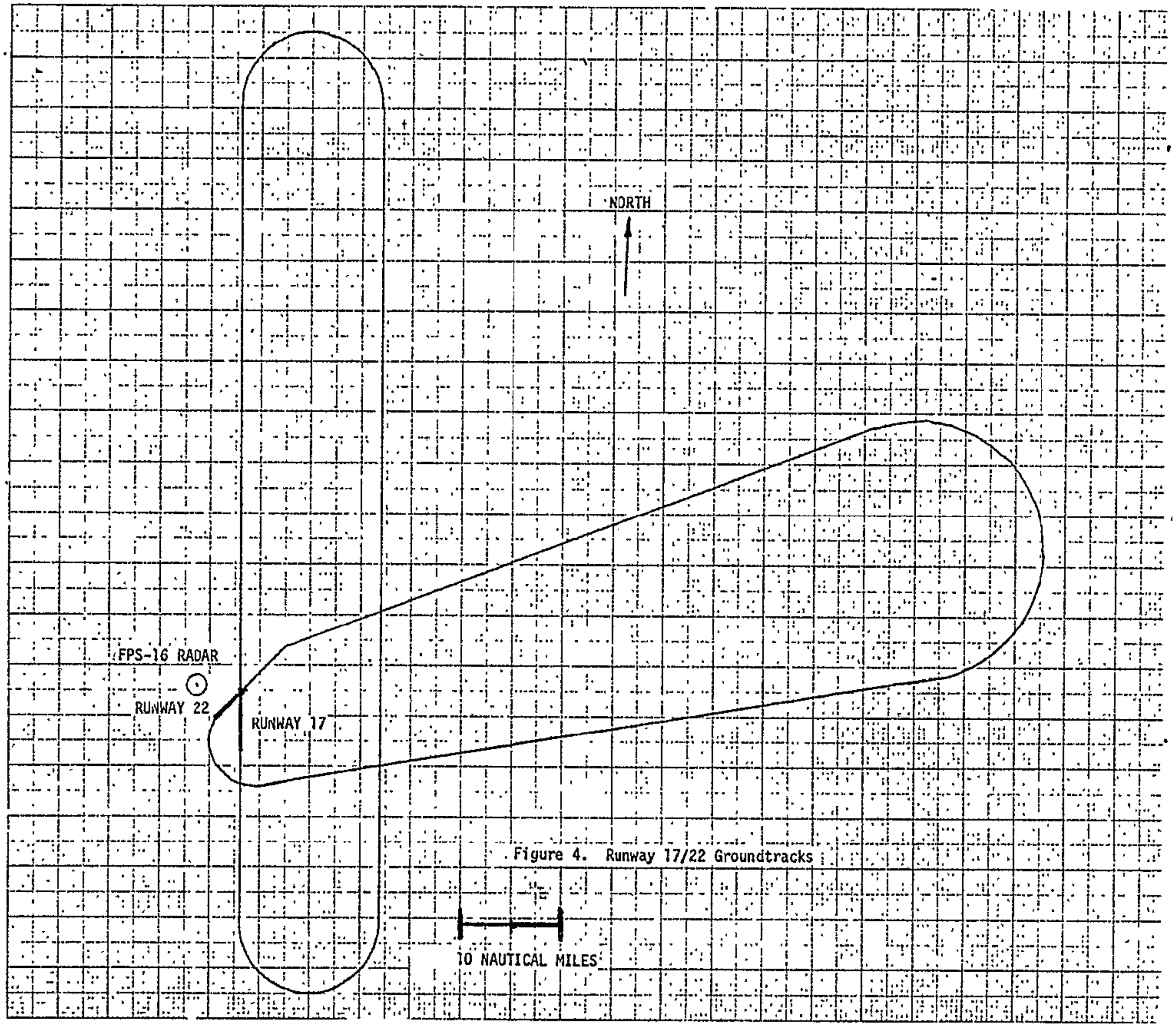


Figure 4. Runway 17/22 Groundtracks

above sea level and the runways are 2275 feet above sea level. This means that the look angles are approximately 1° above the horizontal plane of the Orbiter and/or Boeing 747 while the Orbiter is on the runway. The runways are approximately 4 nautical miles from the radar on hill R-4. The Shuttle Orbiter antenna pattern coordinate system is shown in Figure 5 with the -Z axis (up) corresponding to $\theta = 0°$ and the +Z axis corresponds to $\theta = 180°$. In this system the angle θ is a pitch type angle. The angle Φ is a yaw type angle and is measured from the +X axis such that when $\Phi = 0°$ and $\theta = 90°$ the look angle corresponds to the +X or nose of the Orbiter. Appropriate axes and points are labelled on a standard radiation distribution printout (RDP) form in Figure 6. A plot of the look angles seen by the Orbiter for the racetrack course on runway 17 is shown in Figure 7 and the 25° offset on runway 22 is shown in Figure 8. The Orbiter look angles to the FPS-16 ground radar have been determined from data contained in Reference D. A calculation procedure is given in Figure 9 to demonstrate the look angle calculation method. From Figure 7 and 8 it is apparent that most of the look angles occur in the vicinity of the horizontal plane (X-Y) and that very little coverage is required above the X-Y plane (i.e. $\theta < 90°$). The look angles from immediately before separation to landing are observed to be in vicinity of the nose ($\theta = 90°$, $\Phi = 0°$) and right wing ($\theta = 90°$, $\Phi = 270°$) and close to the horizontal plane ($\theta = 90°$). Immediately after separation changes occur in the Orbiter look angles as much as $\pm$ 17 degrees in θ. The information of this section will be used later for comparison with specific pattern data.

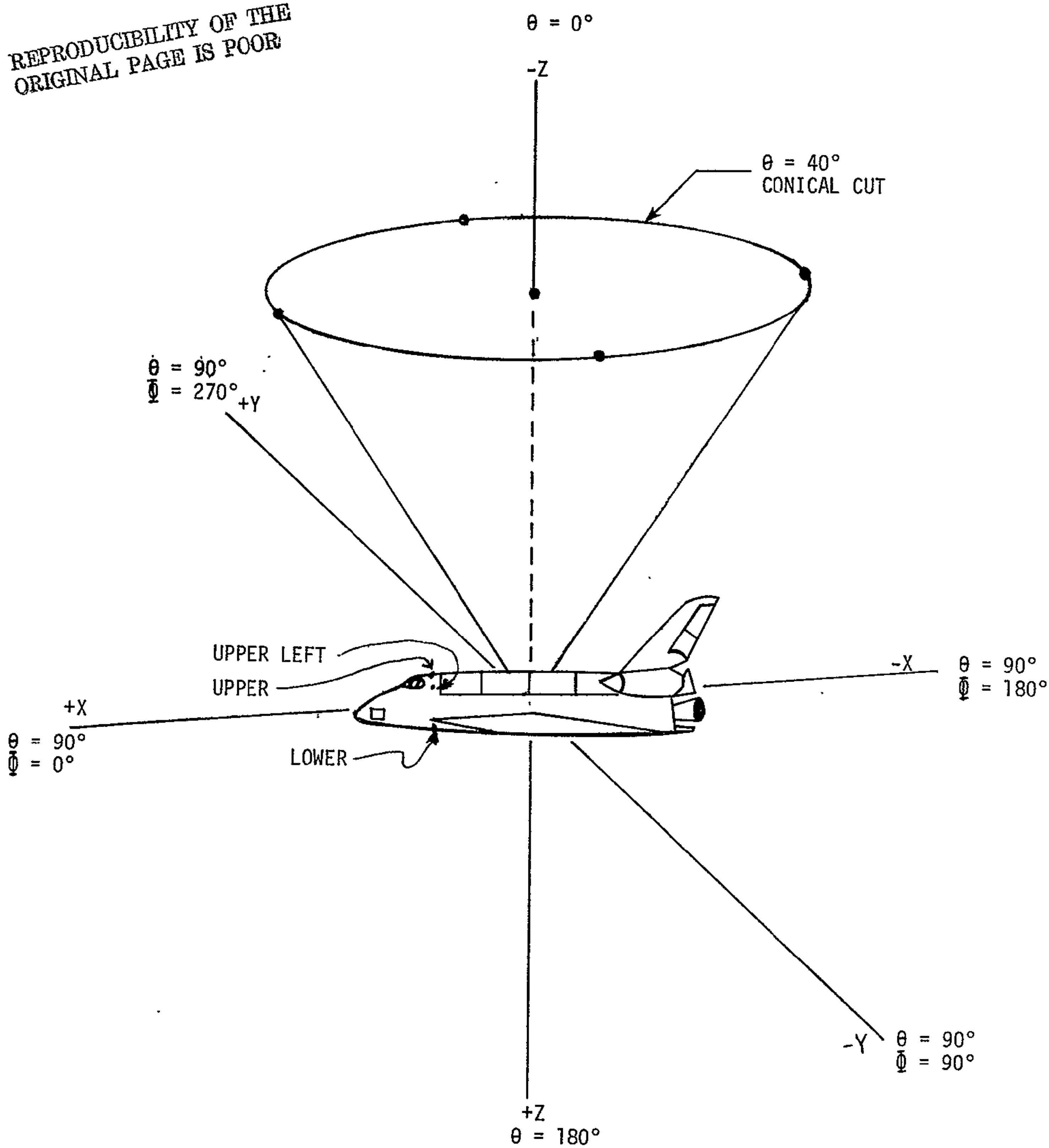


Figure 5. Shuttle Orbiter Antenna Pattern Coordinate System

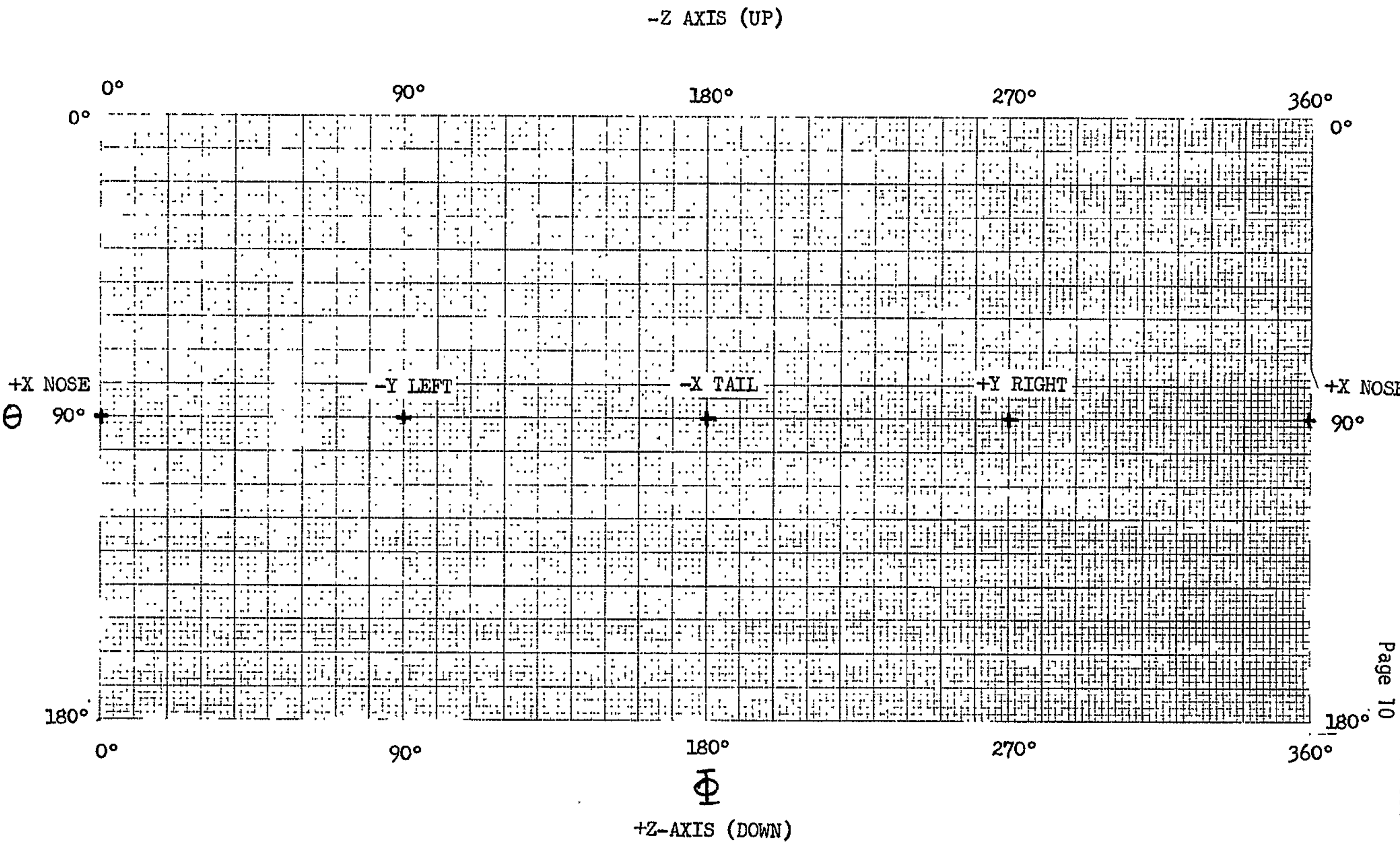


Figure 6. Radiation Distribution Printout Form

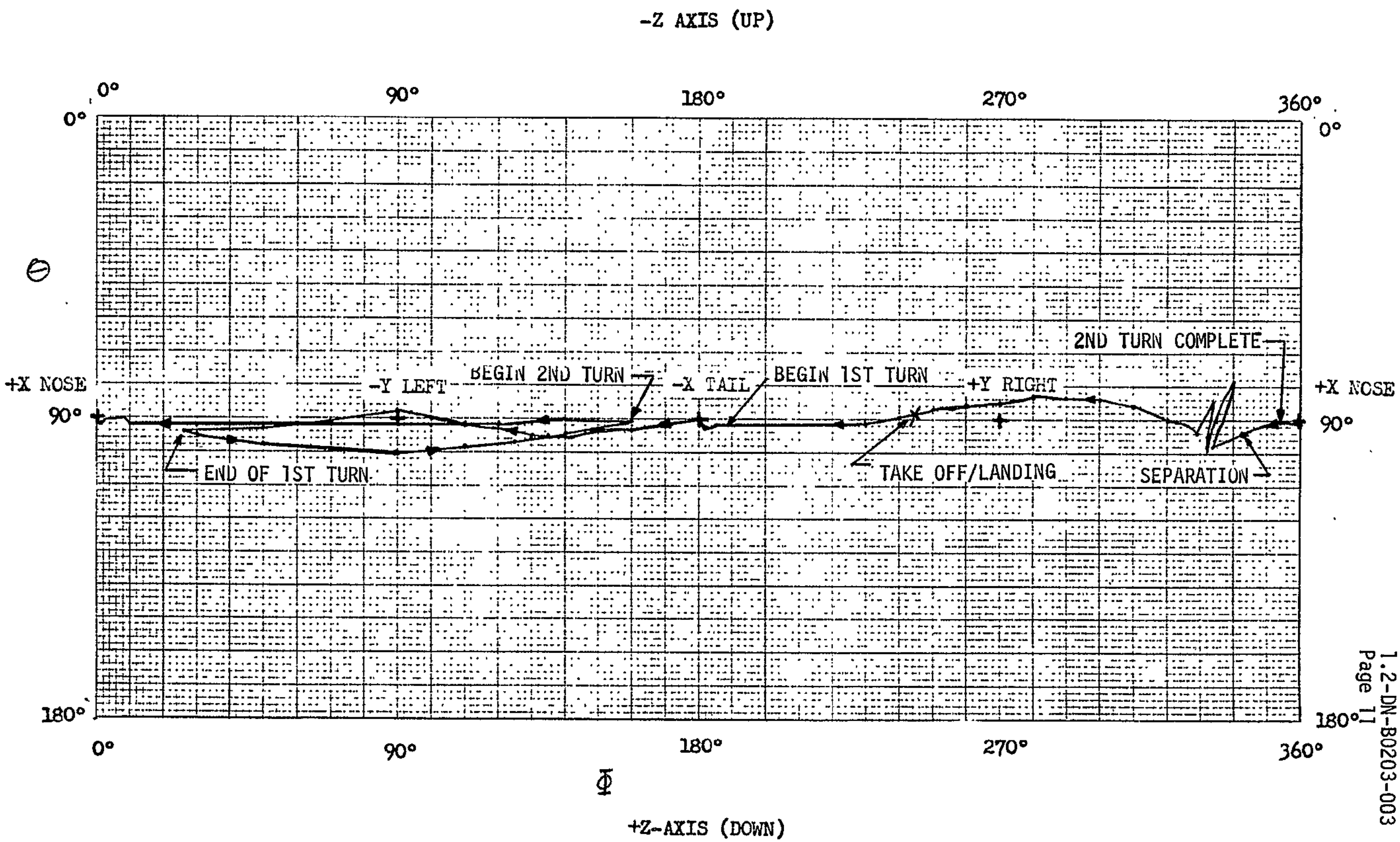


Figure 7. Runway 17 Orbiter-to-Ground Radar Look Angles

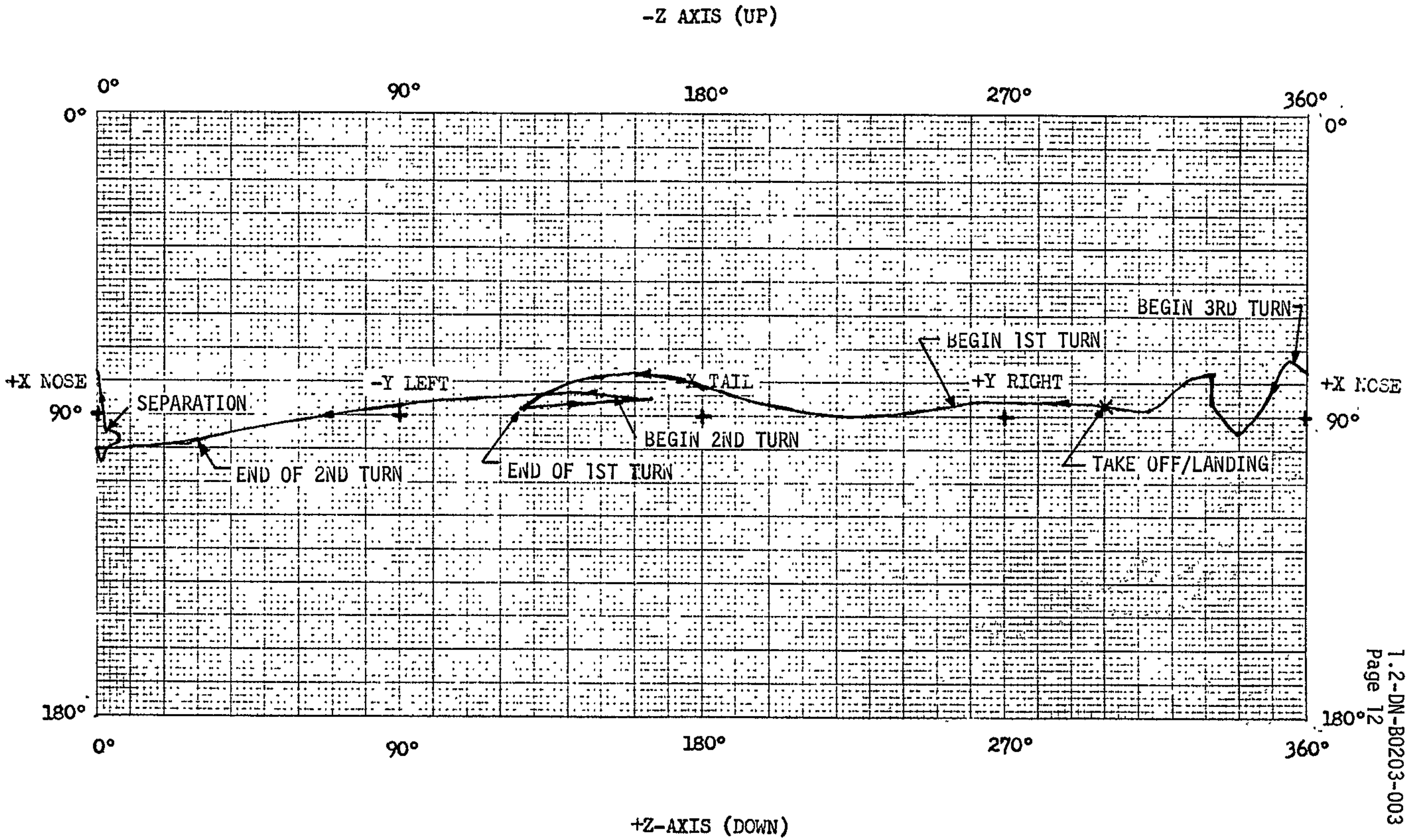
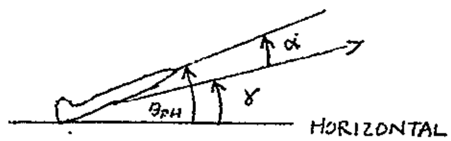


Figure 8. Runway 22 Orbiter-to-Ground Radar Look Angles - 25° Offset

1. Calculate Pitch Angle above Horizontal Plane

$$\theta_{PH} = \alpha + \gamma$$

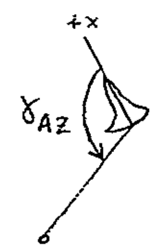
Where α = angle of attack (from graph Ref. G)
γ = flight path angle (from graph Ref. G)



2. Measure angle between vertical plane containing Orbiter X-axis and plane containing the ground radar and Orbiter.

γ_{AZ} (from groundtrack graph)

3. Calculate antenna pattern pitch and yaw type angles such that



$$\theta_o = 90° + \theta_{ele} \cos \theta_{PH} + \theta_{PH} \cos \gamma_{AZ}$$

$$\Phi_o = \gamma_{AZ}$$

where θ_{ele} = ground radar elevation angle

4. To account for the effect of Orbiter roll convert θ & Φ angles from the pitch-yaw system to a pitch-roll system and add Orbiter roll to roll angle in the pitch-roll system. Then convert angles back to the pitch-yaw system. (Step 4 is not necessary if the roll angle is zero.)

$$\begin{bmatrix} \theta_o & \text{pitch} \\ \Phi_o & \text{YAW} \end{bmatrix} \rightarrow \begin{bmatrix} \theta' & \text{pitch} \\ \Phi' & \text{roll} \end{bmatrix} + \begin{bmatrix} \text{roll} \end{bmatrix} \rightarrow \begin{bmatrix} \theta_o' & \text{pitch} \\ \Phi_o' & \text{YAW} \end{bmatrix}$$

UNIT VECTORS:

PITCH-YAW $\vec{V} = \sin\theta\cos\Phi\,\hat{x} - \sin\theta\sin\Phi\,\hat{y} - \cos\theta\,\hat{z}$

PITCH-ROLL $\vec{V} = \cos\theta'\,\hat{x} + \sin\theta'\sin\Phi'\,\hat{y} - \sin\theta'\cos\Phi\,\hat{z}$

Figure 9. Look Angle Calcualtion Procedure

3.3 Vehicle Shadowing Effects

This section shows vehicle blockage effects based on the ray optics techniques utilizing drawings in Reference F. Specific antenna locations for this blockage evaluation are given in Figure 10.

The pattern coordinate system used is shown in Figures 5 and 6. The free flight and 747 geometrical optics blockages are shown in Figures 11-21. The hemispherical blockage interface for the Quad locations appears to approximate a sine wave type variation. It should be noted that some pattern coverage will occur in the shadowed (crosshatched) regions of the patterns; thus, this region should be viewed only as a boundary beyond which normal pattern coverage will be degraded.

Figures 22-24 show blockage effects of the external tank. This is included because the 1/10-scale antenna patterns to simulate the 747 were taken with the external tank. The external tank actually imposes somewhat more severe blockage than the 747 with the exception of the wings as may be observed by comparing Figure 22-24 with Figure 20, 12 and 16 respectively.

3.4 Antenna Pattern Data

Extensive antenna pattern data was taken on a 1/10-scale model of the Orbiter using a scaled C-Band Beacon antenna model developed by McDonnell Aircraft Company personnel (H. T. Smith, R. M. Ousley, D. Russell and J. Kopp). Polar antenna patterns showing the linear and circular response are given in Figures 25 and 26 respectively. The pattern of Figure 25 compares quite favorably with the full scale pattern of Figure 2. The scaled antennas consisted of quarter wave monopoles which were fed directly with 51.6 GHz

ANTENNA	SPACECRAFT COORDINATES		
	X_o	Y_o	Z_o
Lower Right Quad	556"	95.62"	294.65"
Lower Left Quad	556"	-95.62"	294.65"
Upper Left Quad	551.15"	-70.70"	472.5"
Upper Right Quad	551.15"	70.70"	472.5"
Lower Hemi	496.13"	0"	278"
Upper Hemi	510"	0"	498.5"

Figure 10. Candidate Antenna Locations

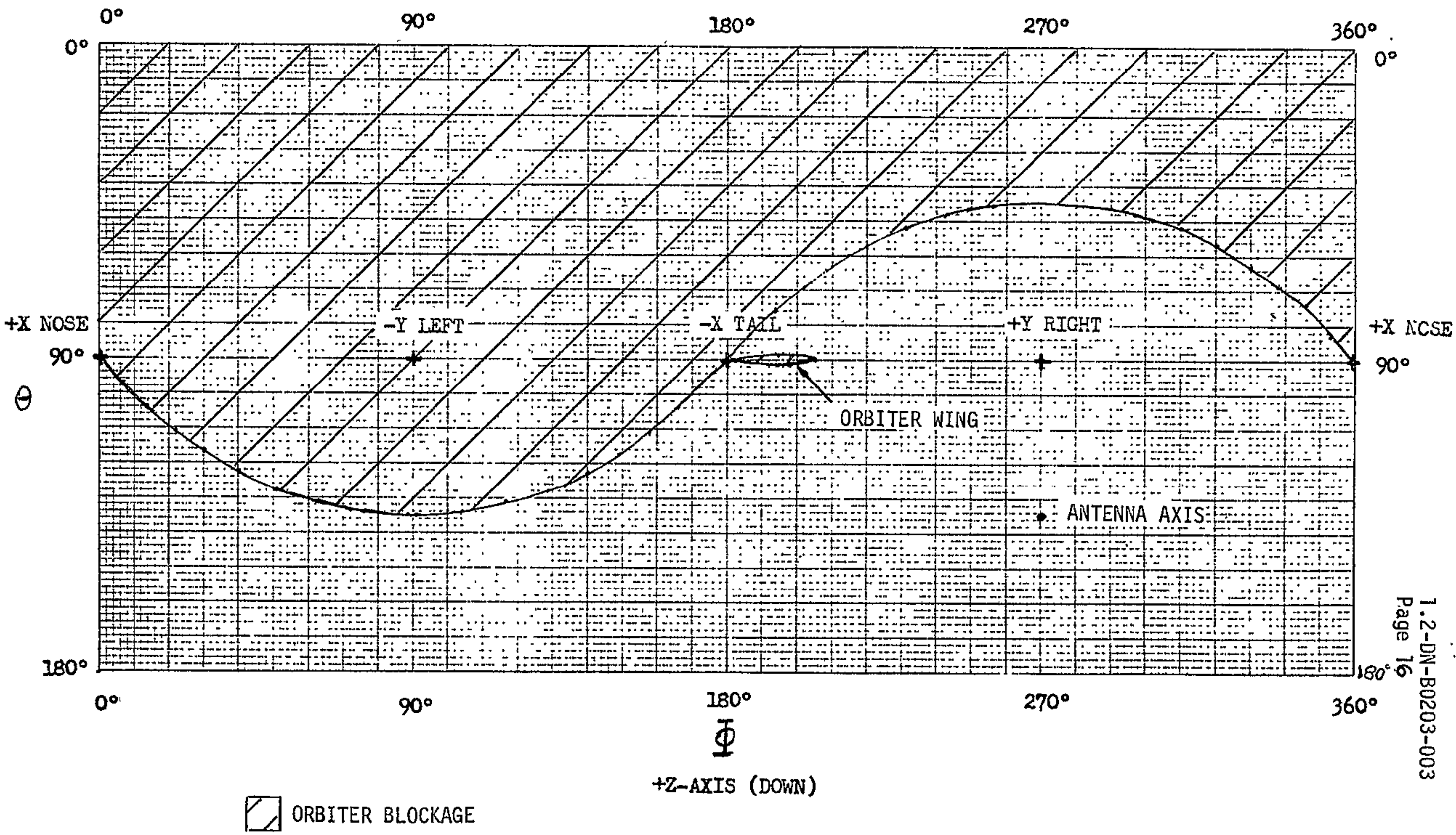


Figure 11. Lower Right-Free Flight Blockage

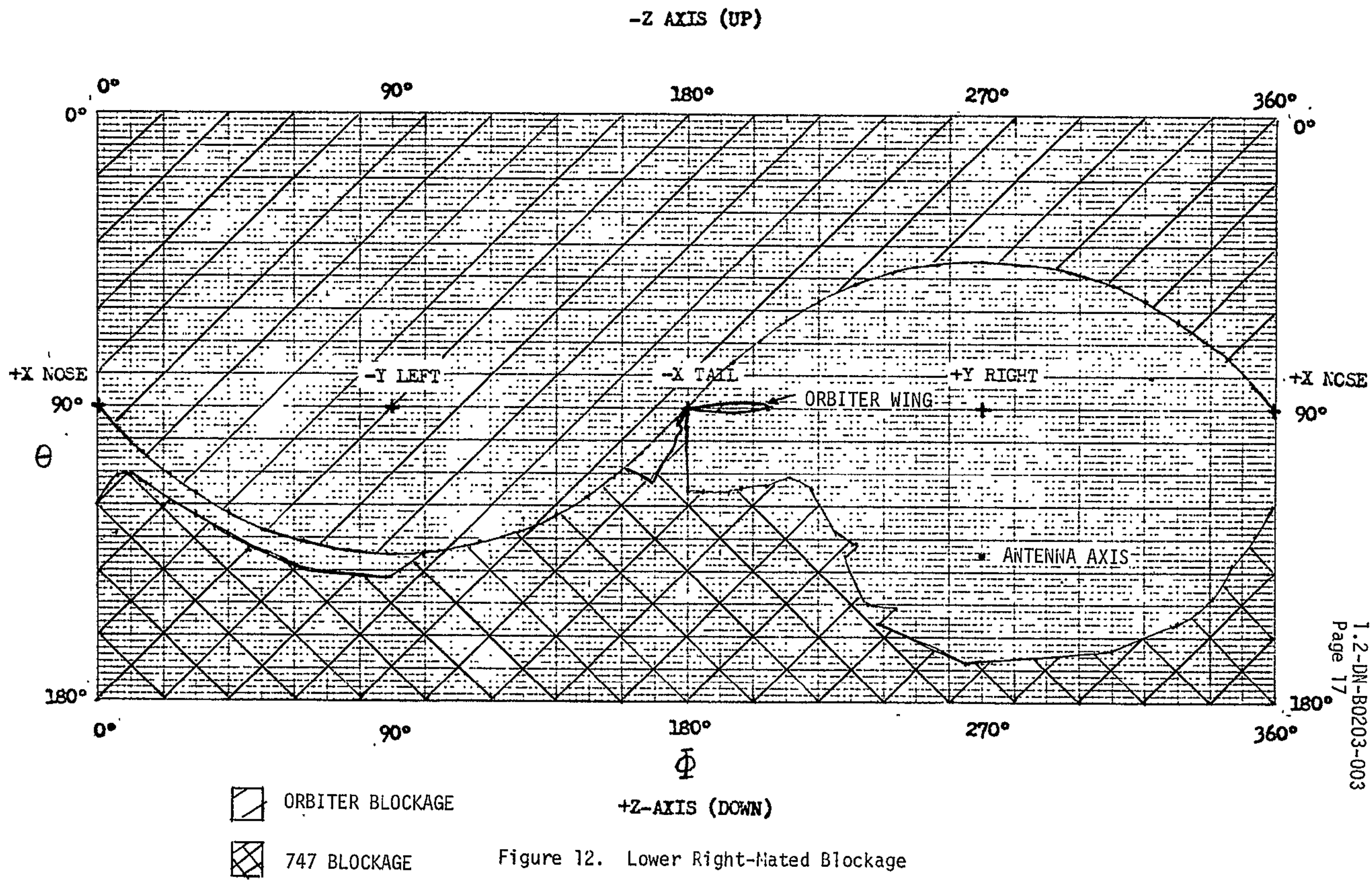


Figure 12. Lower Right-Mated Blockage

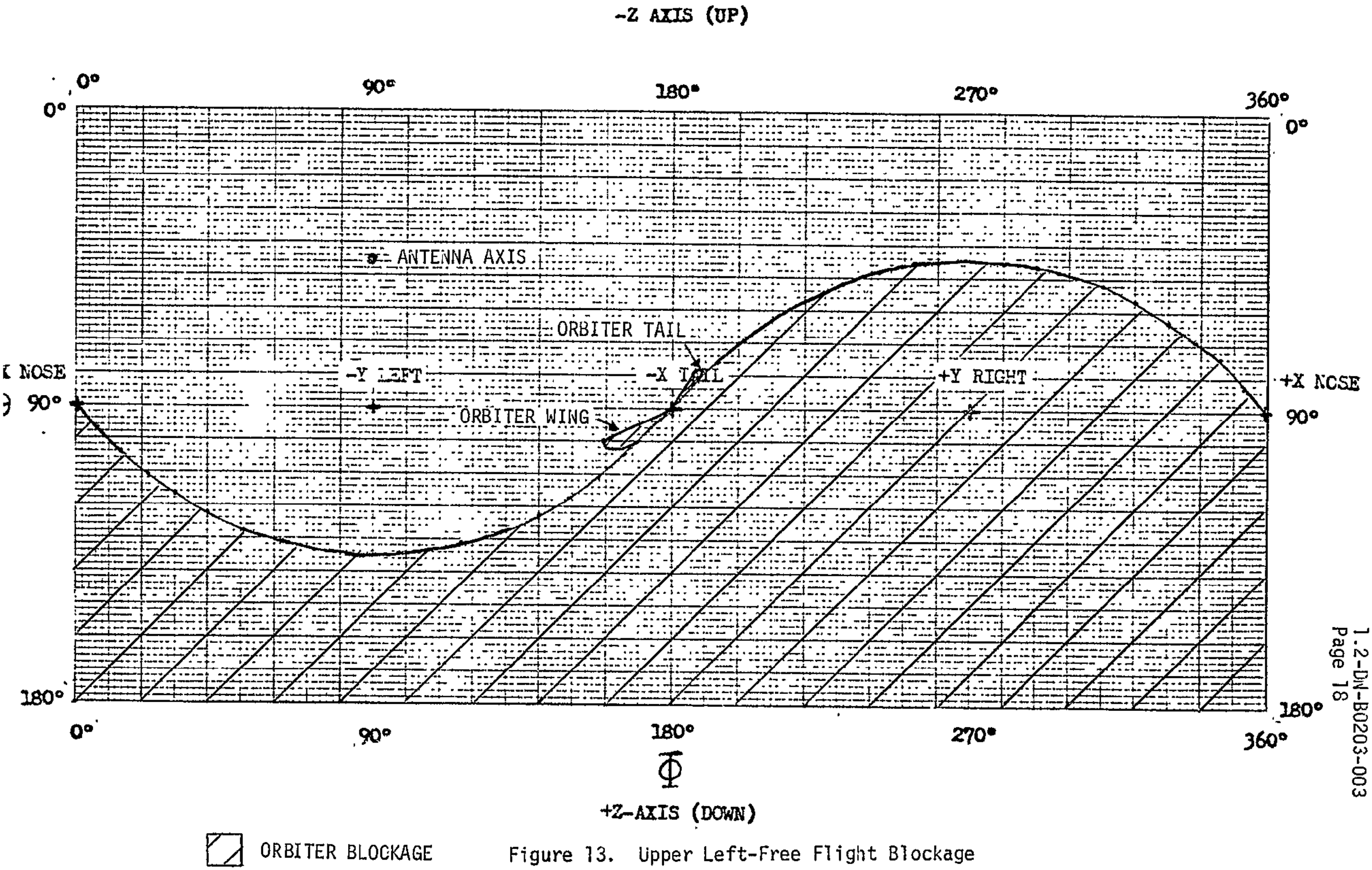


Figure 13. Upper Left-Free Flight Blockage

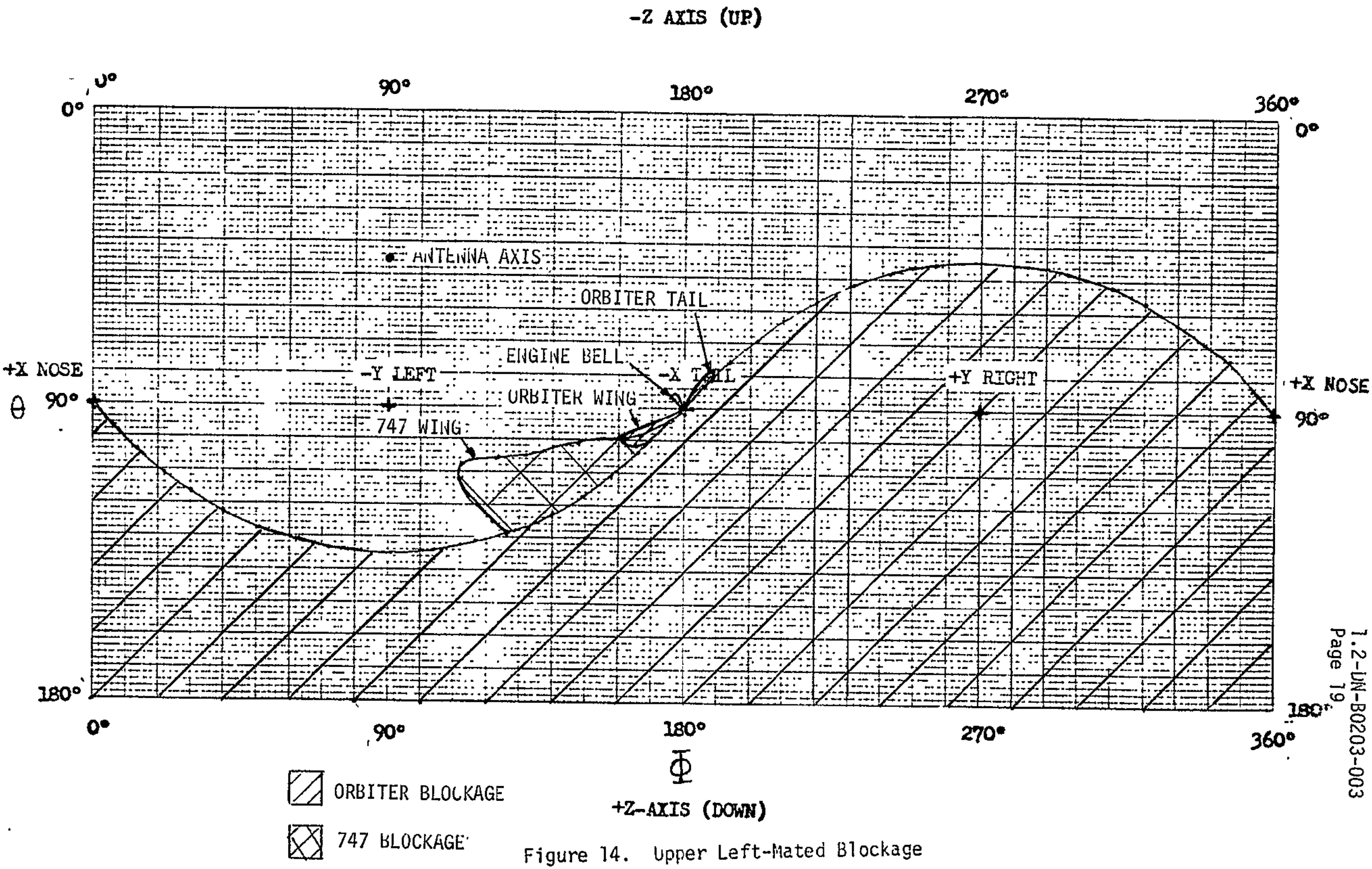
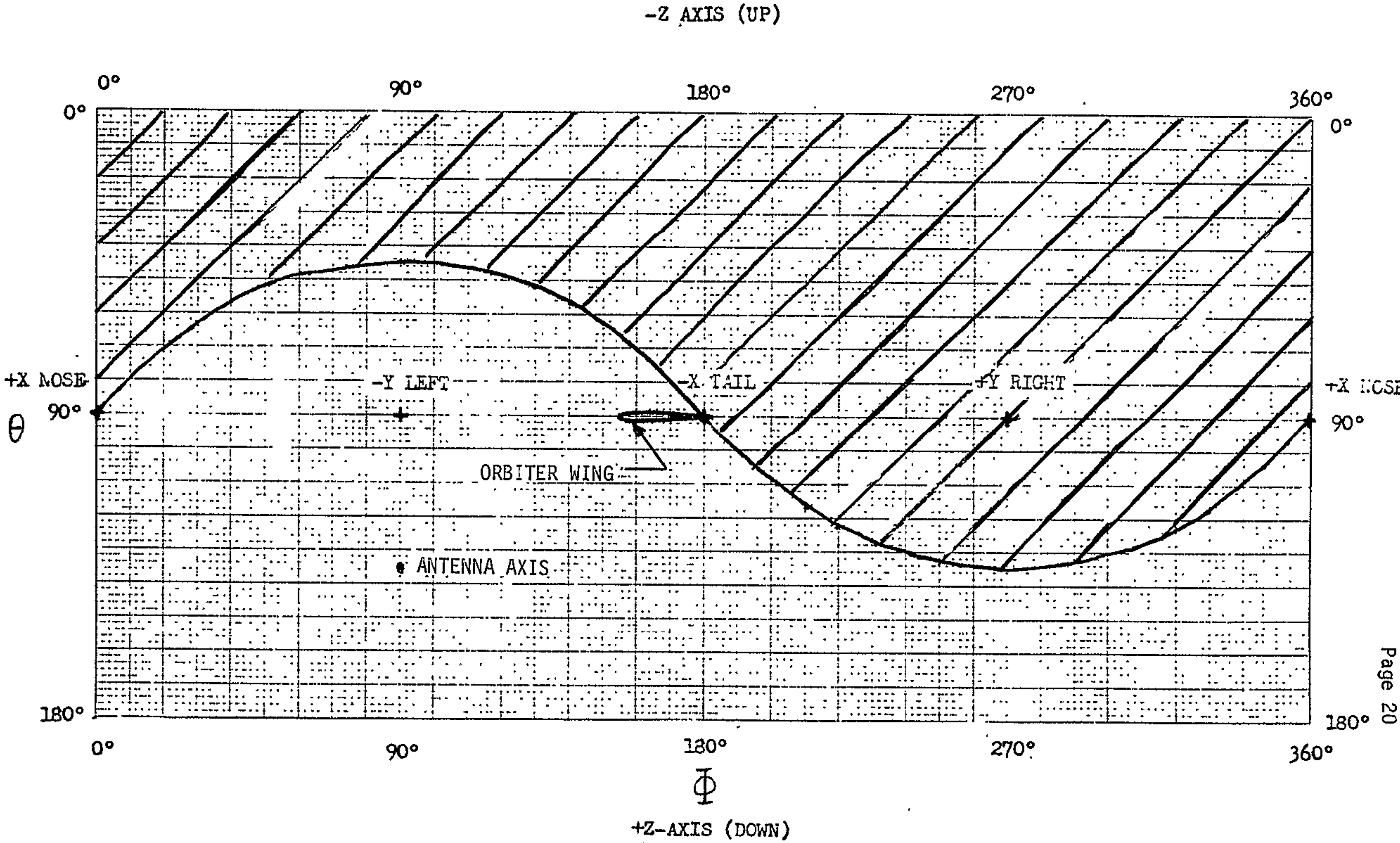


Figure 14. Upper Left-Mated Blockage



ORBITER BLOCKAGE Figure 15. Lower Left - Free Flight Blockage

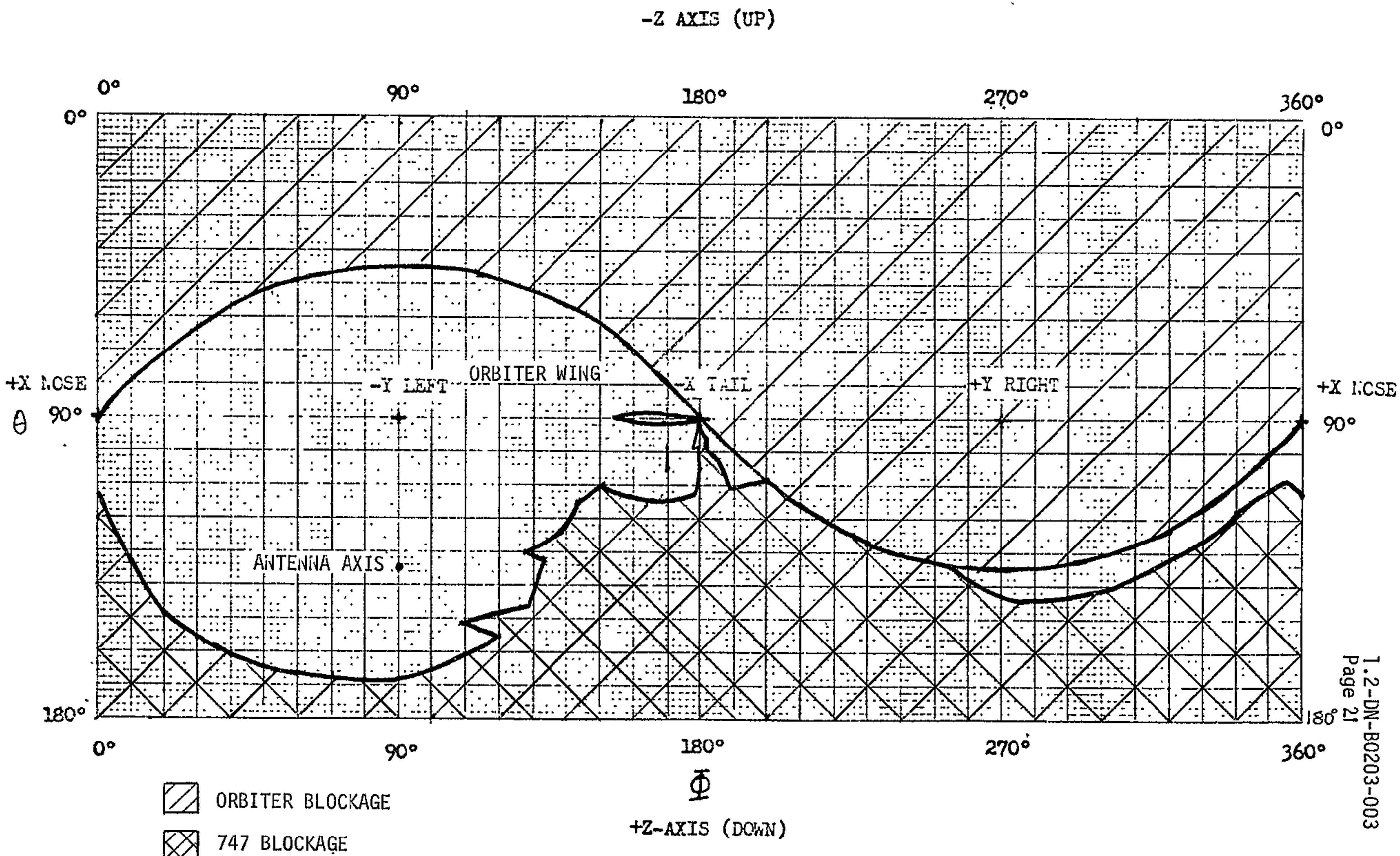
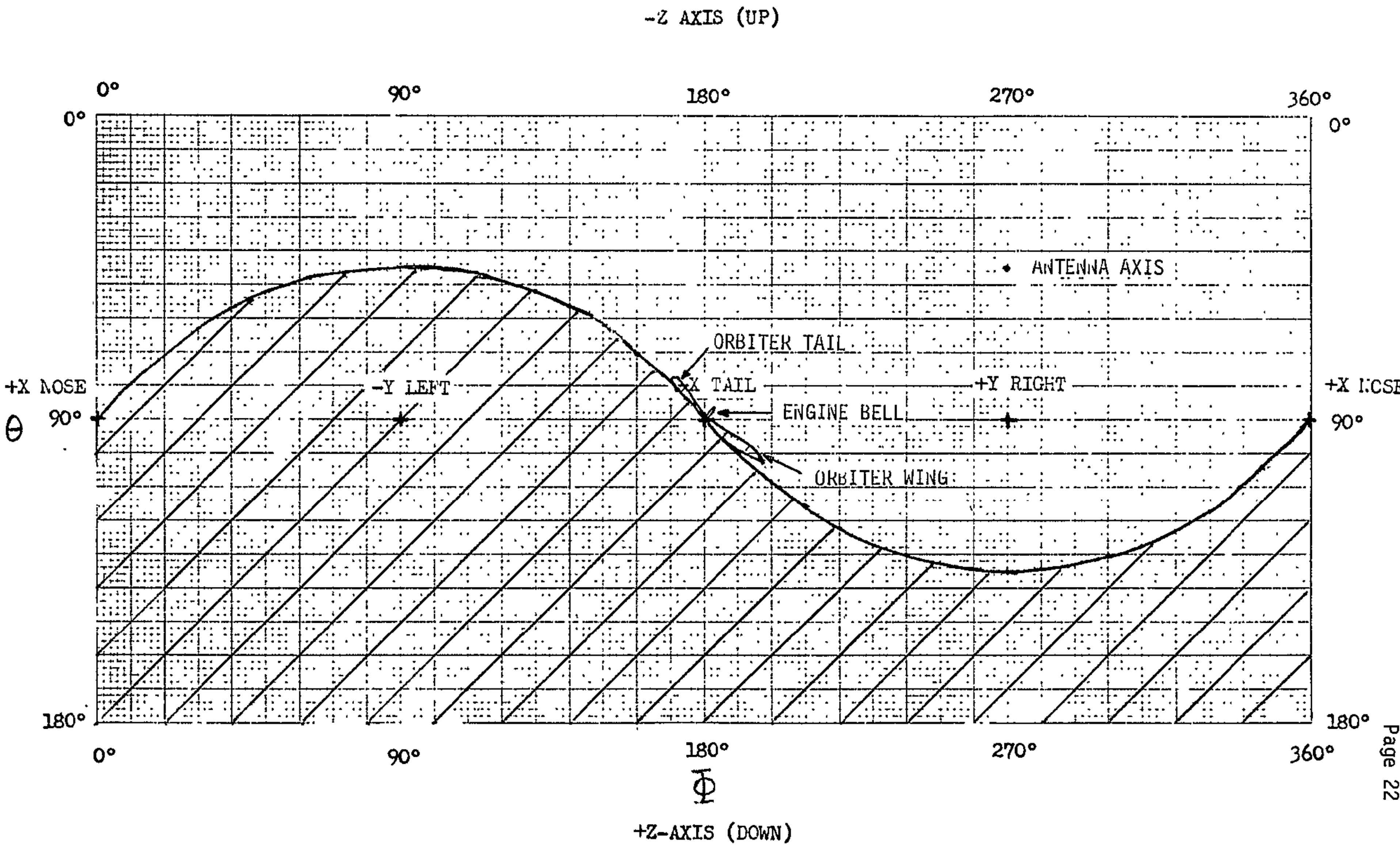


Figure 16. Lower Left-Mated Blockage



ORBITER BLOCKAGE

Figure 17. Upper Right-Free Flight

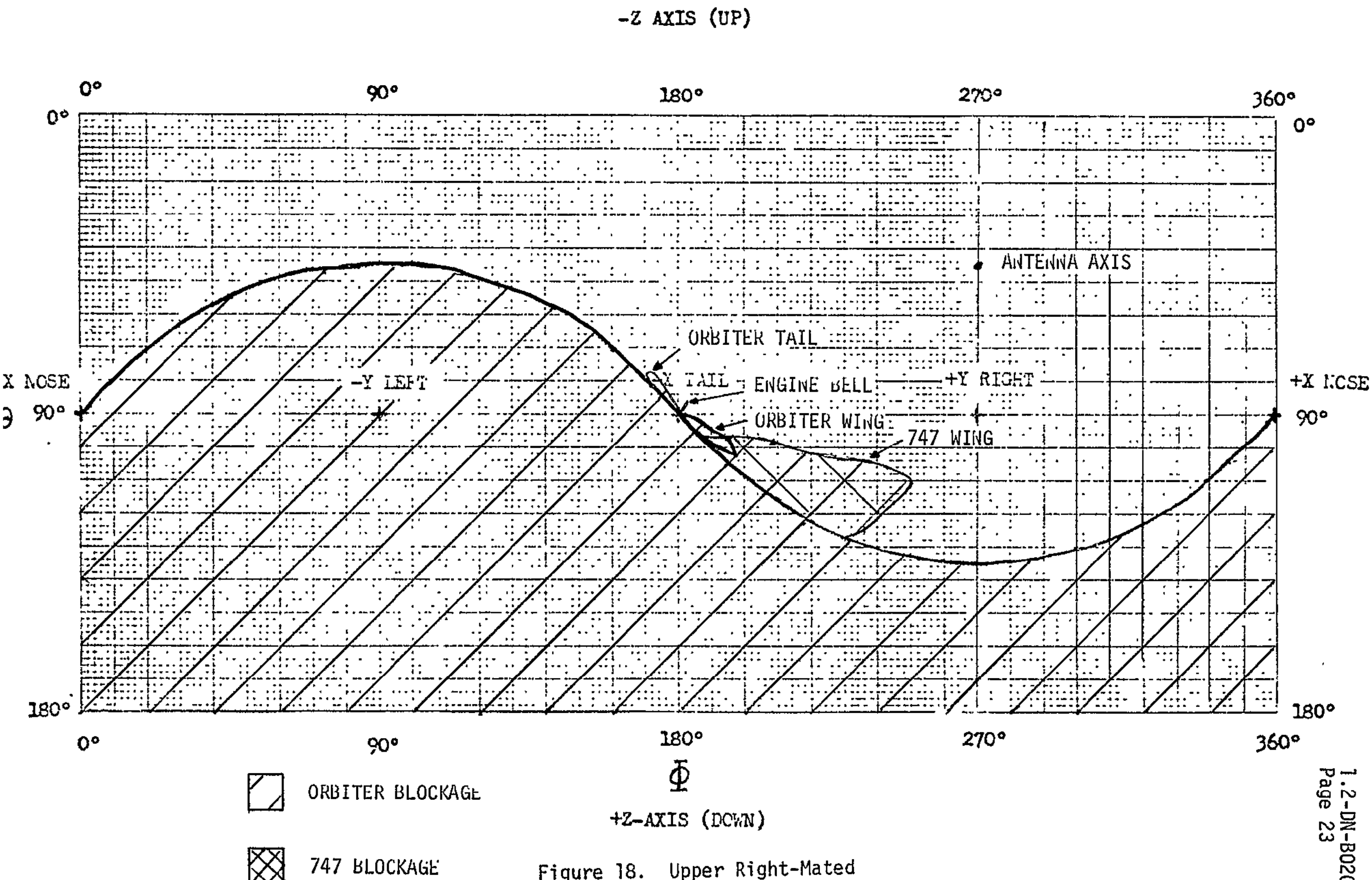
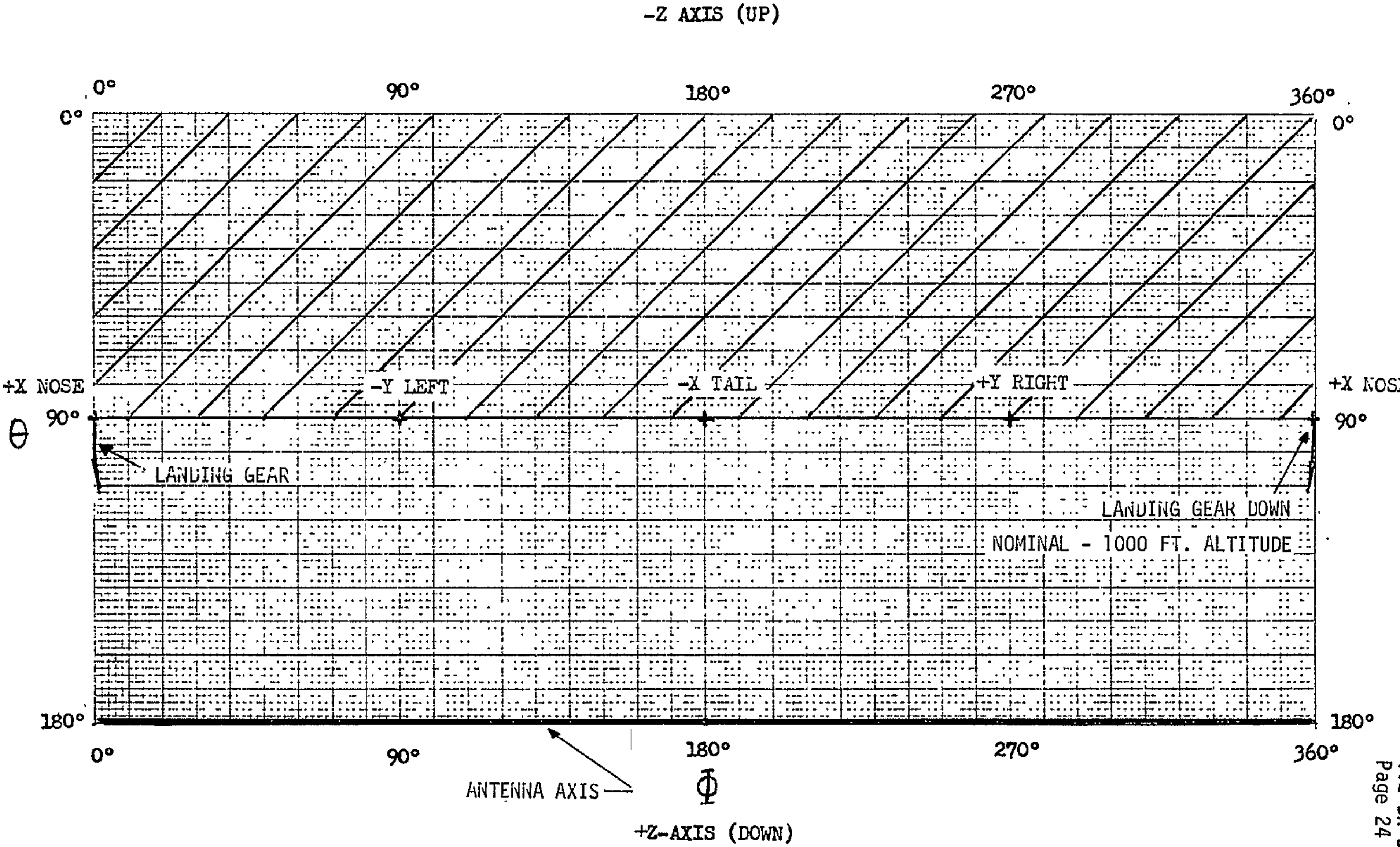
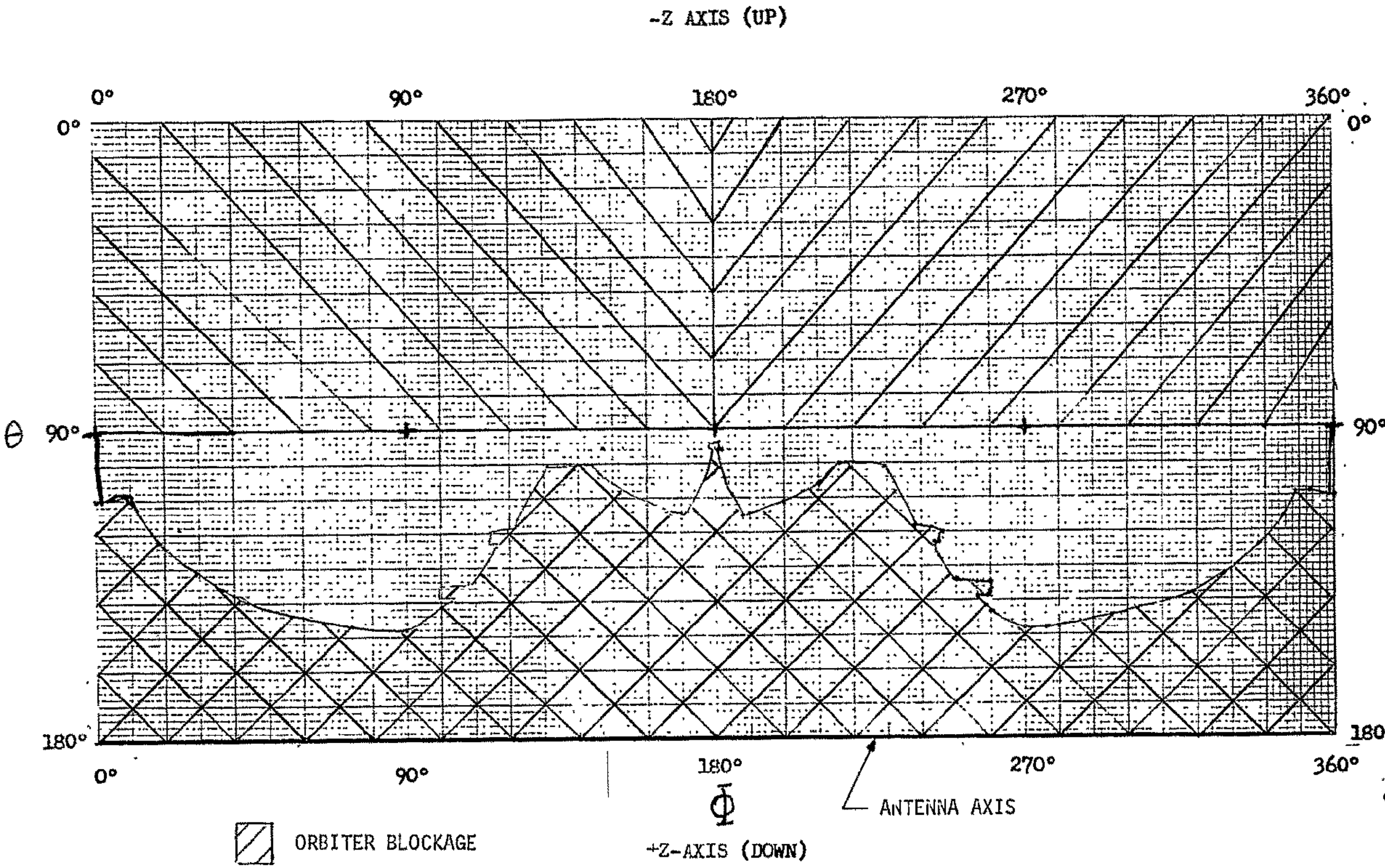


Figure 18. Upper Right-Mated



ORBITER BLOCKAGE

Figure 19. Lower-Free Flight Blockage



ORBITER BLOCKAGE

747 BLOCKAGE

Figure 20. Lower-Mated Blockage

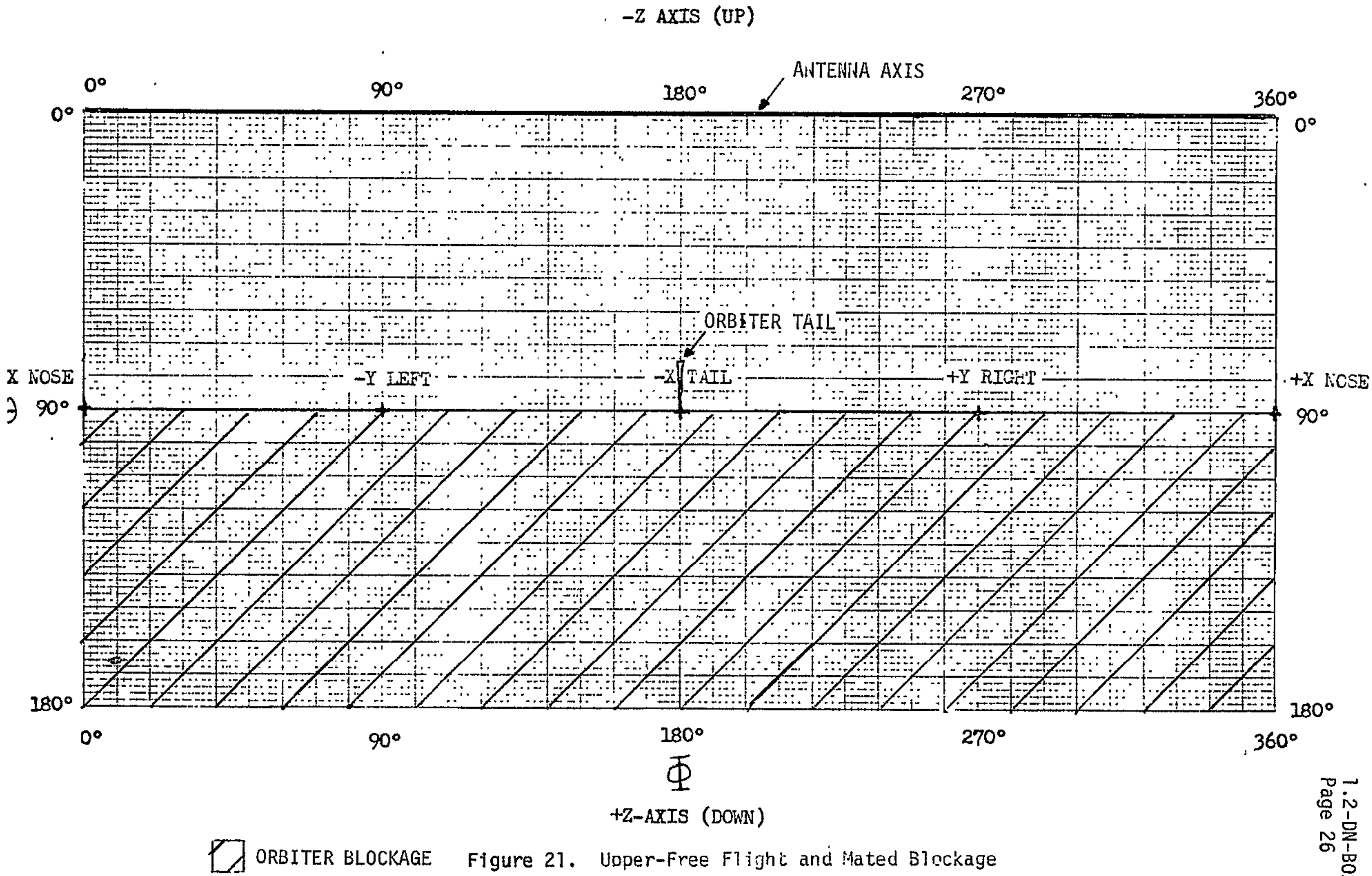


Figure 21. Upper-Free Flight and Mated Blockage

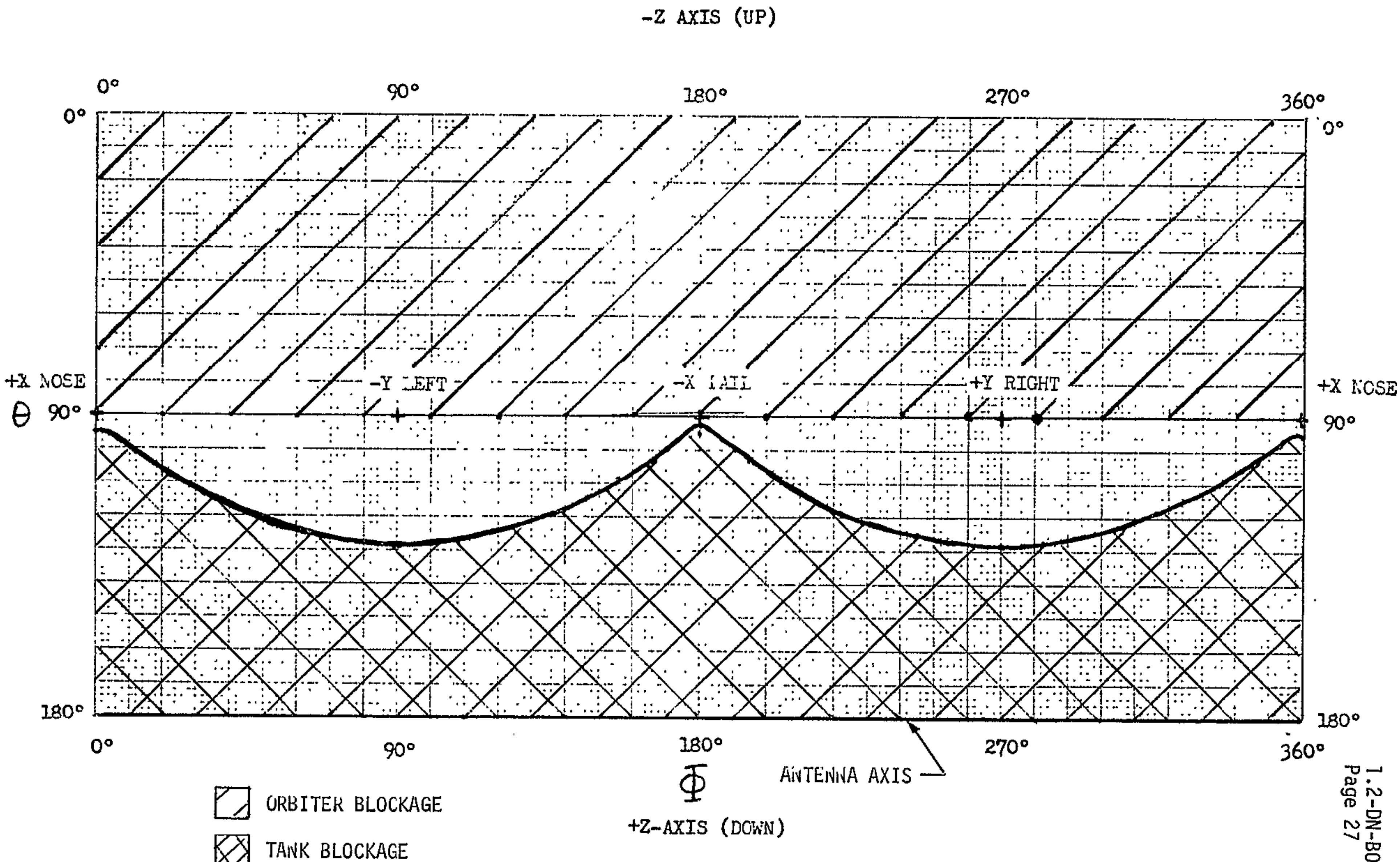


Figure 22. Lower-External Tank Blockage

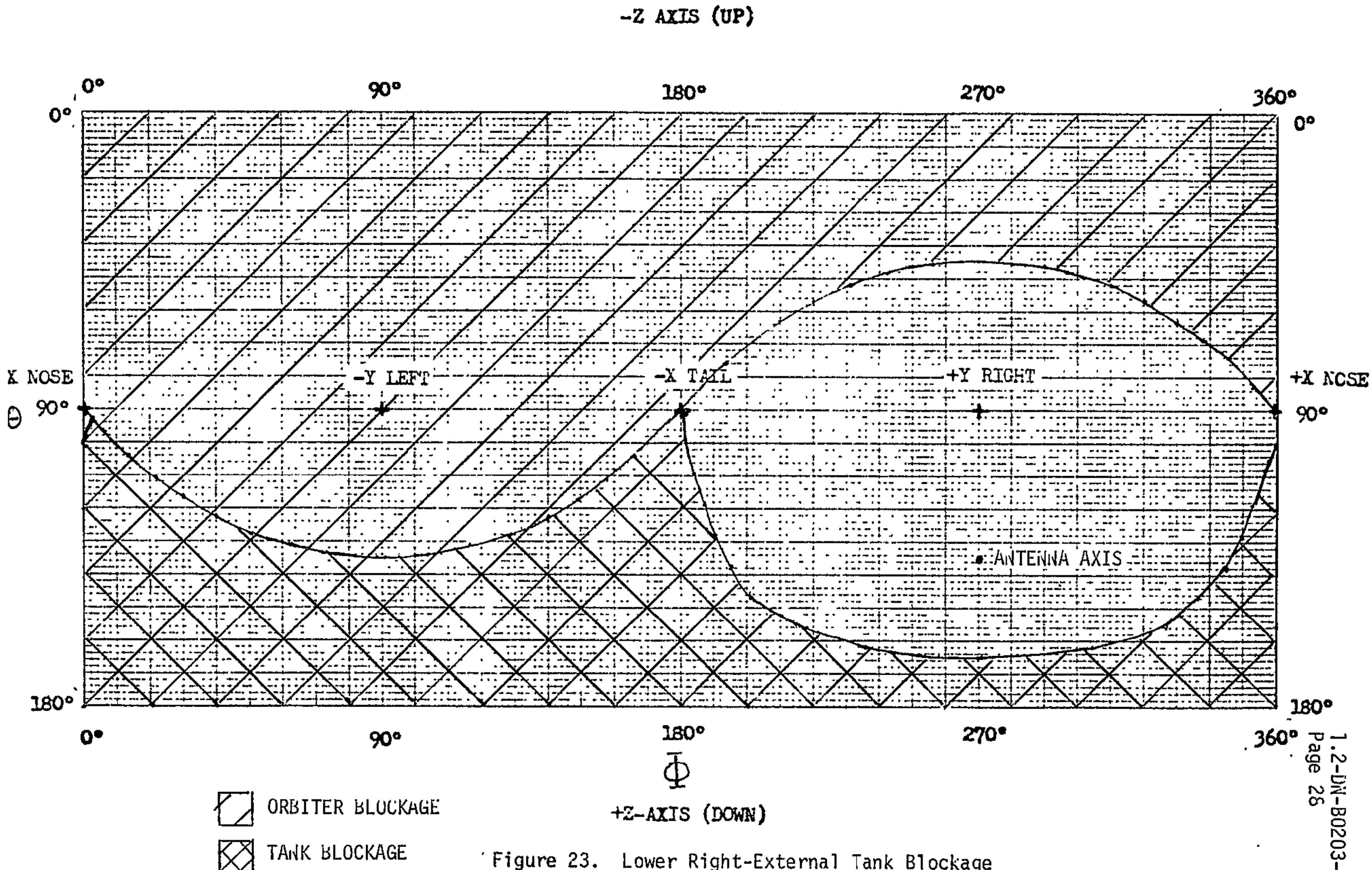


Figure 23. Lower Right-External Tank Blockage

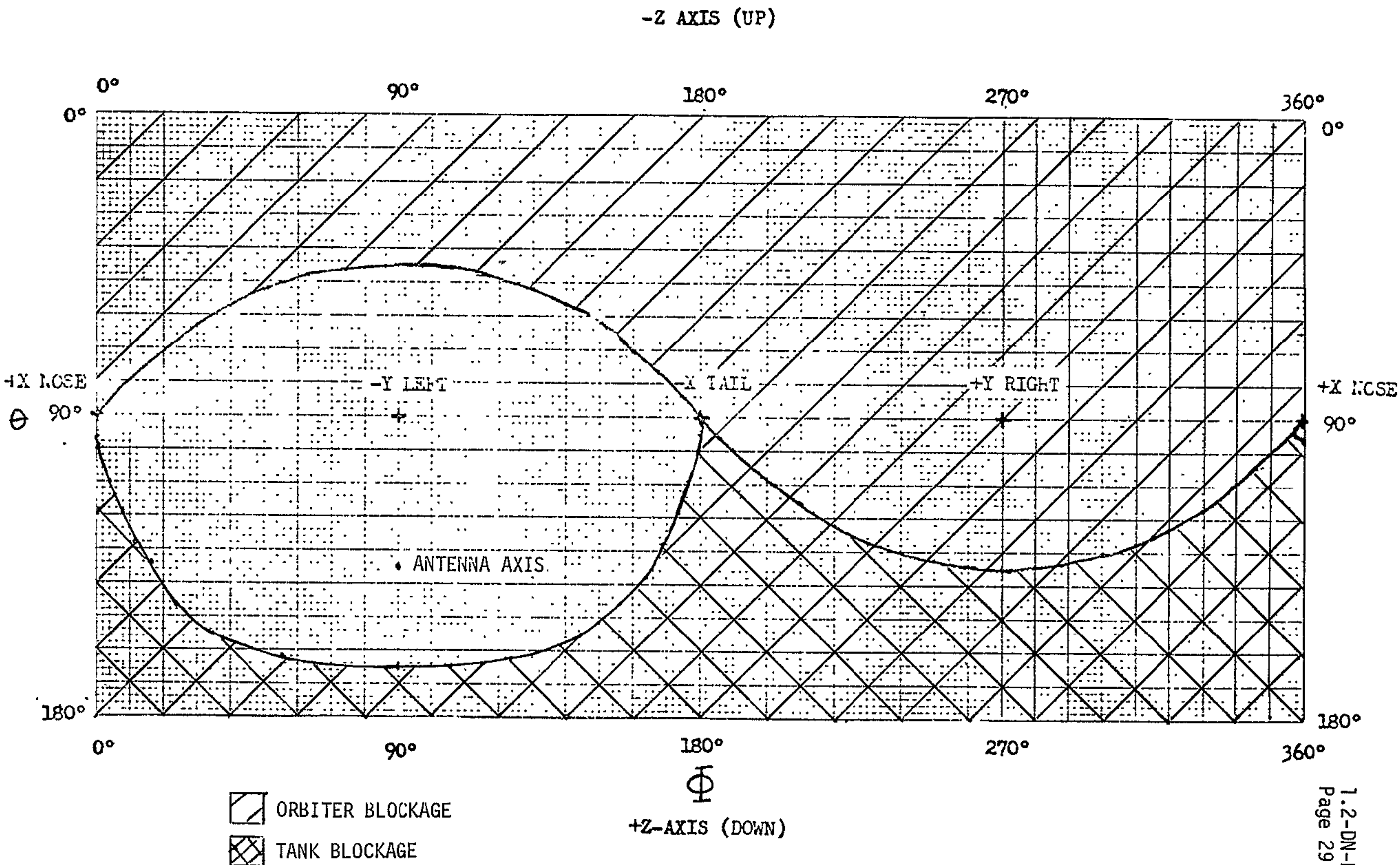


Figure 24. Lower Left-External Tank Blockage

C-Band Beacon Antenna Ground Plane Diameter-0.6 inch

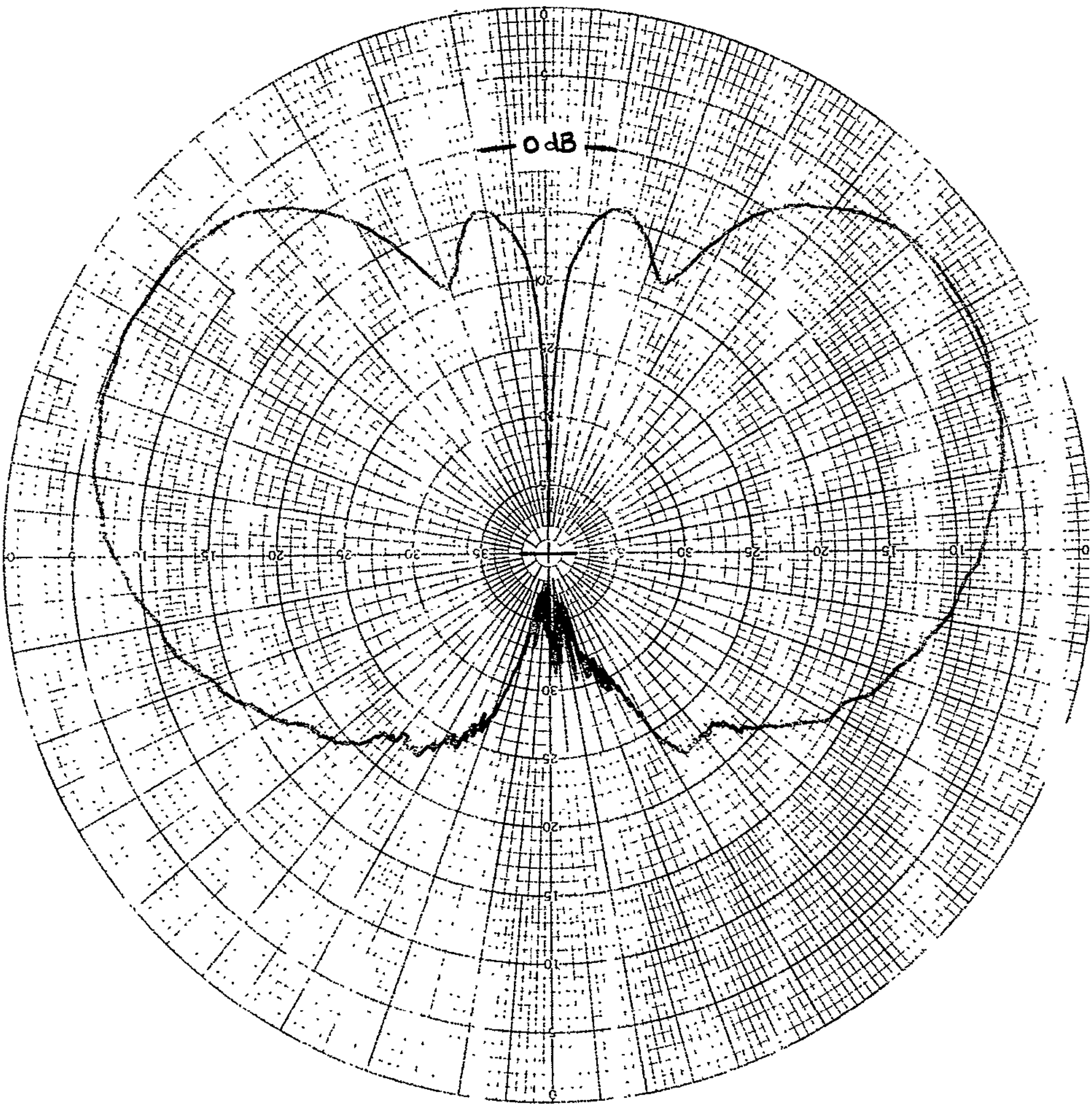


Figure 25. Linear Response-Scaled Model

C-Band Beacon Antenna Ground Plane Diameter-.6 inch

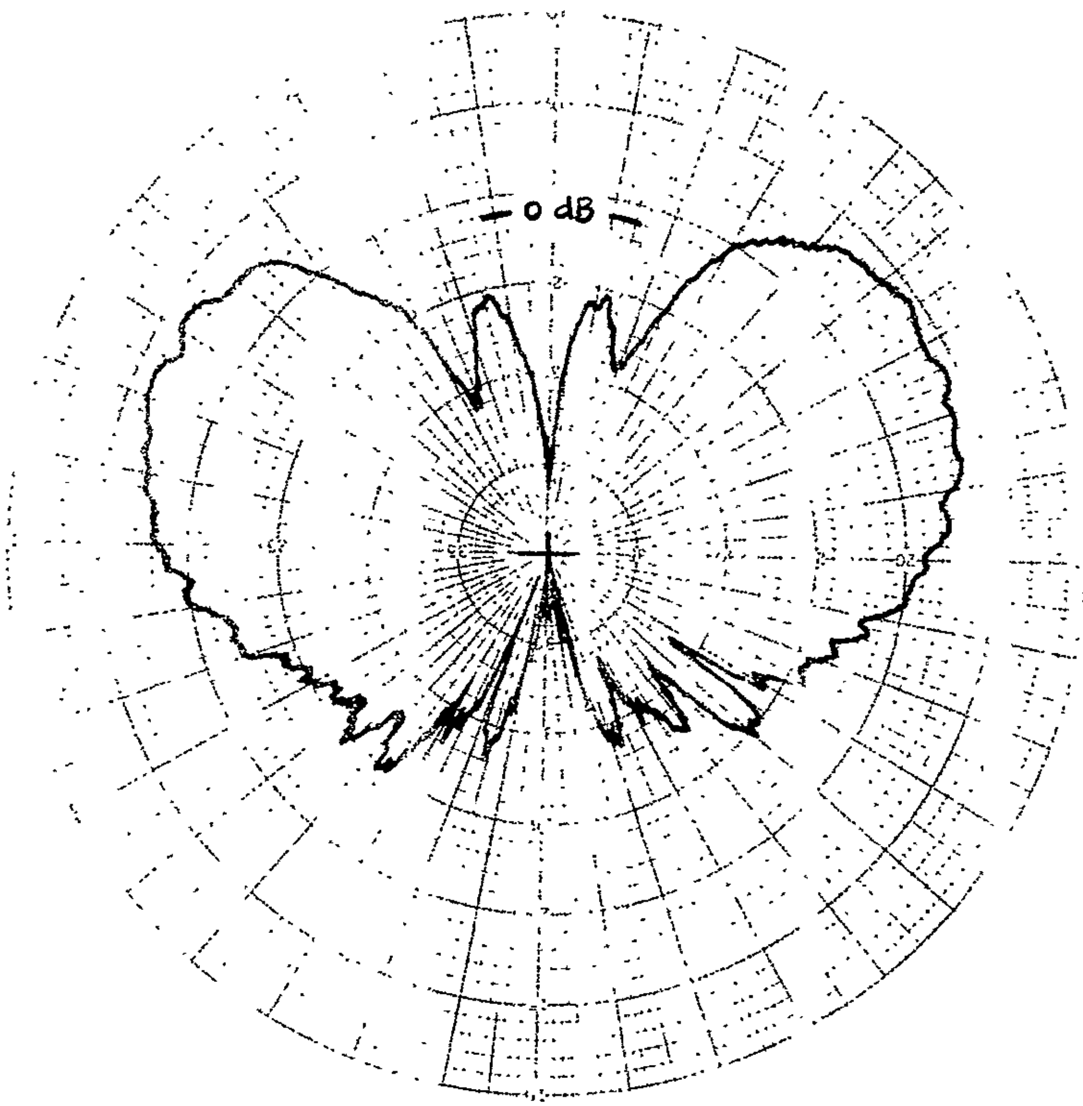


Figure 26. Circular Response-Scaled Model

waveguide. The end of the waveguide was covered by a ground plane with a small hole in the center. An insulated wire was connected to the longer waveguide wall a distance of 1/4-wavelength from the ground plane intersurface and then bent and passed through the center hole of the ground plane. A sketch of the model is shown in Figure 27.

A frequency of 51.6 GHz for antenna patterns was used because of the availability of a power source at this frequency. The amount of error due to the use of a 51.6 GHz source instead of a 56 GHz source is quite small due to the fact that the Orbiter dimensions represent hundreds of wavelengths. The principal errors in the antenna measurements are attributed to reflections within the anechoic chamber which include the model support tower. The pattern coordinate system is given in Figure 5 and a sketch of the antenna pattern setup is shown in Figure 28. Conical patterns were taken using a pitch-yaw (θ-Φ) sequence (see Figure 5). The source antenna was a specially developed circularly polarized horn fed from the 51.6 GHz klystron source. A pinched waveguide was used to produce an axial ratio of less than 1 dB. The 1/10-scale Orbiter was operated at a distance of approximately 110 feet from the source which was mounted in the apex of the horn shaped anechoic chamber.

The antenna patterns were taken as a joint effort involving Dr. H. D. Cubley (NASA-JSC), Dan Flores (Lockheed); Joe Martinez (Lockheed) R. Rethwisch (Lockheed), John Kopp (McDonnell) and D. Russell (McDonnell). Antenna locations which were tested included:

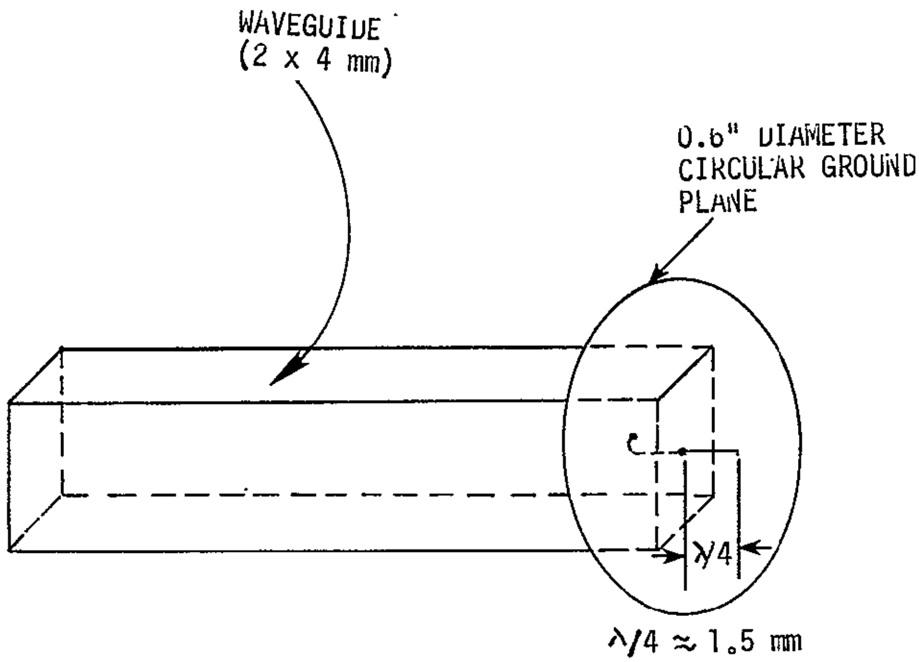


Figure 27. Scaled Model Antenna

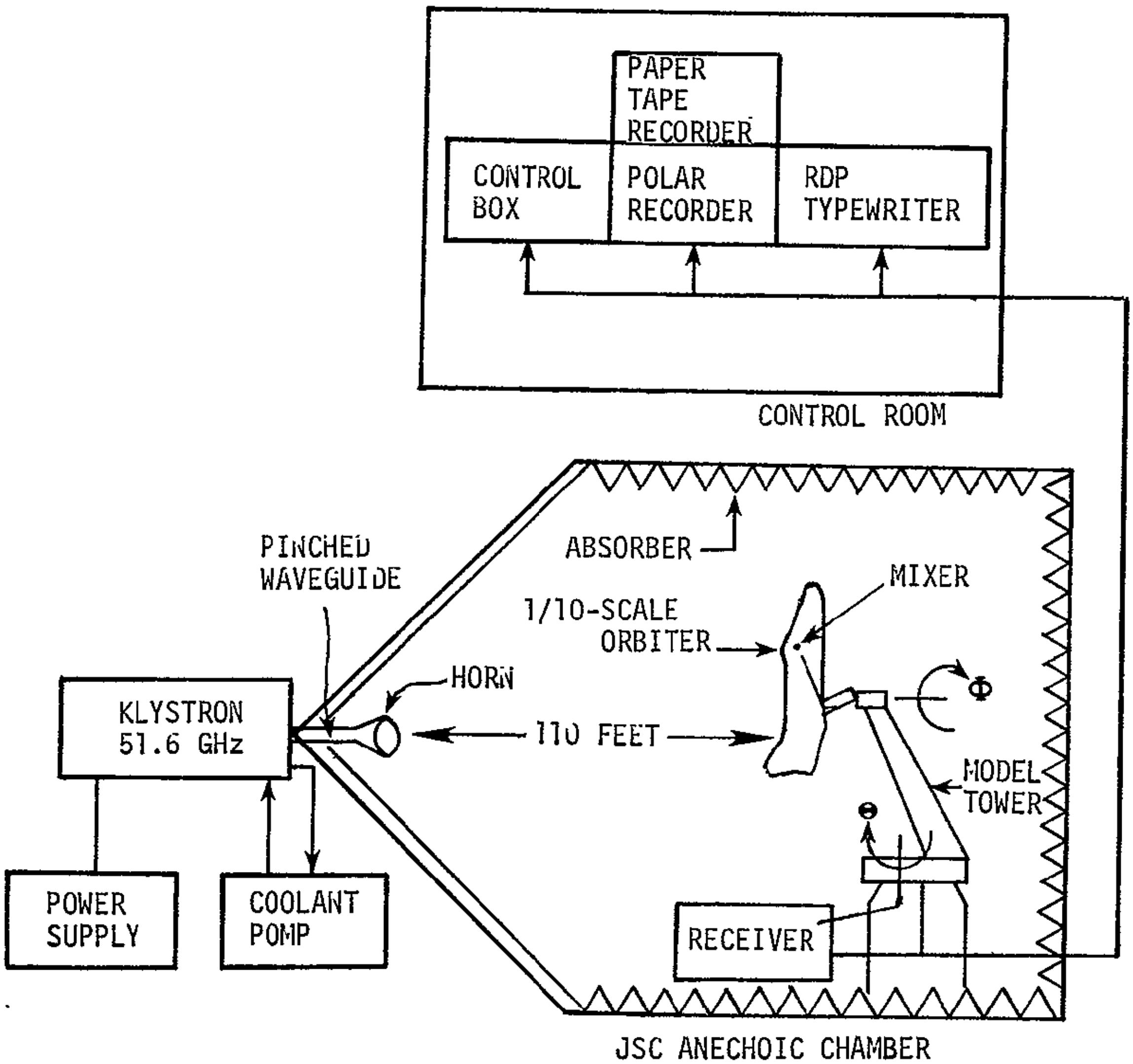


Figure 28. Antenna Pattern Setup

(a) Lower right alone

(b) Upper left alone

(c) Lower alone

(d) Upper alone

(e) Lower right/upper left in parallel

(f) Lower/upper in parallel

The lower left and upper right locations were not tested because of symmetry with the lower right and upper left locations. Patterns were taken for the free-flight (Orbiter alone) configuration as well as the captive (with a booster tank to roughly show 747 shadowing effects) configuration.

Three principal plane polar patterns are given in Figures 29-46 for the six antenna connections listed above using the free-flight configuration. Figures 47-52 show the RDP's for the same six connections. Figures 53-77 show principal plane patterns and selected conical cuts to demonstrate blockage of a large structure like the 747. The external tank used was somewhat larger than the 747; thus patterns are worse than will actually be encountered in the mated configuration with the exception of the look angles through the 747 wings. The upper antenna alone was omitted since the Orbiter shadows the lower hemisphere. The peak gain levels in the patterns correspond to the peak gain of a full scale monopole which is approximately 5dB over a linear isotropic level and 2dB with two antenna in parallel having main beams in different directions. The numbers on the patterns represent relative dB's and large numbers represent lower levels such that a reading of 30 or 40 on a pattern represents 30 dB or 40 dB below a 0 dB reading. To determine the

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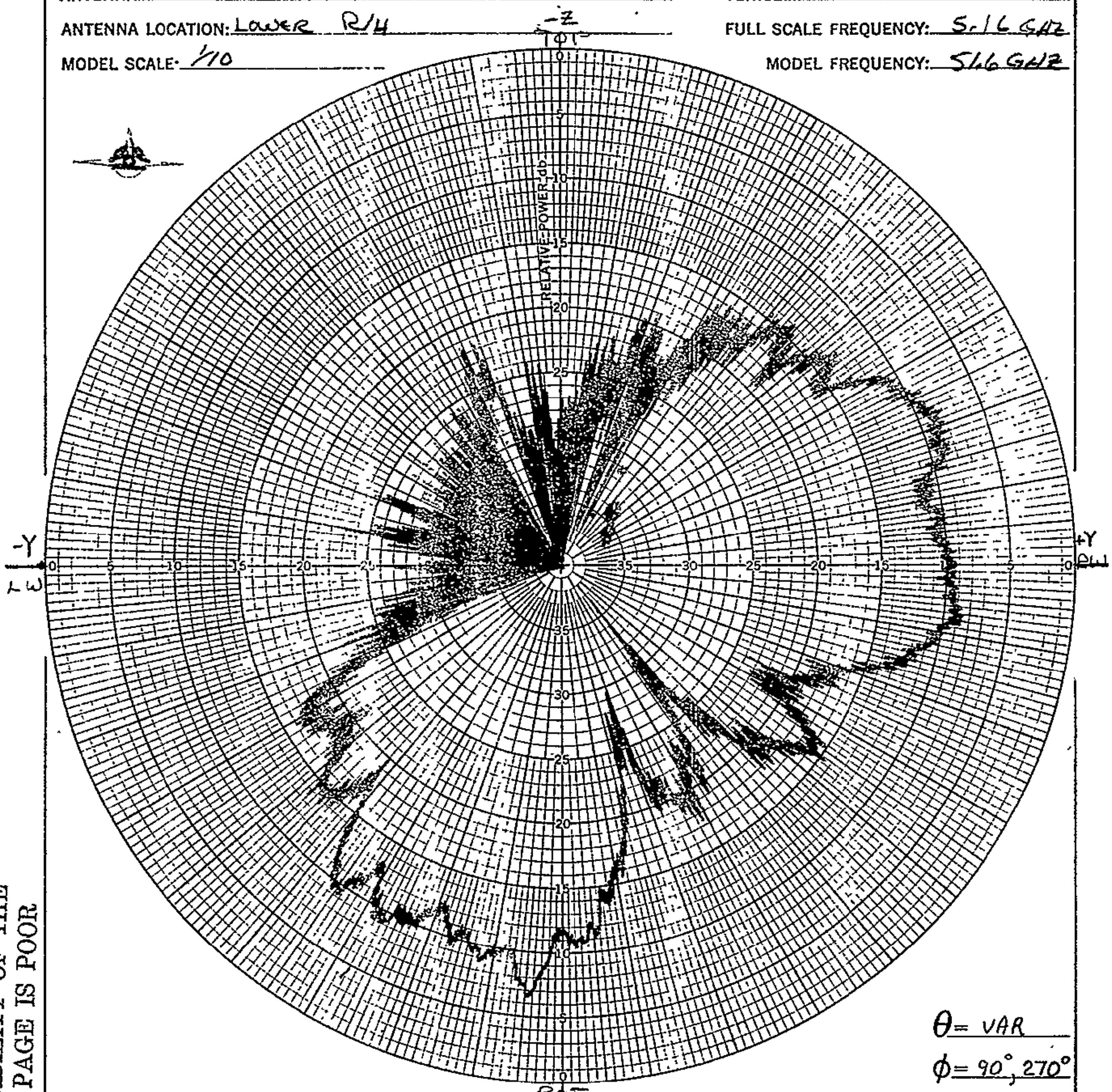
REPORT
MODEL

ANTENNA: C-BAND BEACON
ANTENNA LOCATION: LOWER R/H
MODEL SCALE: 1/10

VEHICLE: SHUTTLE
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL FREQUENCY: 5.16 GHZ



θ= VAR
ϕ= 90°, 270°

CONFIGURATION: FREE FLIGHT

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER:
DATE: 4-7-75

MAC 231YL (7 MAY 64)

Figure 29. Lower Right Antenna Y-Z plane

K&E CO.

DATE	**MCDONNELL DOUGLAS** ST. LOUIS, MISSOURI	PAGE Page 37
REVISED		REPORT
REVISED		MODEL

ANTENNA: C-BAND BEACON

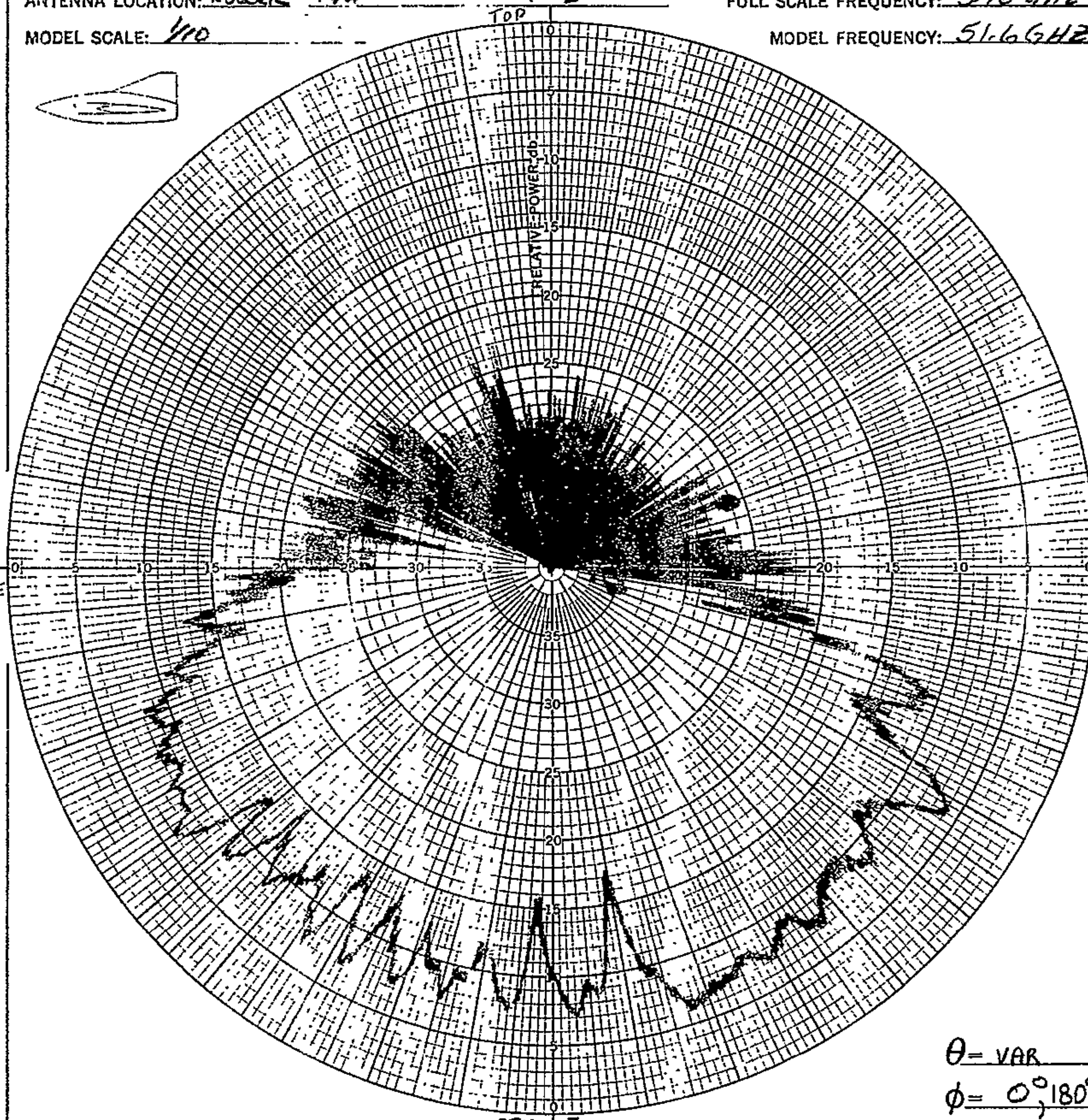
VEHICLE: SHUTTLE

ANTENNA LOCATION: LOWER R/H -Z

FULL SCALE FREQUENCY: 5.16 GHZ

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6 GHZ



θ = VAR

φ = 0°, 180°

CONFIGURATION: FREE FLIGHT	INTEGRATOR COUNT:
	POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
	PLOTTED IN: RELATIVE POWER db
REMARKS:	TRANSMISSION DISTANCE: 110'
	OBSERVER: RR-JM-NJ DATE: 4-7-75

MAC 231YL (7 MAY 64) Figure 30. Lower Right Antenna X-Z plane K&E CO.

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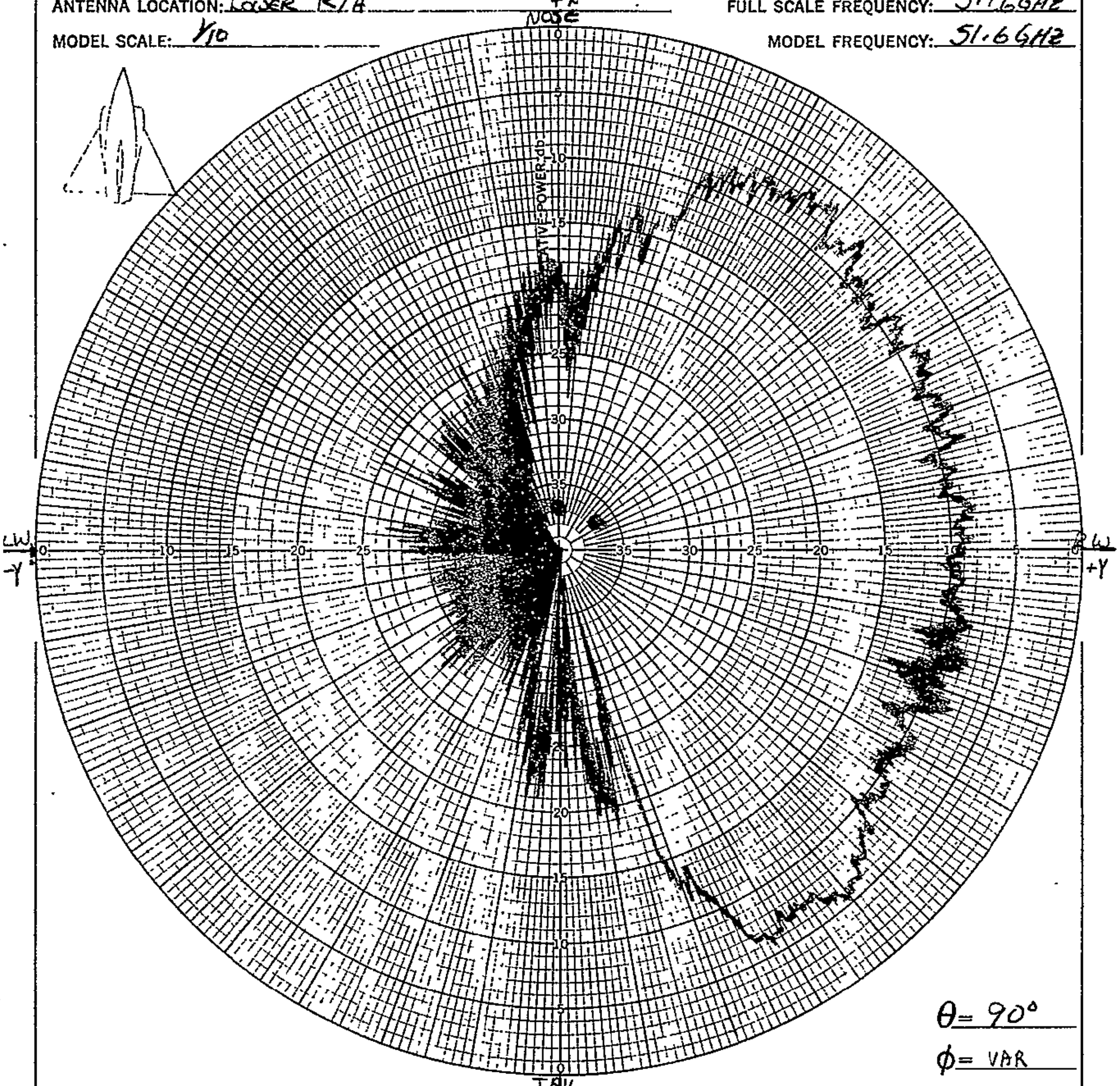
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: Lower R/H
FULL SCALE FREQUENCY: 5.16GHz
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHz

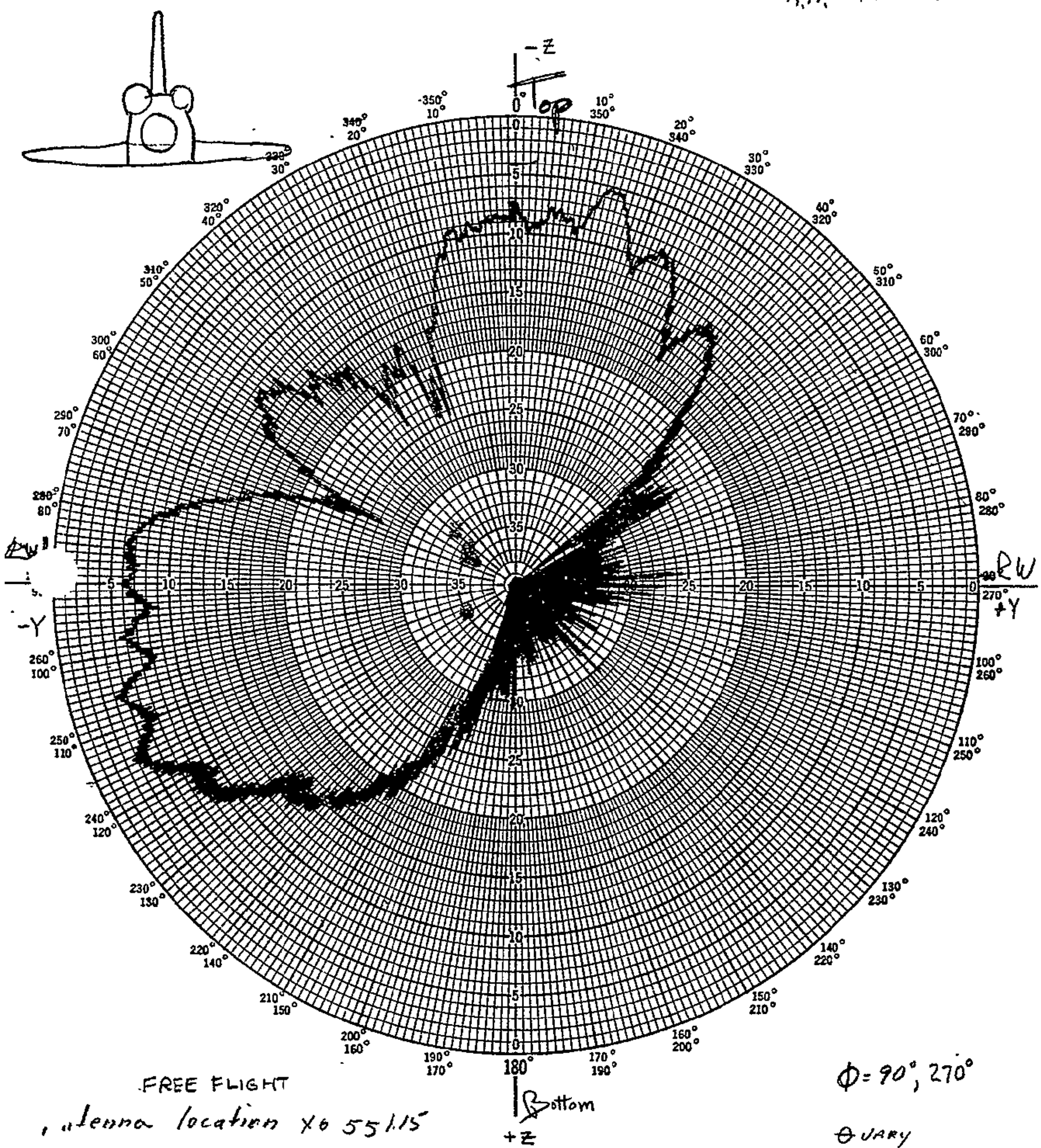


CONFIGURATION: FREE FLIGHT
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: [illegible]
DATE: 4-7-75

MAC 231YL (7 MAY 64)
Figure 31. Lower Right Antenna X-Y plane
K&E CO.

1/10 scale C Band Beacon #1

R.H.C. polarization



FREE FLIGHT

antenna location Xo 551.15

Yo 70.70" upper left

.25" cork spacer between antenna and skin

$\Phi = 90°, 270°$

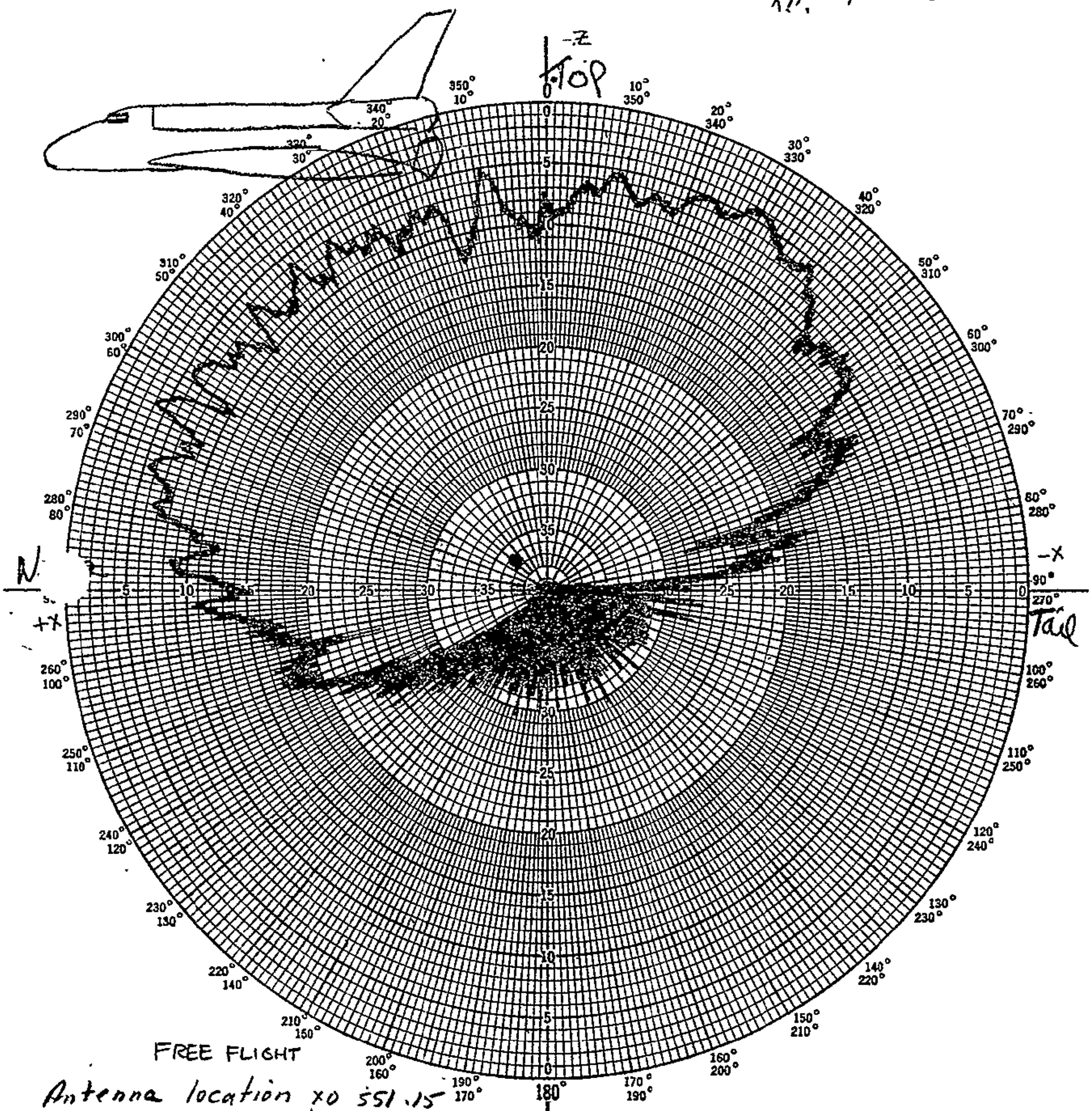
θ VARY

Figure 32. Upper Left Antenna Y-Z plane

NASA-JSC

to Scale C Band Beacon #1

RHC polarization



Bottom

FREE FLIGHT

Antenna location xo 551.15
70.70" upper left

φ=0°,180°

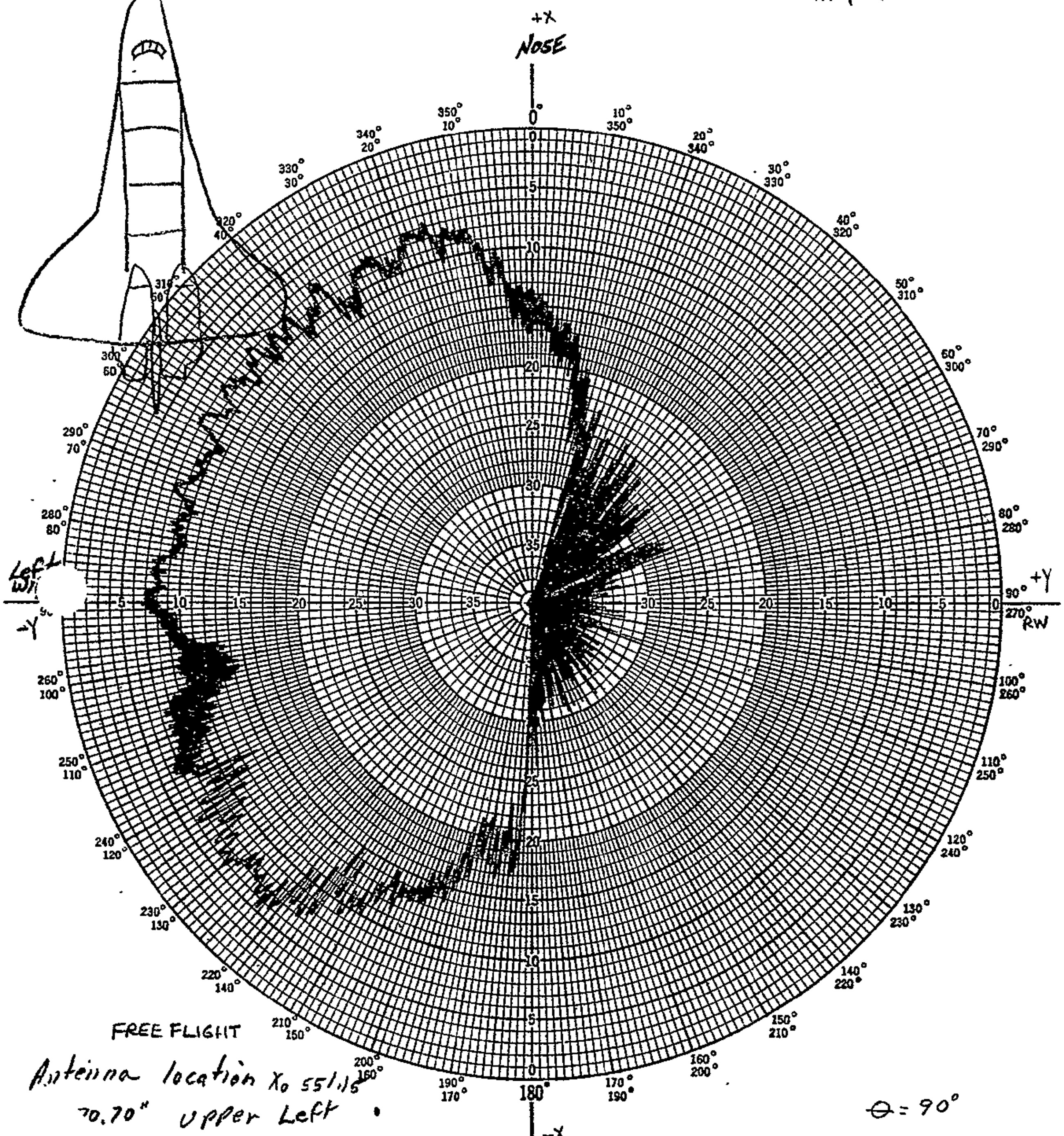
.25" cork spacer between antenna +Z
and skin of model

θ Vary

Figure 33. Upper Left Antenna X-Z plane

1/10 Scale C Band Beacon #1

R.H.C. Polarization



FREE FLIGHT

Antenna location X_o 551.15
70.70" upper Left

.25" cork spacer between antenna
and skin of model

$\theta = 90°$

ϕ vary

Figure 34. Upper Left Antenna X-Y plane

DATE ______ **MCDONNELL DOUGLAS** ST. LOUIS, MISSOURI PAGE Page 42

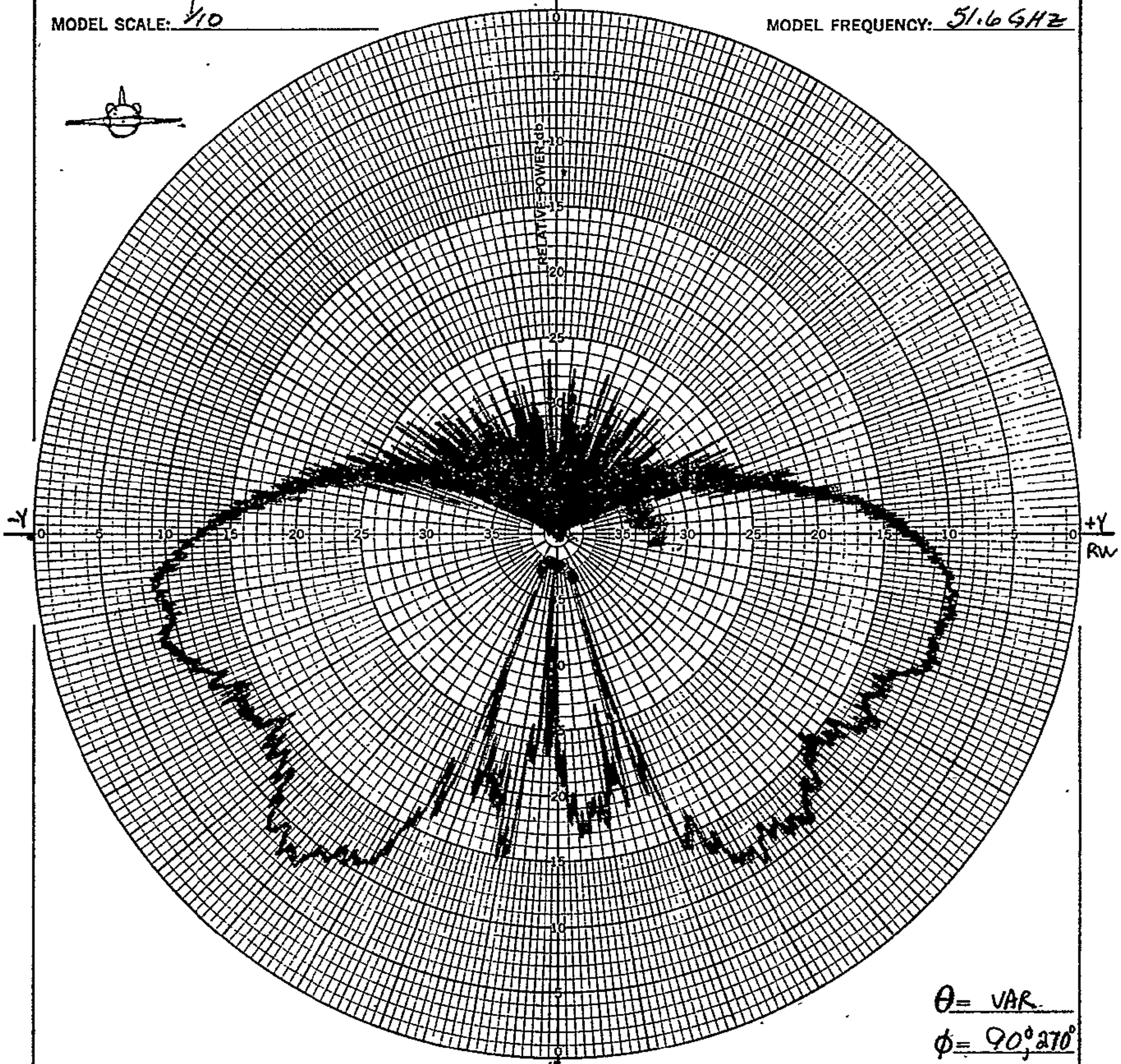
REVISED ______ REPORT ______

REVISED ______ MODEL ______

ANTENNA: C-Band Beacon VEHICLE: SHUTTLE

ANTENNA LOCATION: Lower ℄ FULL SCALE FREQUENCY: 5.16 GHZ

MODEL SCALE: 1/10 MODEL FREQUENCY: 51.6 GHZ



θ= VAR.
ϕ= 90°, 270°

CONFIGURATION: FREE FLIGHT

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: DR-JM DATE: 4-8-75

MAC 231YL (7 MAY 64) K&E CO.

Figure 35. Lower Antenna Y-Z plane

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

ANTENNA: C-Band Beacon

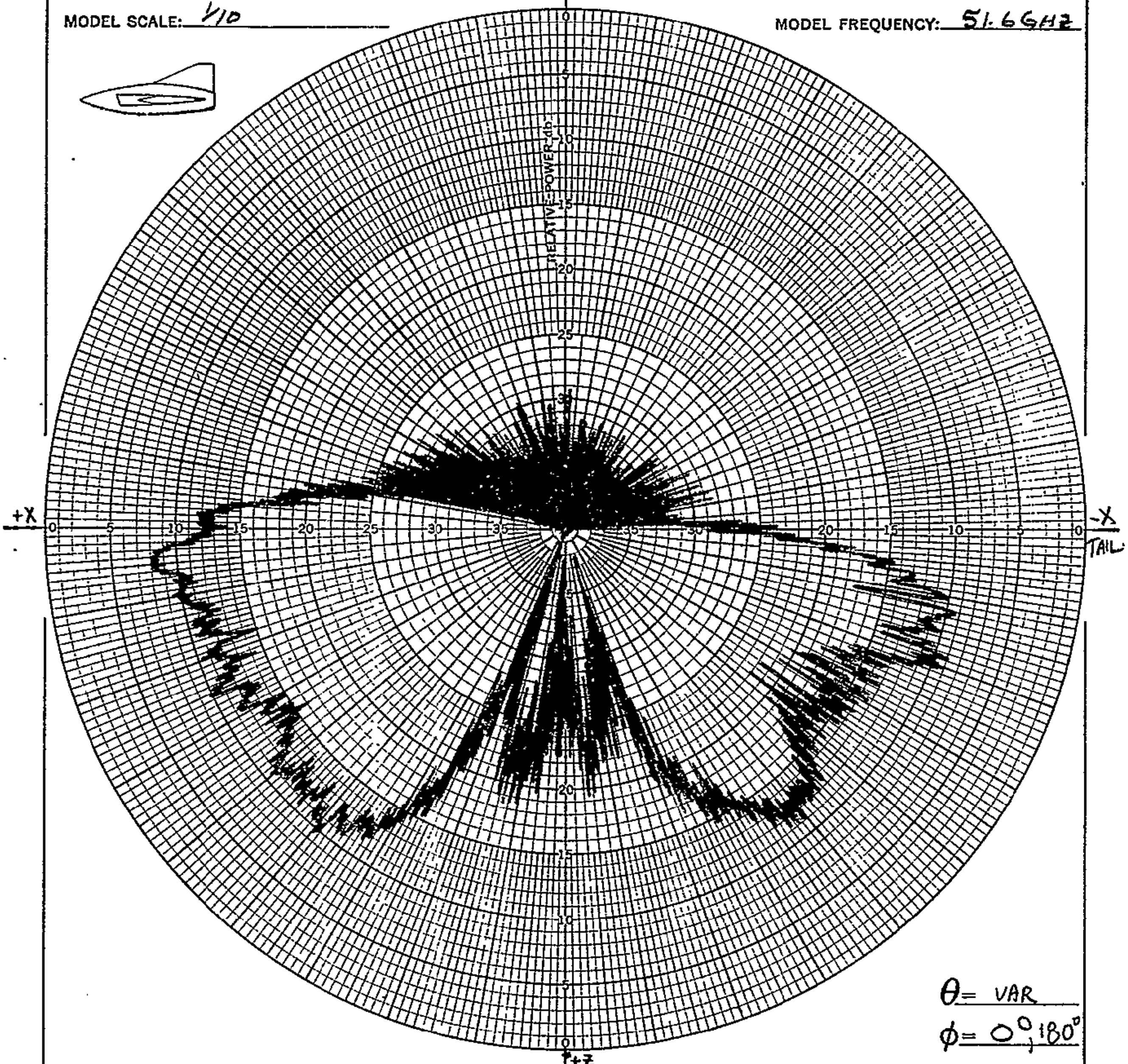
VEHICLE: SHUTTLE

ANTENNA LOCATION: Lower ℄

FULL SCALE FREQUENCY: 5.16GHZ

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6GHZ



θ= VAR

φ= 0°, 180°

CONFIGURATION: FREE FLIGHT

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: GR-JM

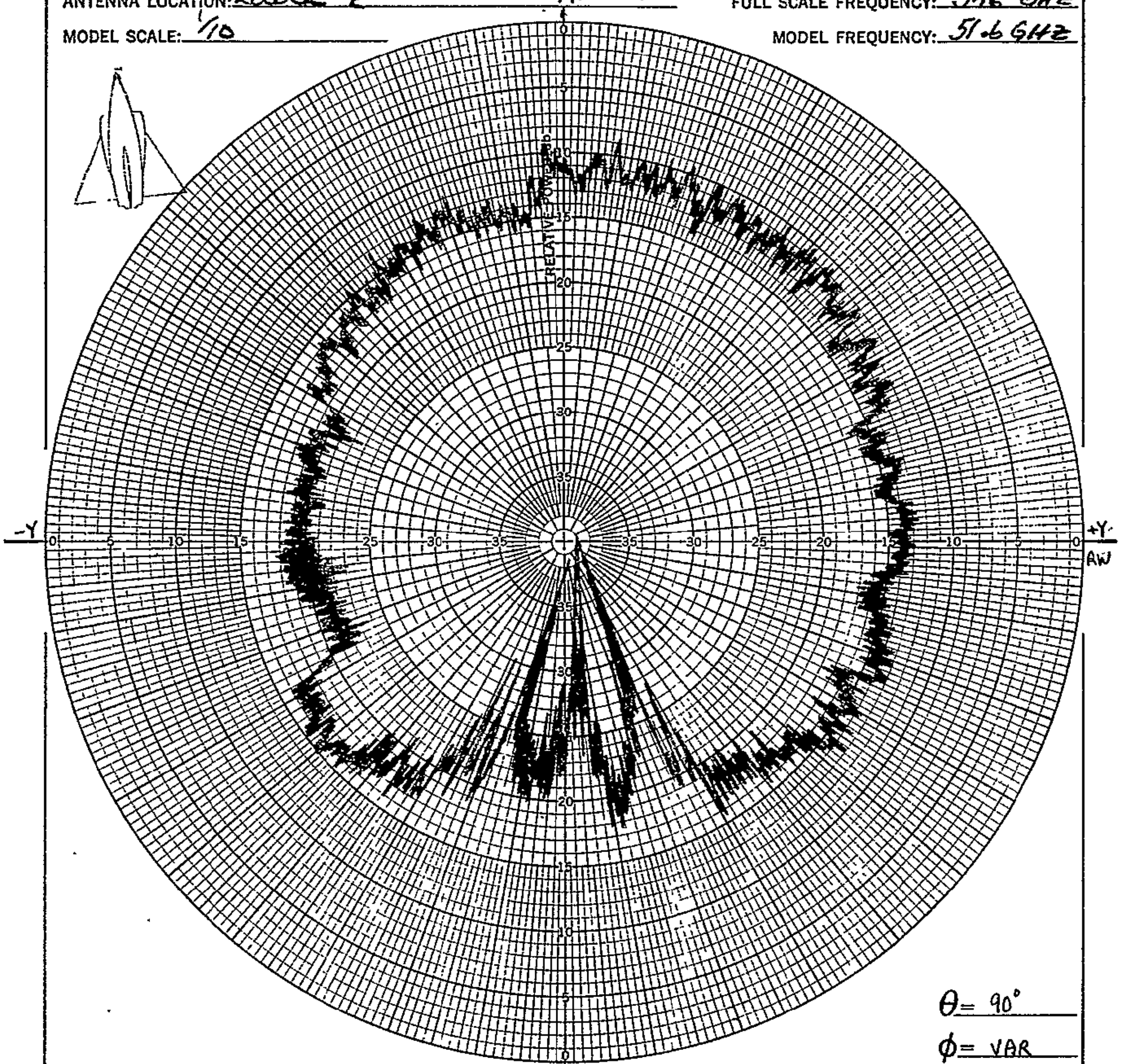
DATE: 4-8-75

Figure 36. Lower Antenna X-Z plane

ANTENNA: C-Band Beacon VEHICLE: SHUTTLE

ANTENNA LOCATION: Lower ℄ FULL SCALE FREQUENCY: 5.16 GHZ

MODEL SCALE: 1/10 MODEL FREQUENCY: 51.6 GHZ



θ= 90°

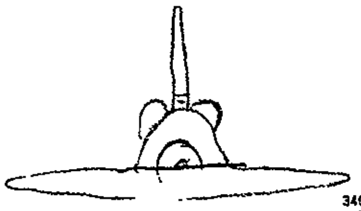
ϕ= VAR

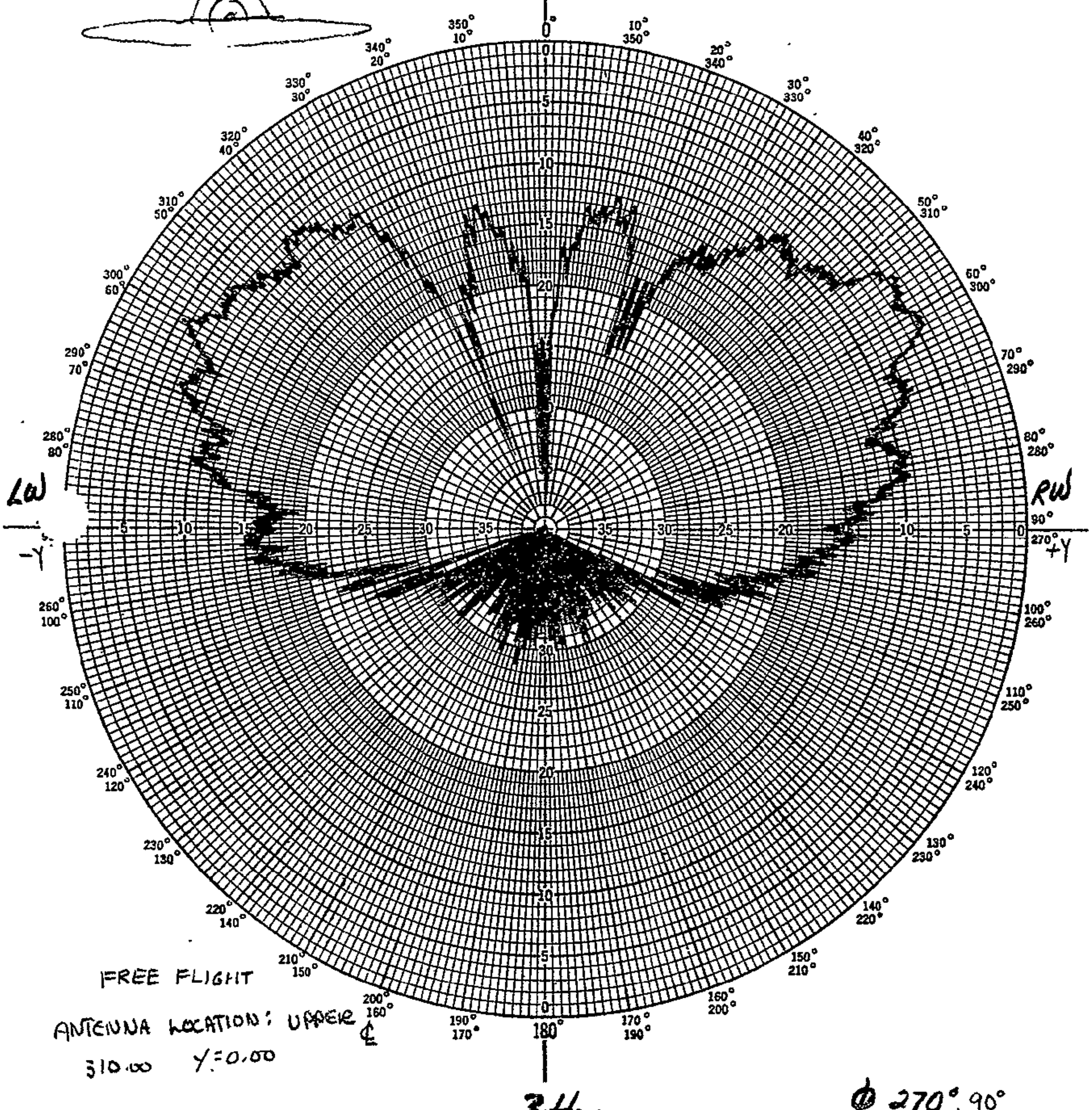
CONFIGURATION: FREE FLIGHT	INTEGRATOR COUNT:
	POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
	PLOTTED IN: RELATIVE POWER db
REMARKS:	TRANSMISSION DISTANCE:
	OBSERVER: DATE:

MAC 231YL (7 MAY 64) Figure 37. Lower Antenna X-Y plane K&E CO.

1/10 SCALE C-BAND BEACON

51.6 GHZ
R/H/C





FREE FLIGHT

ANTENNA LOCATION: UPPER ℄

310.00 Y=0.00

ϕ 270°, 90°

θ VARY

Figure 38. Upper Antenna Y-Z plane

4-3-75

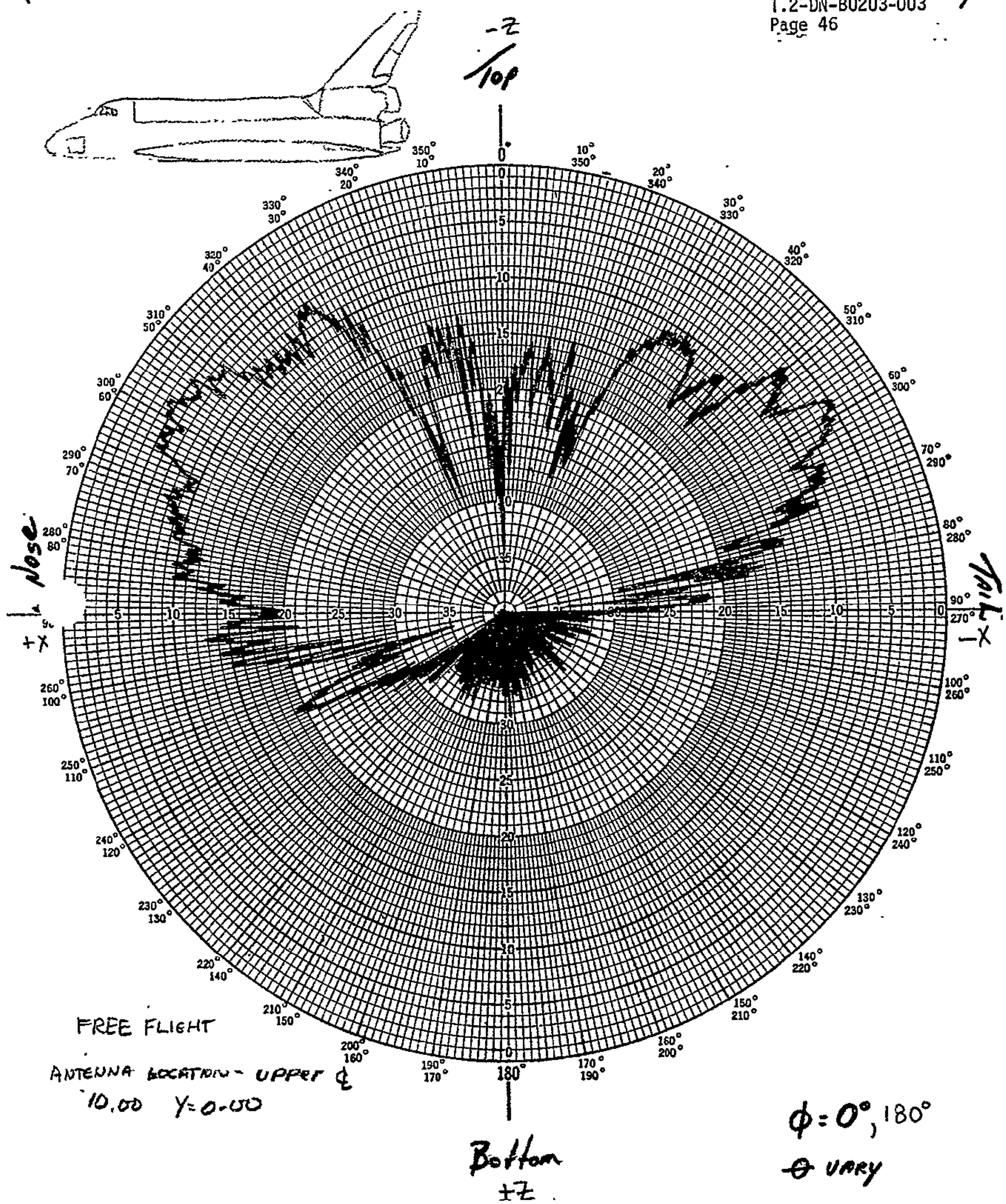


Figure 39. Upper Antenna X-Z plane 4-3-75

NASA-JSC

1/10 SCALE C-BAND BEACON

51.6 GHz
R/H/C

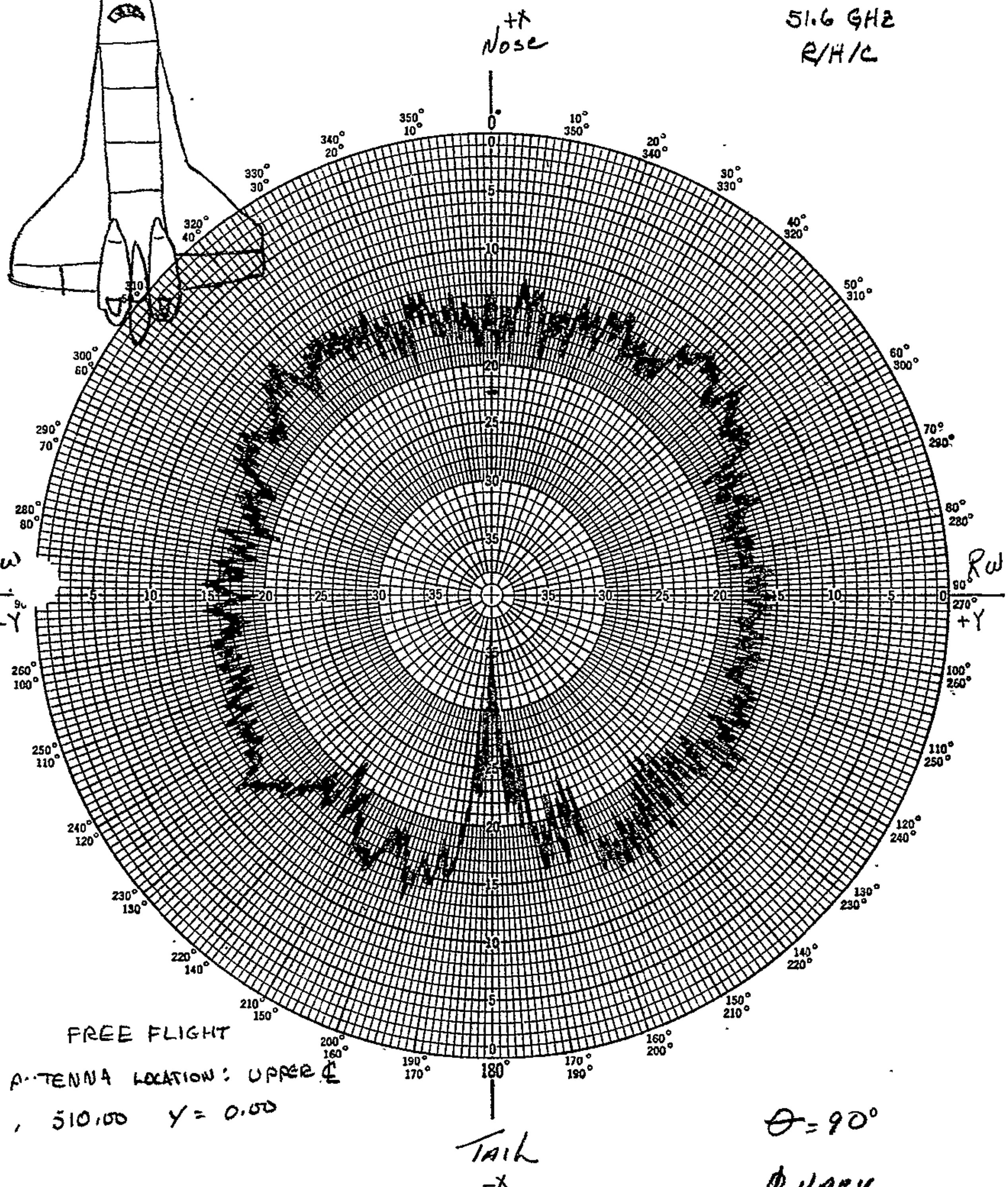


Figure 40. Upper Antenna X-Y plane

DATE
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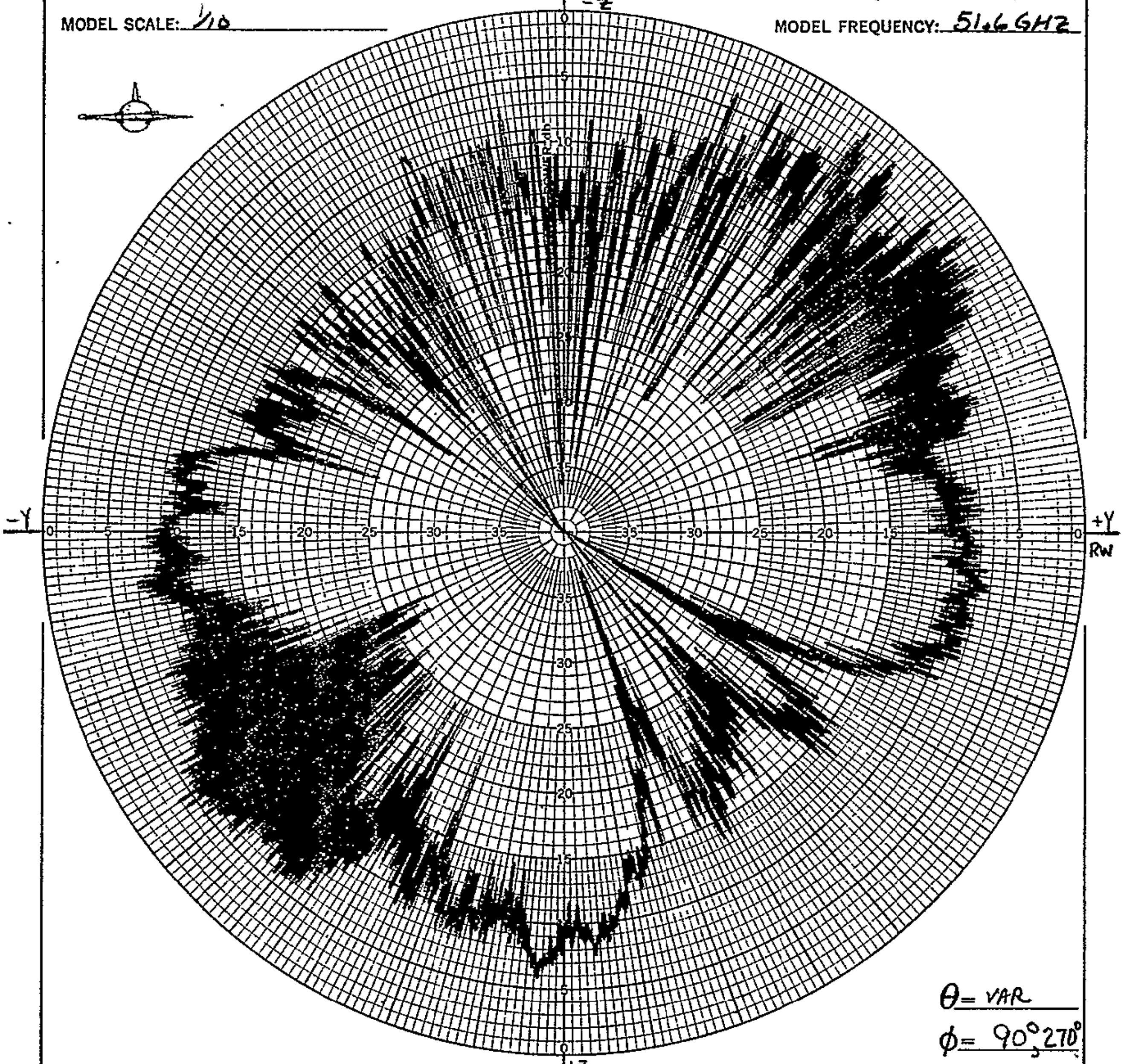
REPORT
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER LEFT / LOWER RIGHT
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHZ



θ = VAR
ϕ = 90°, 270°

CONFIGURATION: FREE FLIGHT

REMARKS:

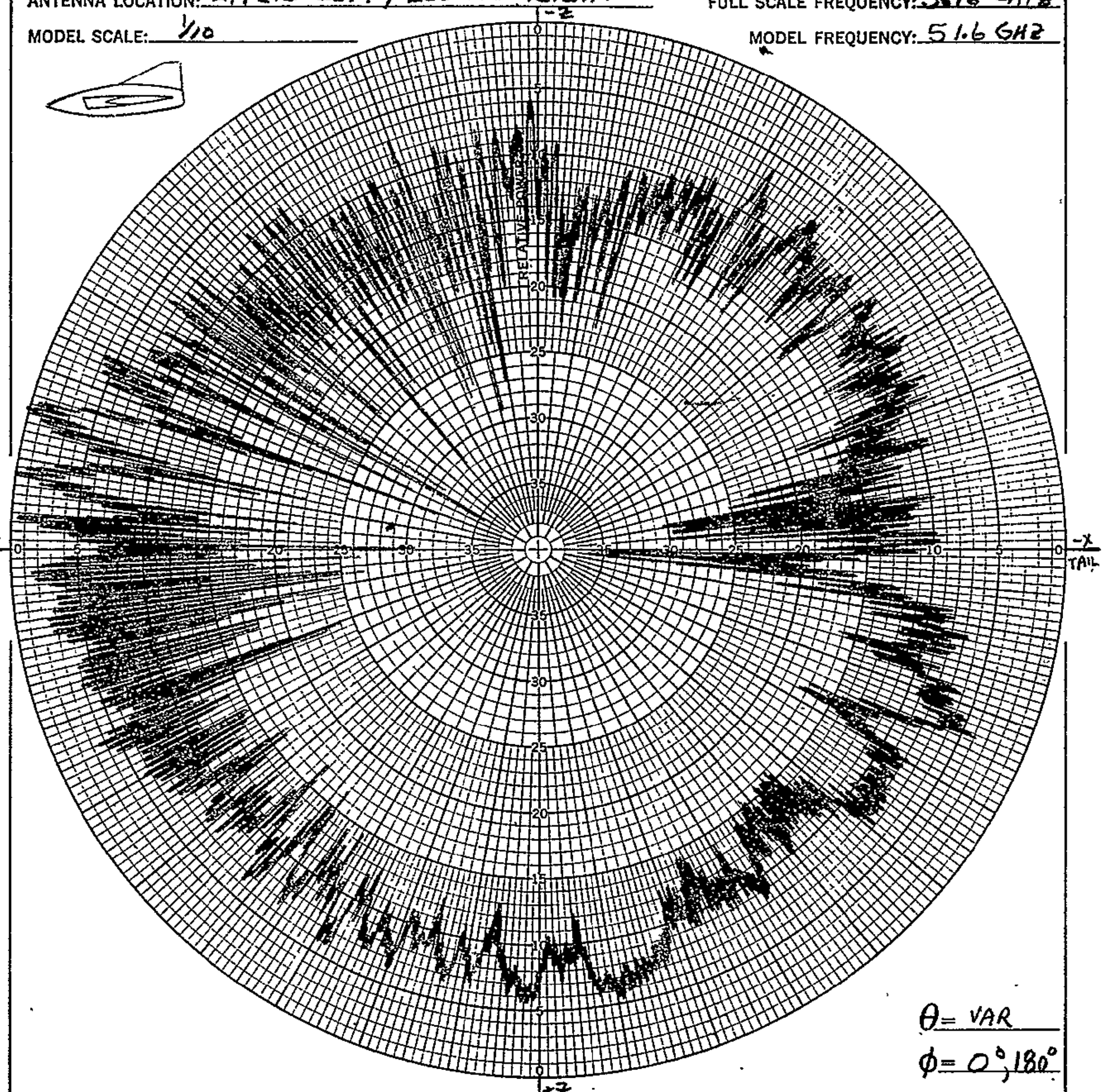
INTEGRATOR COUNT:
POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER:
DATE: 4-11-75

MAC 231YL (7 MAY 64)

Figure 41. Lower Right/Upper Left Y-Z plane

K&E CO.

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER LEFT / LOWER RIGHT
FULL SCALE FREQUENCY: 5.16 GHz
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHz



θ= VAR
φ= 0°, 180°

CONFIGURATION: FREE FLIGHT

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: [illegible]
DATE: 4-11-75

Figure 42. Lower Right/Upper Left X-Z plane

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REPORT

MODEL

ANTENNA: C-BAND BEACON

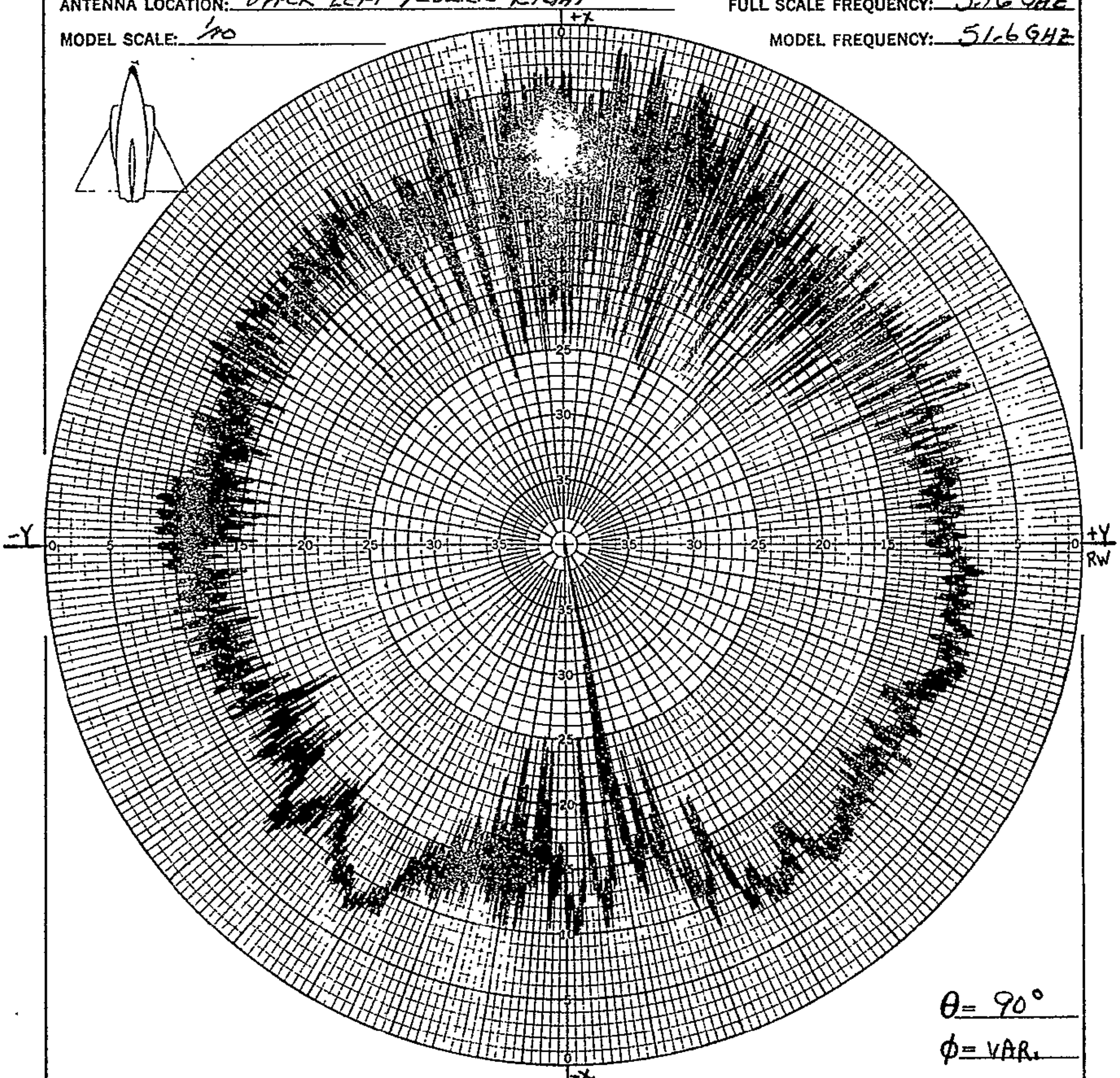
VEHICLE: SHUTTLE

ANTENNA LOCATION: UPPER LEFT / LOWER RIGHT

FULL SCALE FREQUENCY: 5.16 GHZ

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6 GHZ



θ = 90°

ϕ = VAR.

CONFIGURATION: FREE FLIGHT

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: [illegible] DATE: 4-11-75

MAC 231YL (7 MAY 64)

Figure 43. Lower Right/Upper Left X-Y plane

K&E CO.

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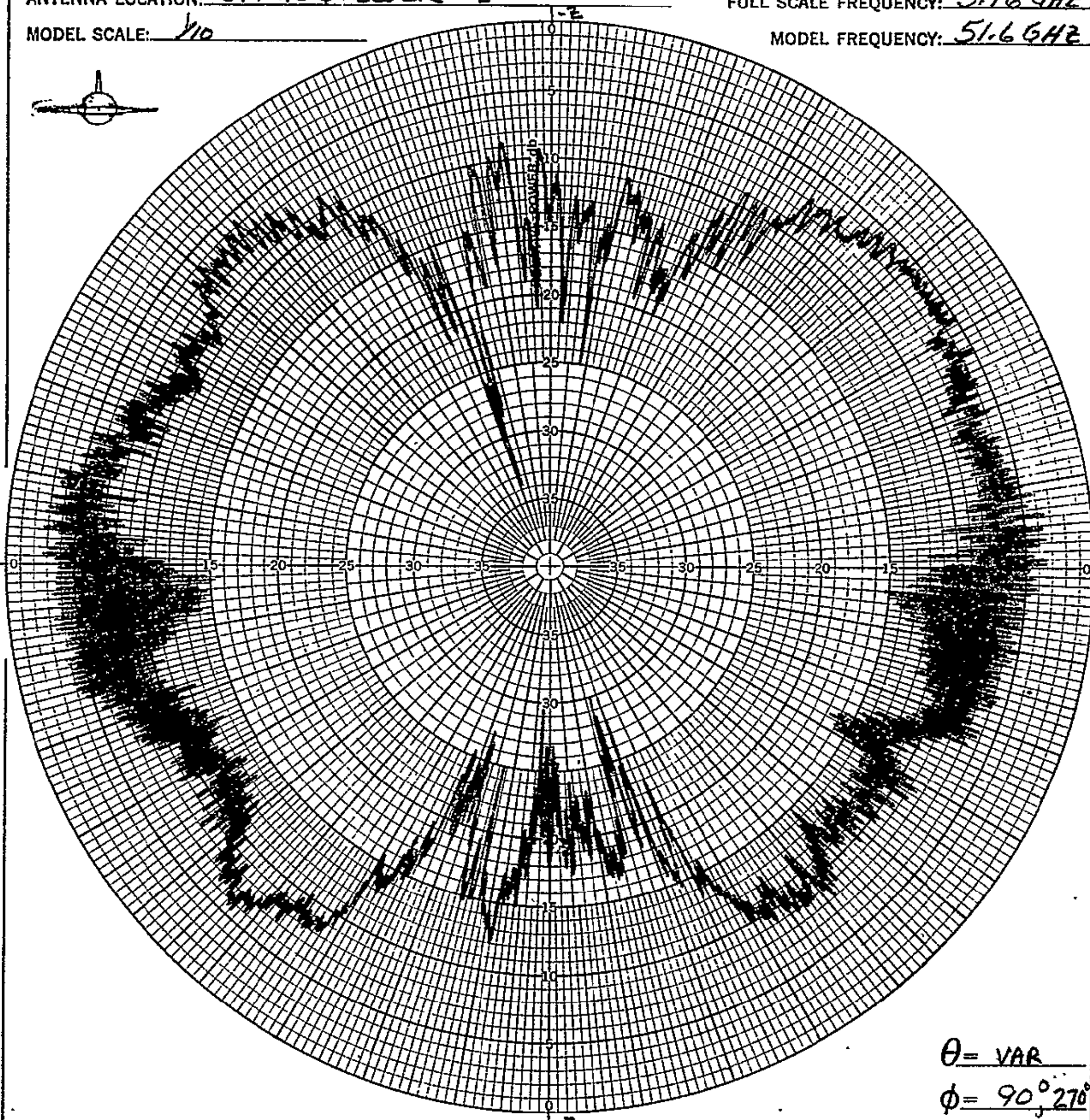
ST. LOUIS, MISSOURI

REPORT
MODEL

ANTENNA: C-BAND BEACON (S)
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER & LOWER ℄
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHZ



θ = VAR
φ = 90°, 270°

CONFIGURATION: FREE FLIGHT
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: DR-DM-DF
DATE: 4-15-75

MAC 231YL (7 MAY 64)
K&E CO.

Figure 44. Lower/Upper Y-Z plane

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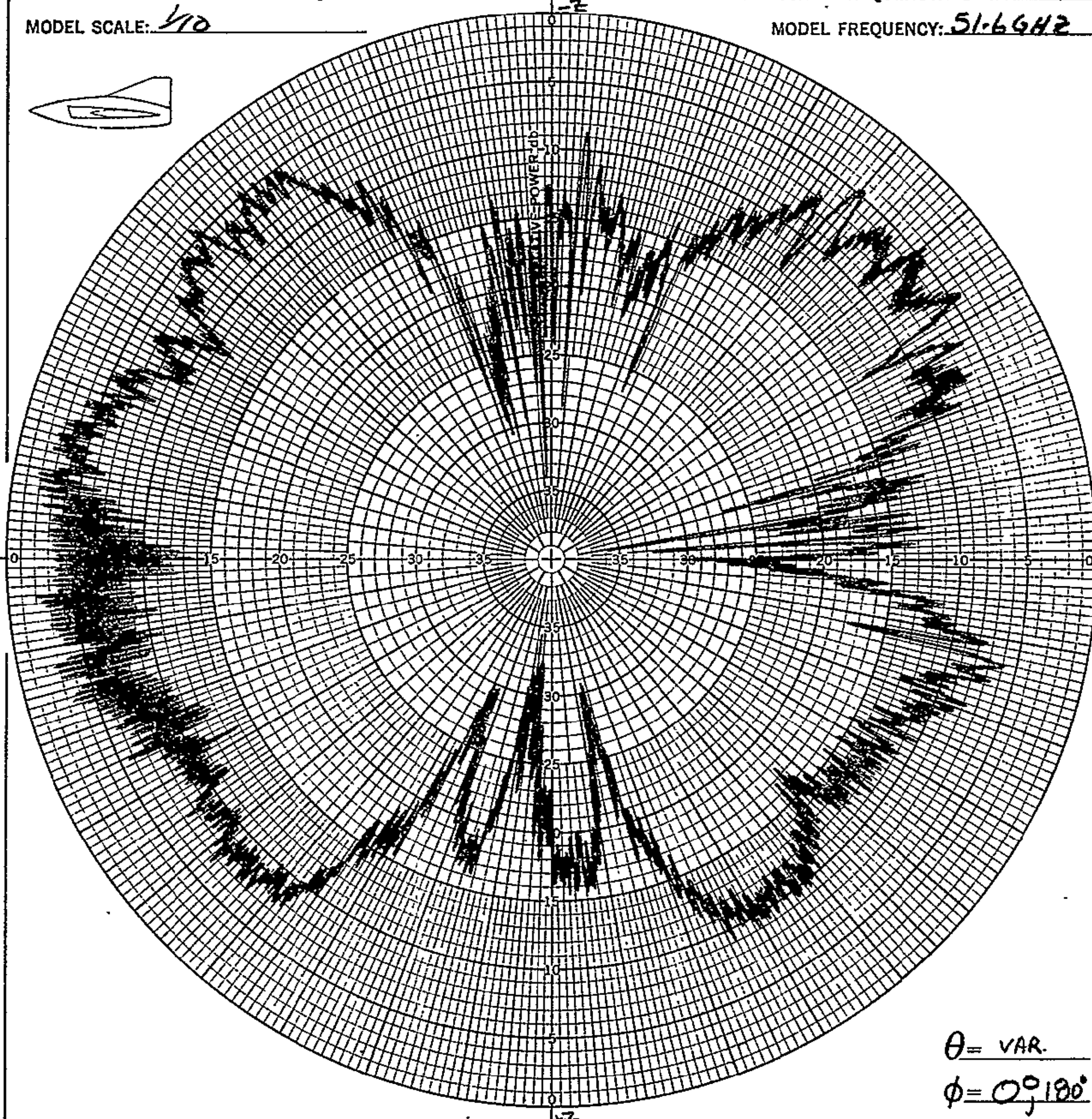
ST. LOUIS, MISSOURI

REPORT
MODEL

ANTENNA: C-BAND BEACON(S)
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER & LOWER ℄
FULL SCALE FREQUENCY: 5.16GHz
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHz



θ= VAR.
φ= 0°, 180°

CONFIGURATION: FREE FLIGHT

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: OR-JM-DF
DATE: 4-15-75

MAC 231YL (7 MAY 64)

Figure 45. Lower/Upper X-Z plane

K&E CO.

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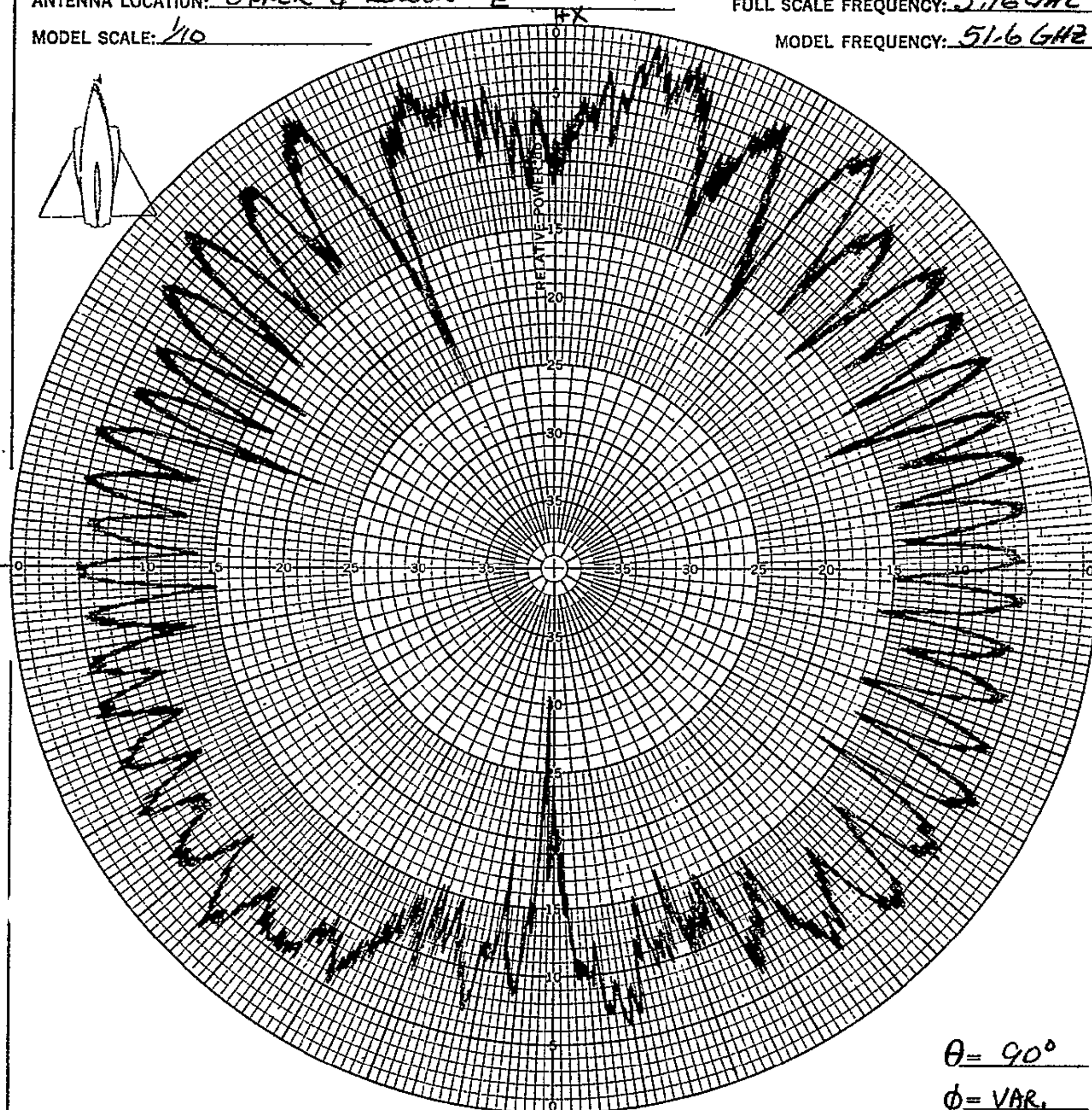
REVISED ____ MODEL ____

ANTENNA: C-BAND BEACON(S)
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER & LOWER ℄
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHZ



θ = 90°
φ = VAR.

CONFIGURATION: FREE FLIGHT
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: [illegible] DATE: 4-15-75

MAC 231YL (7 MAY 64) K&E CO.

Figure 46. Lower/Upper X-Y plane

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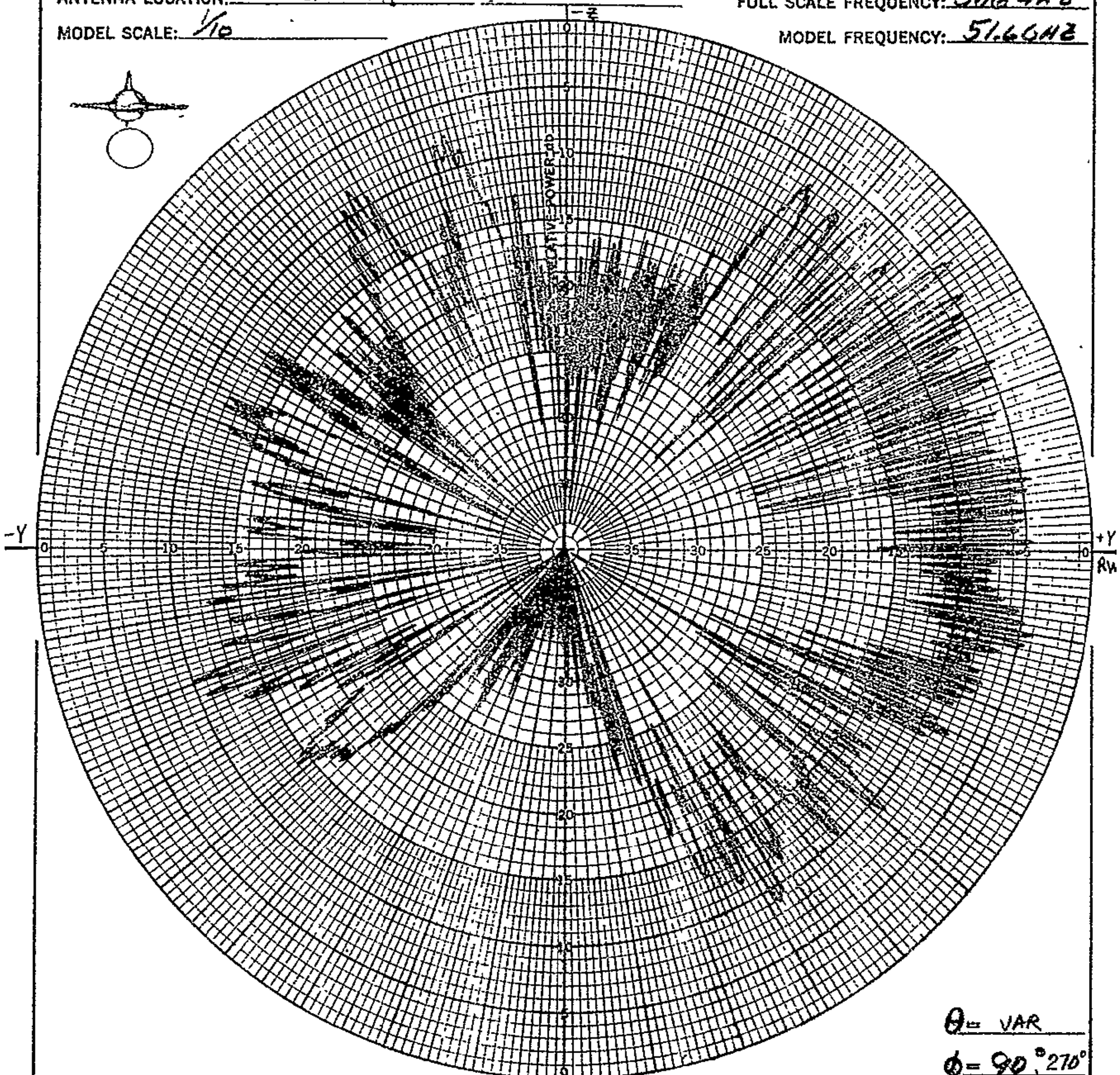
MODEL

ANTENNA: C-BAND BEACON
ANTENNA LOCATION: LOWER R/H
MODEL SCALE: 1/10

VEHICLE: SHUTTLE
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL FREQUENCY: 51.6 GHZ



θ = VAR
φ = 90°, 270°

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: DC JM-WF
DATE: 4-21-75

MAC 231YL (7 MAY 64)
K&E CO.

Figure 53. Lower Right Antenna with Tank Y-Z plane.

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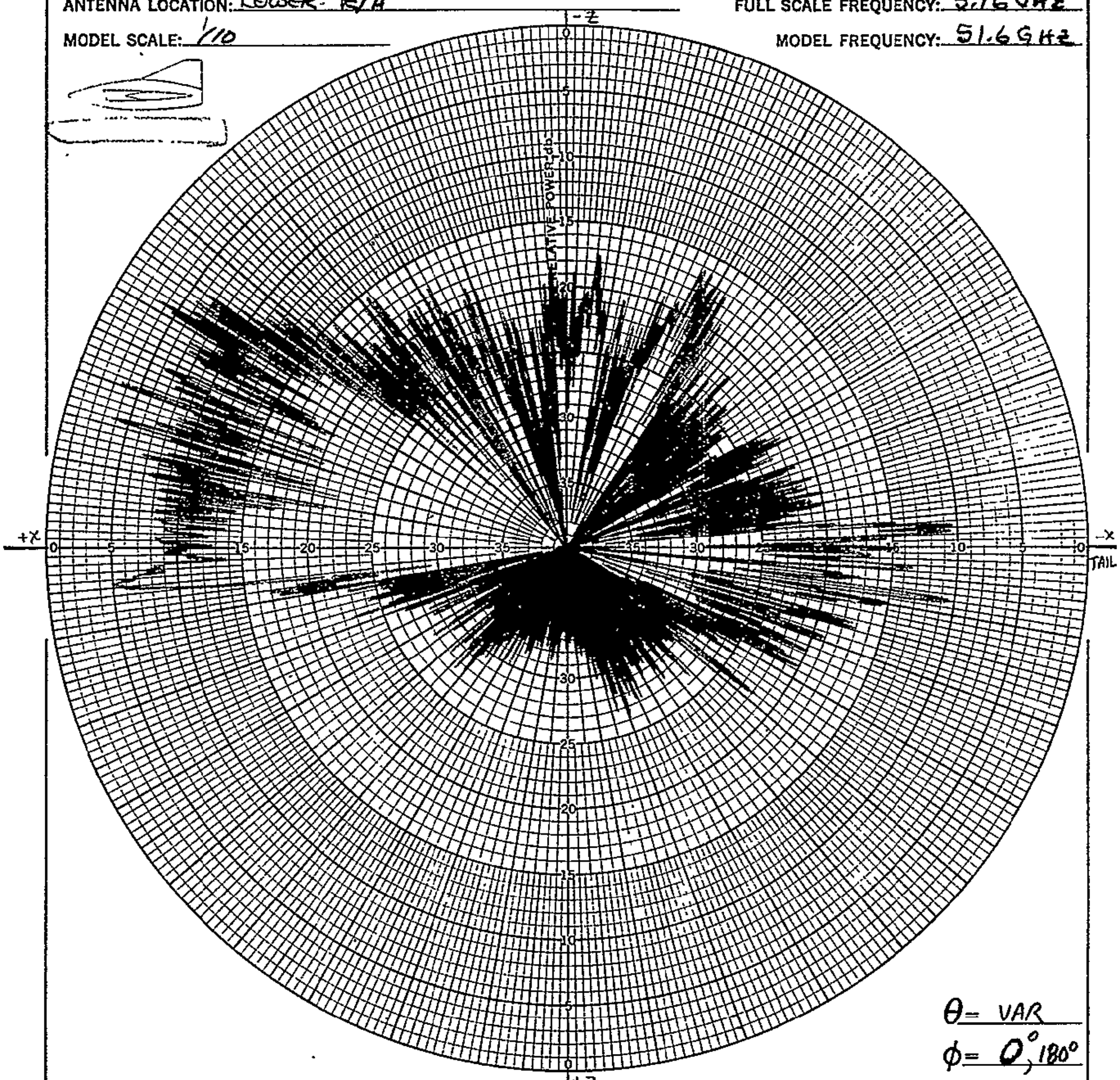
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: LOWER R/H
FULL SCALE FREQUENCY: 5.16 GHz
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHz



CONFIGURATION: W/TANK
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: KOR - OM - OF
DATE: 4-21-75

MAC 231YL (7 MAY 64)
K&E CO.

Figure 54. Lower Right Antenna with Tank X-Z plane

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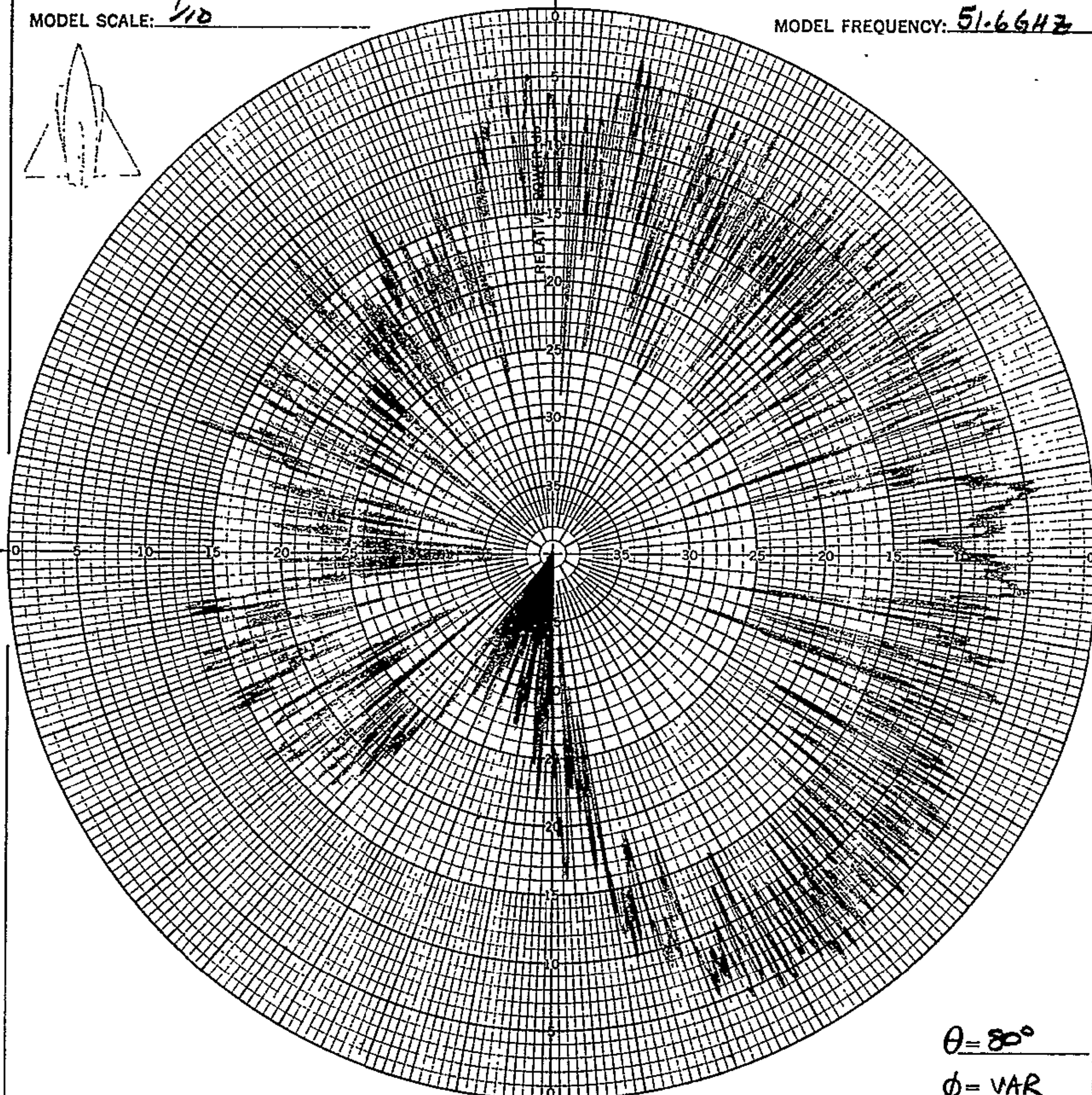
ST. LOUIS, MISSOURI

REPORT
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: Lower R/H
FULL SCALE FREQUENCY: 5.16GHz
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHz



θ = 80°
ϕ = VAR
CONICAL CUT

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: DR-JM-10F DATE: 4-21-75

MAC 231YL (7 MAY 64)
K&E CO.

Figure 55. Lower Right Antenna with Tank θ = 80°

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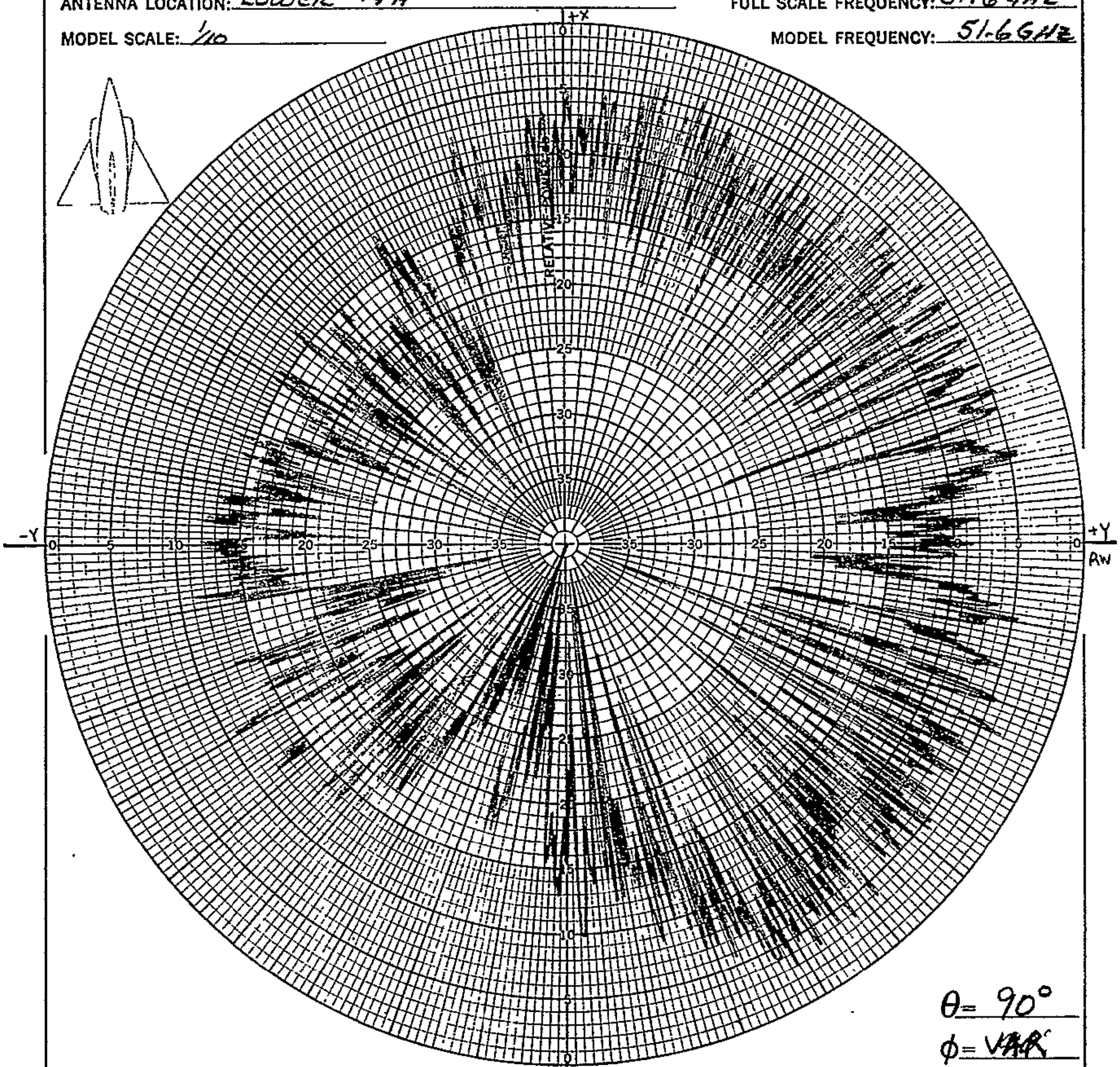
REPORT
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: LOWER R/H
FULL SCALE FREQUENCY: 5.16GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHZ



CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: RP - DM - RF
DATE: 4-21-75

MAC 231YL (7 MAY 64)
K&E CO.

Figure 56. Lower Right Antenna with Tank X-Y plane

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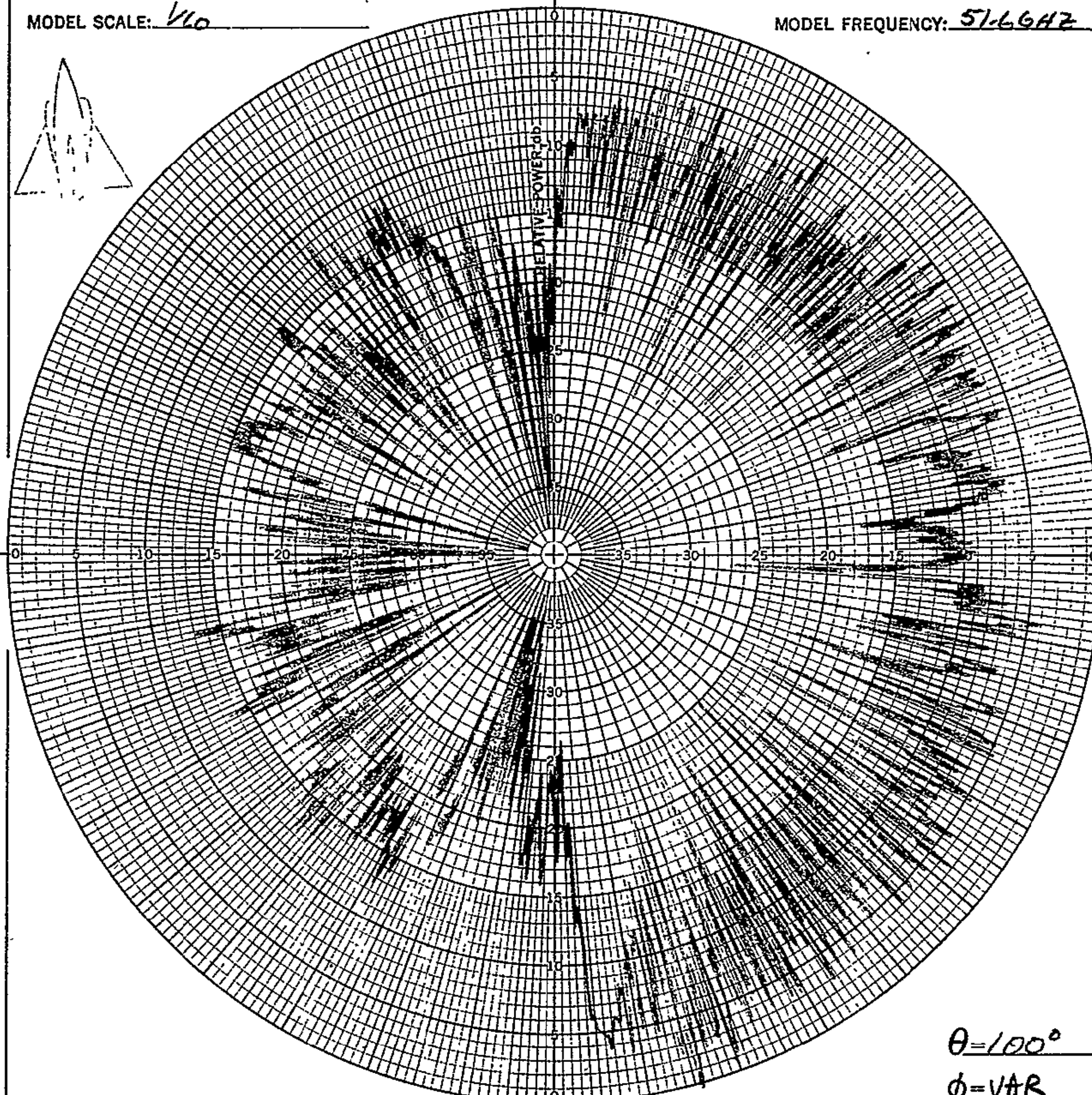
REVISED ______ REPORT ______

REVISED ______ MODEL ______

ANTENNA: C-BAND BEACON VEHICLE: SHUTTLE

ANTENNA LOCATION: LOWER R/H FULL SCALE FREQUENCY: 5.16 GHZ

MODEL SCALE: 1/10 MODEL FREQUENCY: 51.6 GHZ



θ=100°
φ=VAR
CONICAL CUT

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: DE DM - DF DATE: 4-21-75

MAC 231YL (7 MAY 64) K&E CO.

Figure 57. Lower Right Antenna with Tank θ= 100°

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MCDONNELL DOUGLAS
ST. LOUIS, MISSOURI

REPORT

MODEL

ANTENNA: C-BAND BEACON

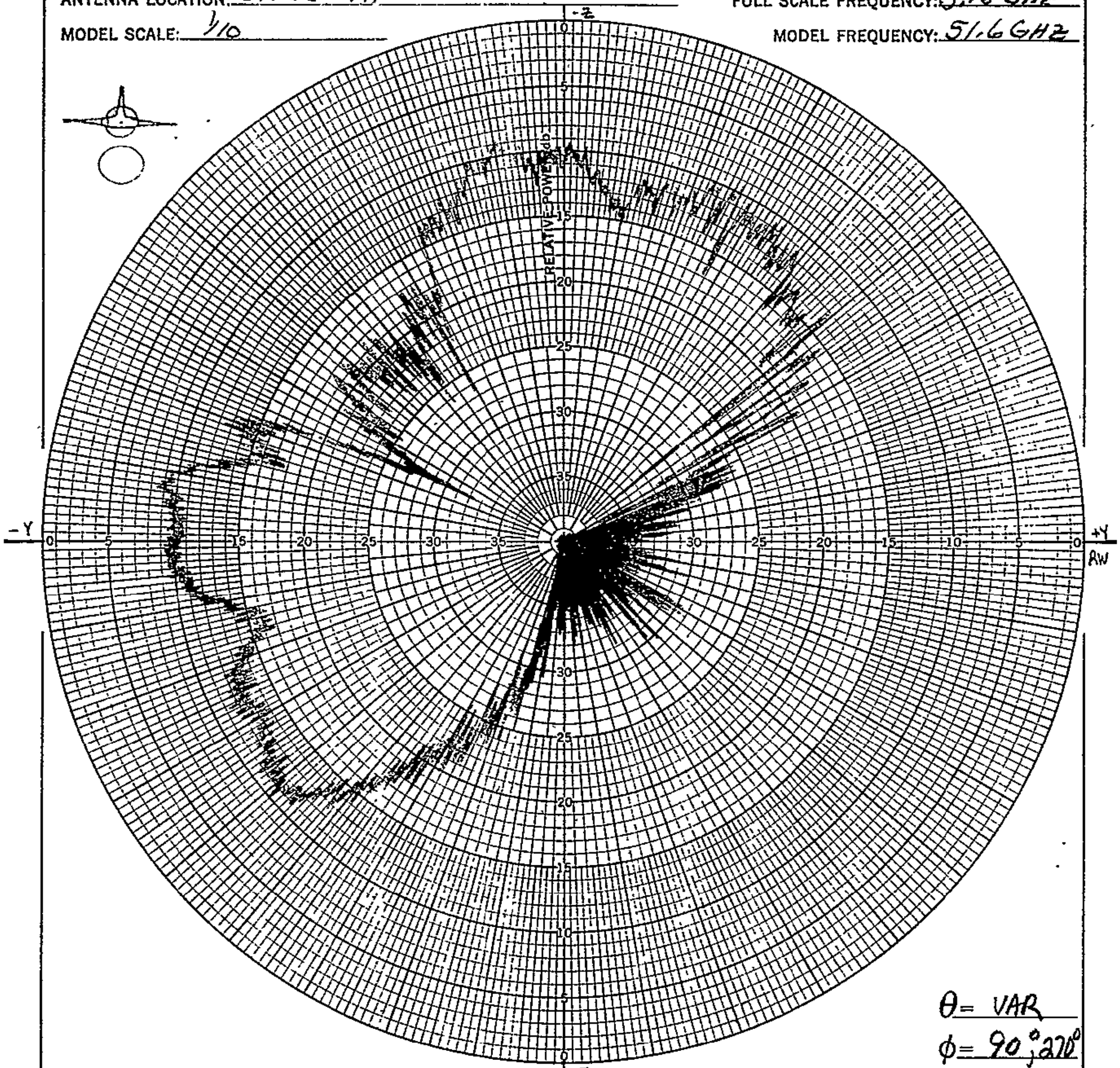
VEHICLE: SHUTTLE

ANTENNA LOCATION: UPPER L/H

FULL SCALE FREQUENCY: 5.16 GHz

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6 GHz



θ= VAR
φ= 90°, 270°

CONFIGURATION: W/TANK

INTEGRATOR COUNT:

POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

REMARKS:

TRANSMISSION DISTANCE: 110

OBSERVER: [illegible]

DATE: 4-22-75

MAC 231YL (7 MAY 6

K&E CO.

Figure 58. Upper Left Antenna with Tank. Y-Z plane

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REPORT

REVISED

MODEL

ANTENNA: C-BAND BEACON

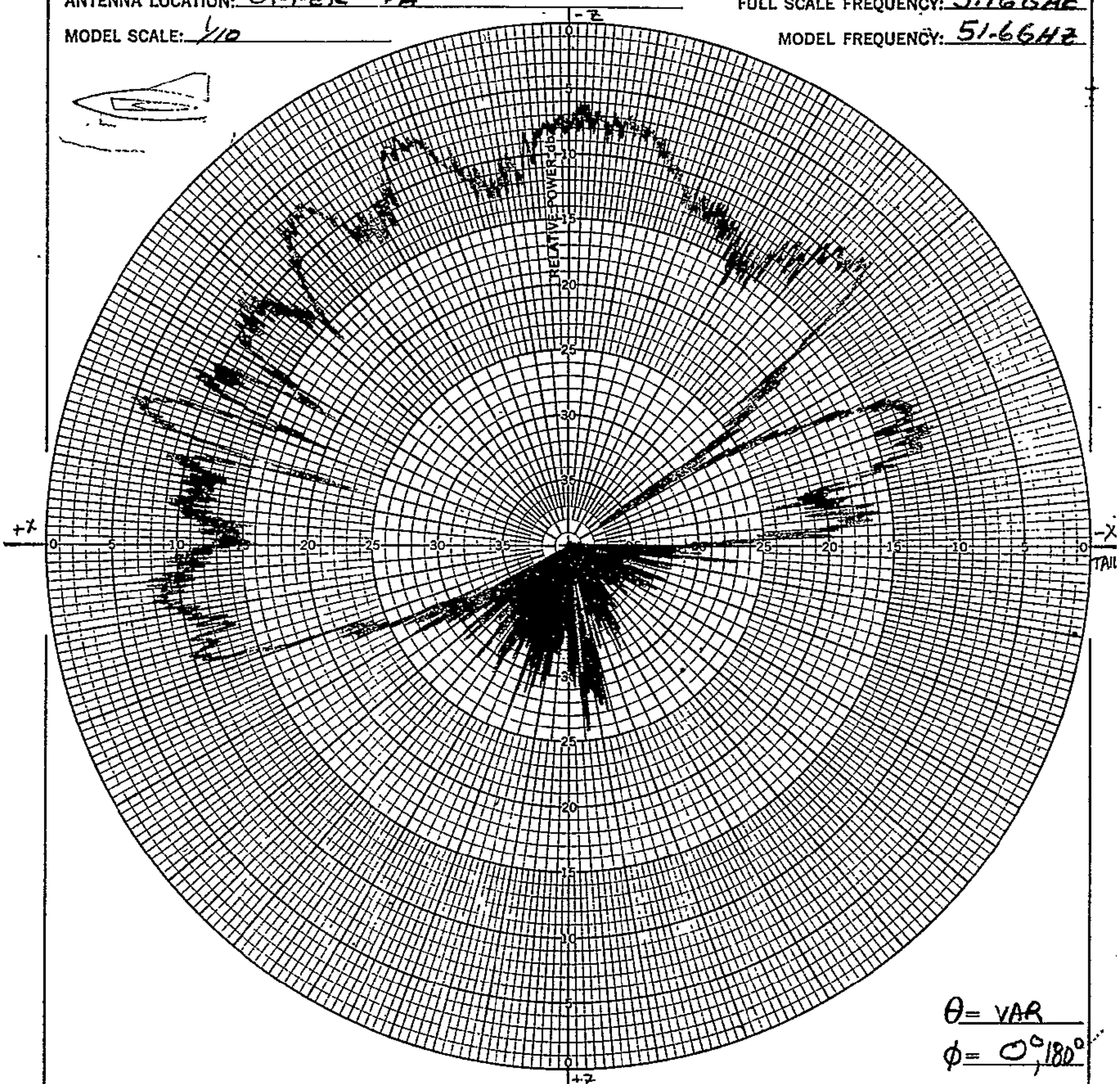
VEHICLE: SHUTTLE

ANTENNA LOCATION: UPPER L/H

FULL SCALE FREQUENCY: 5.16GHz

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6GHz



CONFIGURATION: W/TANK

INTEGRATOR COUNT:

POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

REMARKS:

TRANSMISSION DISTANCE: 110°

OBSERVER: RR-JM-AF

DATE: 4-22-75

MAC 231YL (7 MAY 64)

Figure 59. Upper Left Antenna with Tank X-Z plane

K&E CO.

DATE

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REPORT

MODEL

ANTENNA: C-BAND BEACON

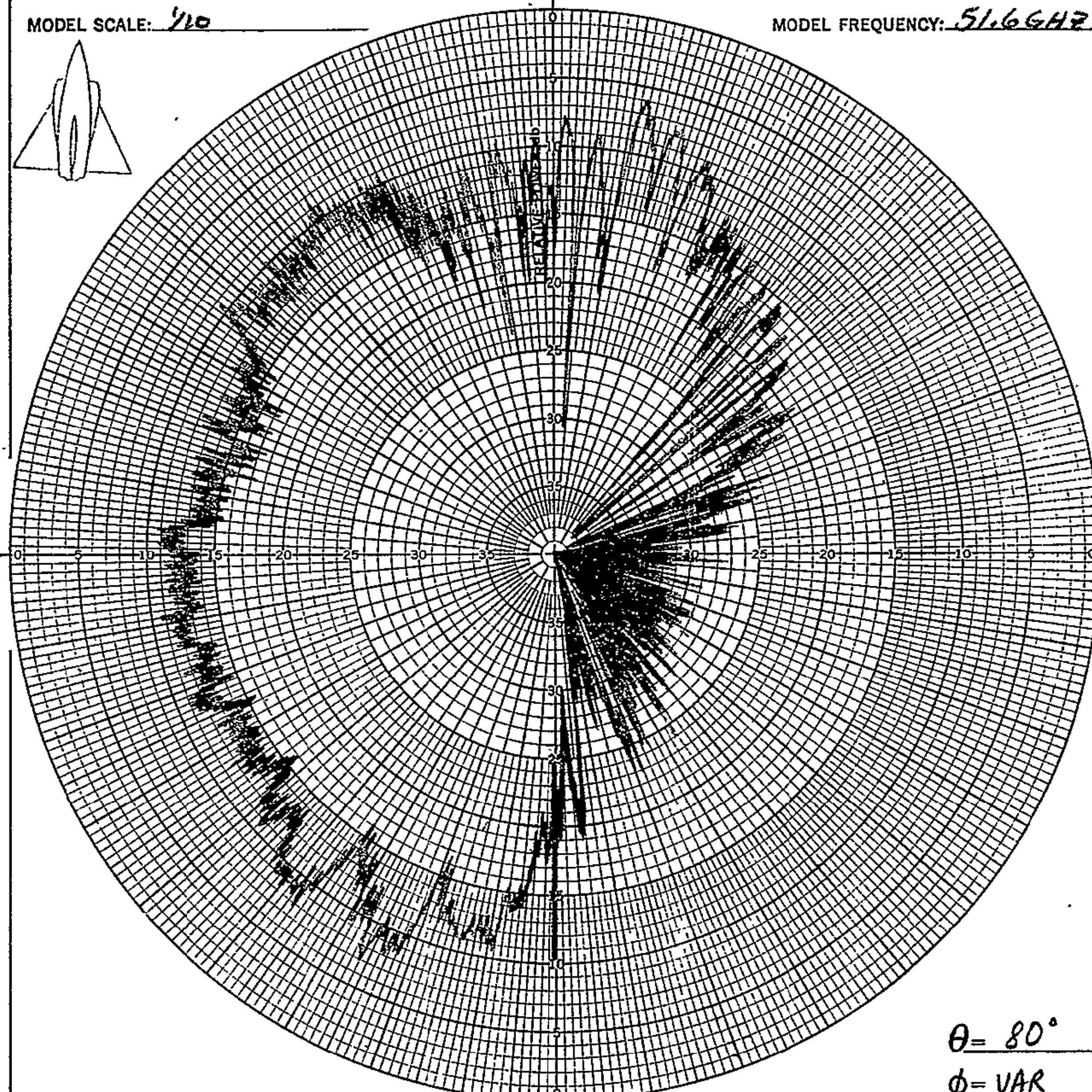
VEHICLE: SHUTTLE

ANTENNA LOCATION: UPPER L/H

FULL SCALE FREQUENCY: 5.16GHZ

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6GHZ



θ= 80°
φ= VAR
CONICAL CUT

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: WE-DM-DF

DATE: 4-22-75

MAC 231YL (7 MAY 6

Figure 60. Uppar Left Antenna with Tank θ= 80°

K&E CO.

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ST. LOUIS, MISSOURI

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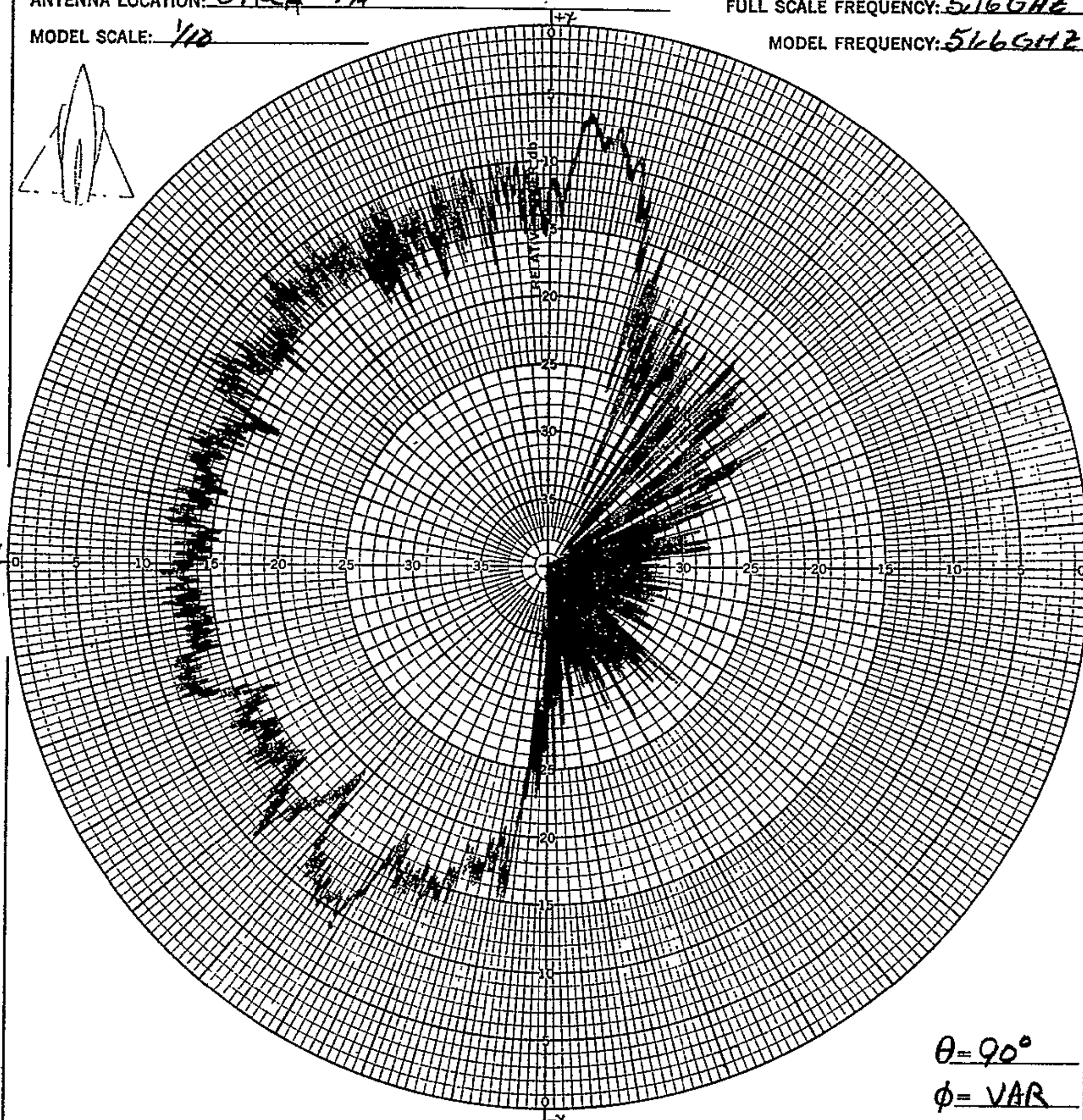
REPORT
MODEL

ANTENNA: C-BAND BEACON
ANTENNA LOCATION: UPPER L/H
MODEL SCALE: 1/10

VEHICLE: SHUTTLE
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL FREQUENCY: 5.16 GHZ



CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: DE-AM-DF DATE: 4-22-75

MAC 231YL (7 MAY 64) K&E CO.

Figure 61. Upper Left Antenna with Tank X-Y plane

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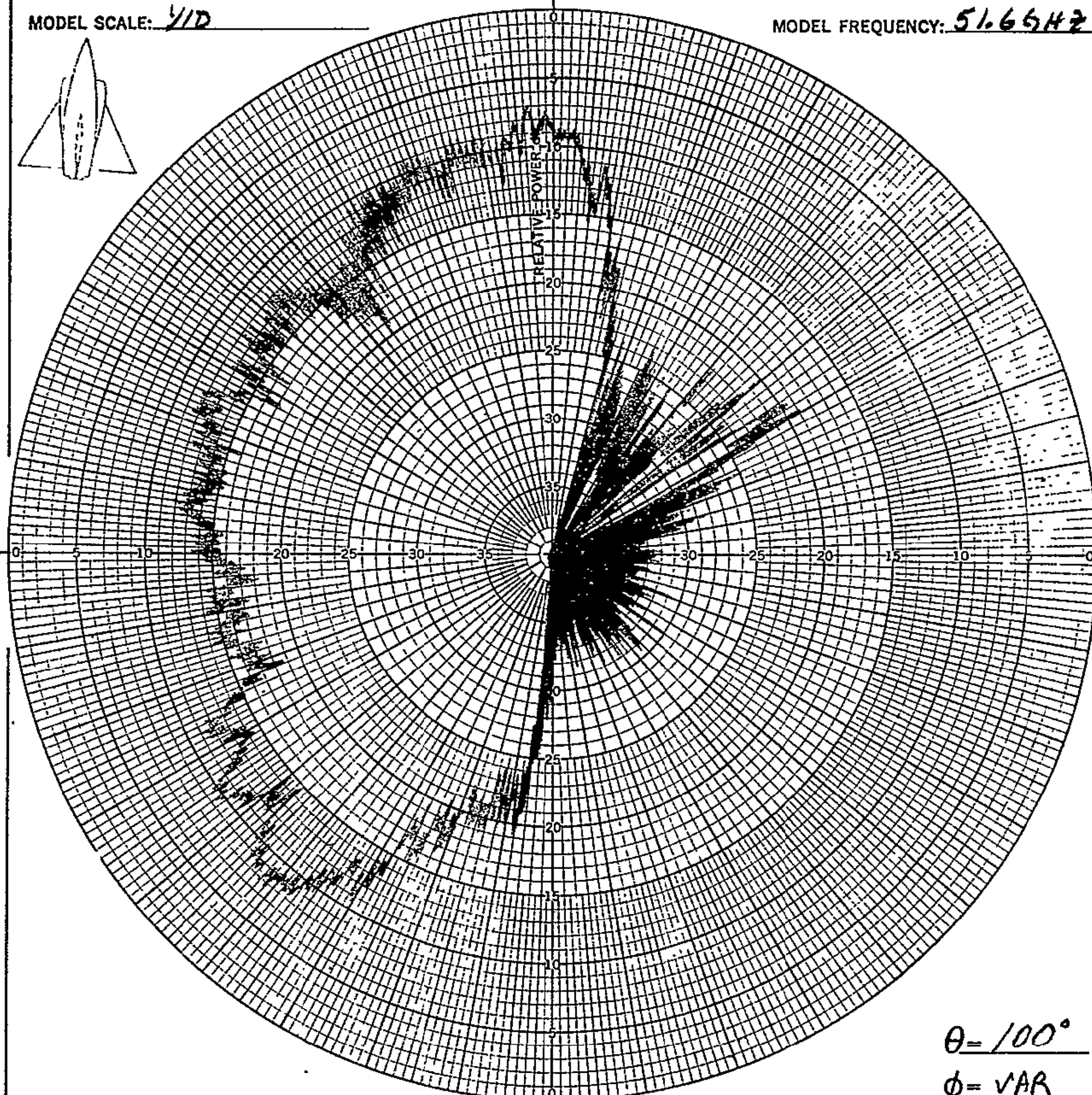
MCDONNELL DOUGLAS
ST. LOUIS, MISSOURI

REPORT
MODEL

ANTENNA: C-BAND BCN
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER L/H
FULL SCALE FREQUENCY: 5.16GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHZ



θ= 100°
φ= VAR
CONICAL CUT

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: WR-JM-DF DATE: 4-22-75

MAC 231YL (7 MAY 64)

Figure 62. Upper Left Antenna with Tank θ = 100°

K&E CO.

ANTENNA: C-BAND BEACON

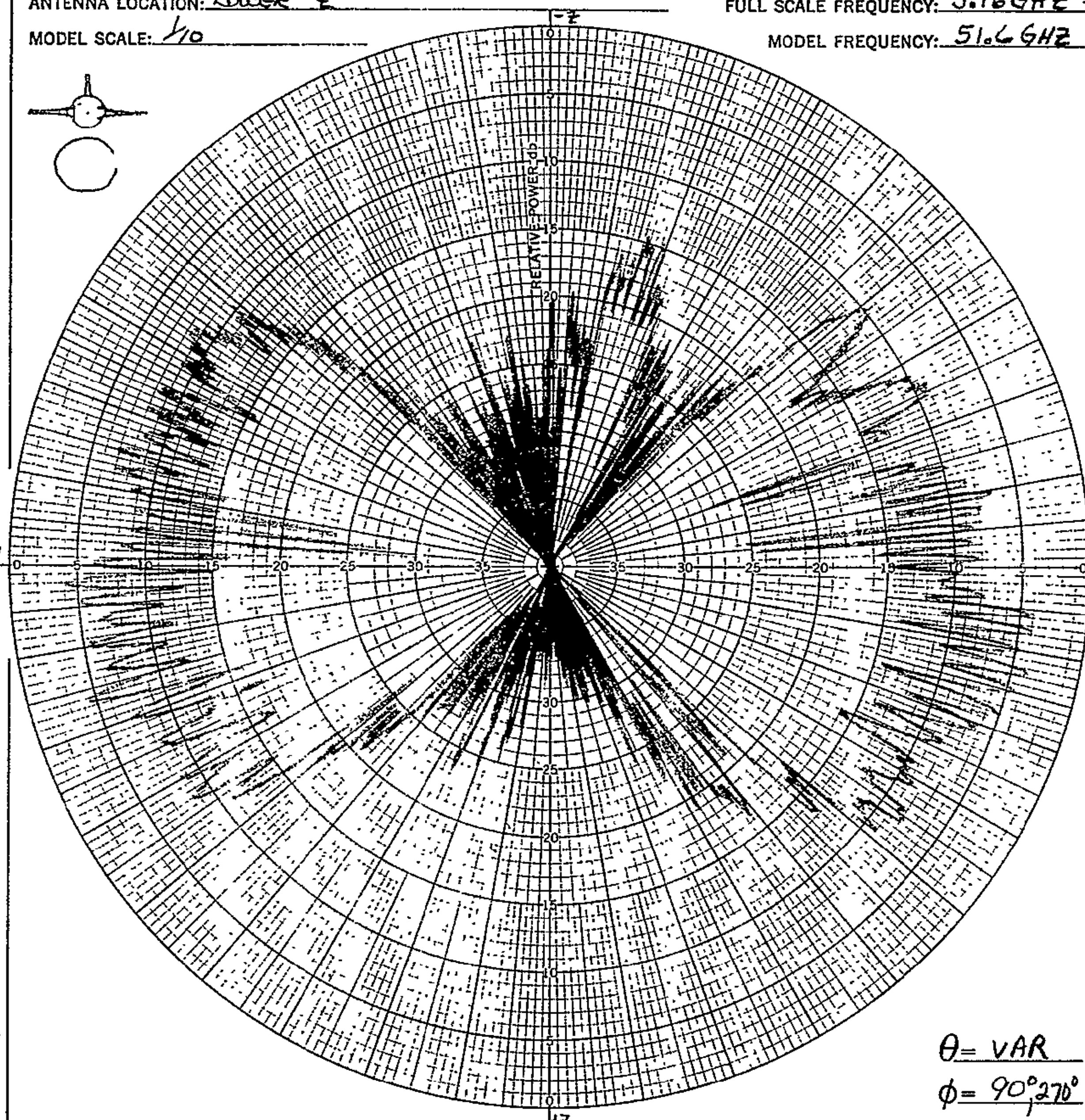
VEHICLE: SHUTTLE

ANTENNA LOCATION: LOWER ℄

FULL SCALE FREQUENCY: 5.16GHZ

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6GHZ



θ= VAR

φ= 90°, 270°

CONFIGURATION: W/ TANK

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eφ [ ] Eθ [ ] OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: [illegible]

DATE: 4-18-75

MAC 231YL (7 MAY 64)

Figure 63. Lower Antenna with Tank Y-Z plane

K&E CO.

DATE ____________ **MCDONNELL DOUGLAS** ST. LOUIS, MISSOURI PAGE ____________

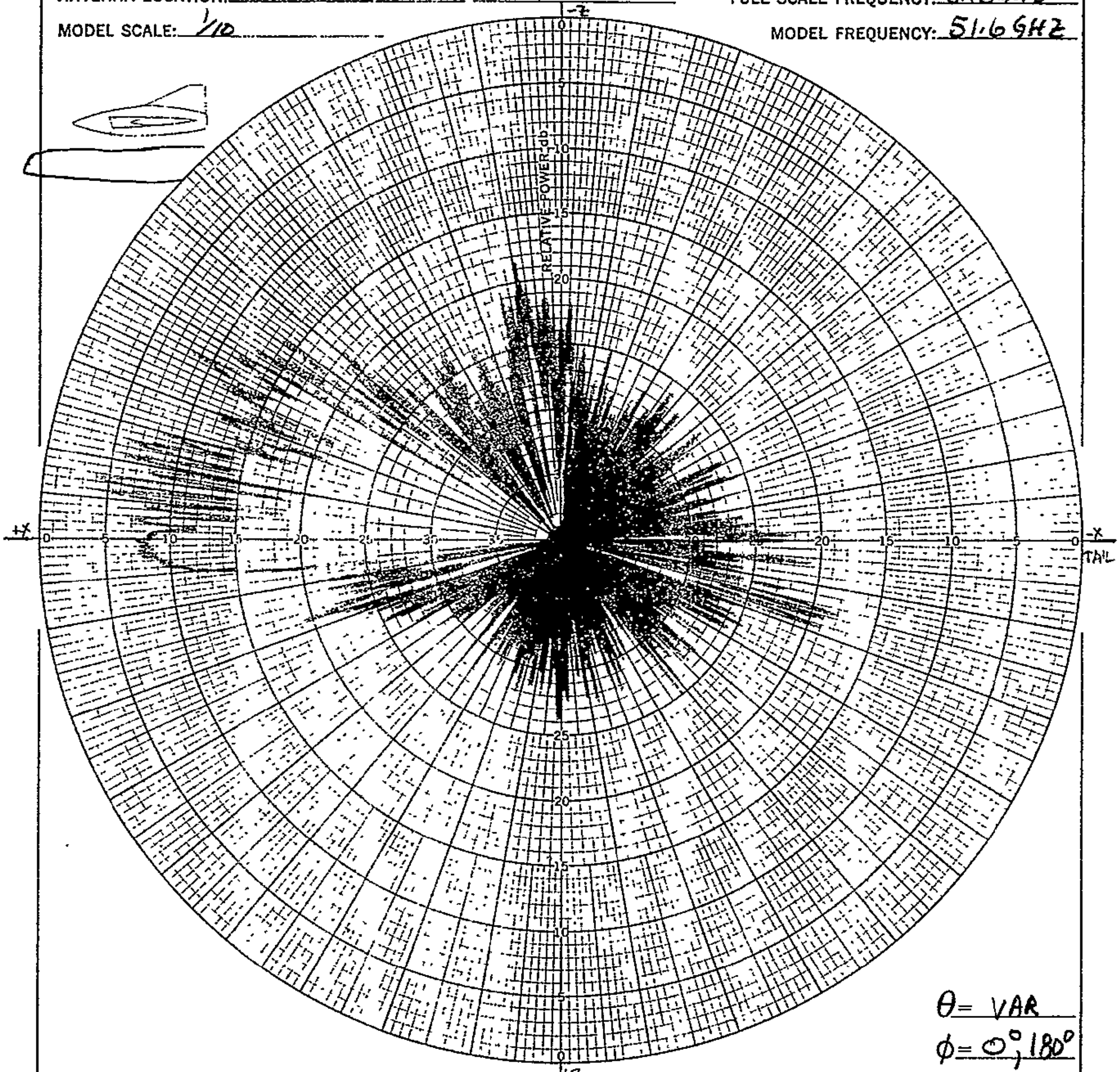
REVISED ____________ REPORT ____________

REVISED ____________ MODEL ____________

ANTENNA: C-BAND BEACON VEHICLE: SHUTTLE

ANTENNA LOCATION: LOWER ₵ FULL SCALE FREQUENCY: 5.16GHZ

MODEL SCALE: 1/10 MODEL FREQUENCY: 51.6GHZ



θ= VAR
ϕ= 0°, 180°

CONFIGURATION: [illegible]	INTEGRATOR COUNT:
	POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
	PLOTTED IN: RELATIVE POWER db
REMARKS:	TRANSMISSION DISTANCE: 110'
	OBSERVER: DR - JM DATE: 4-18-75

MAC 231YL (7 MAY 64

Figure 64. Lower Antenna with Tank X-Z plane

K&E CO.

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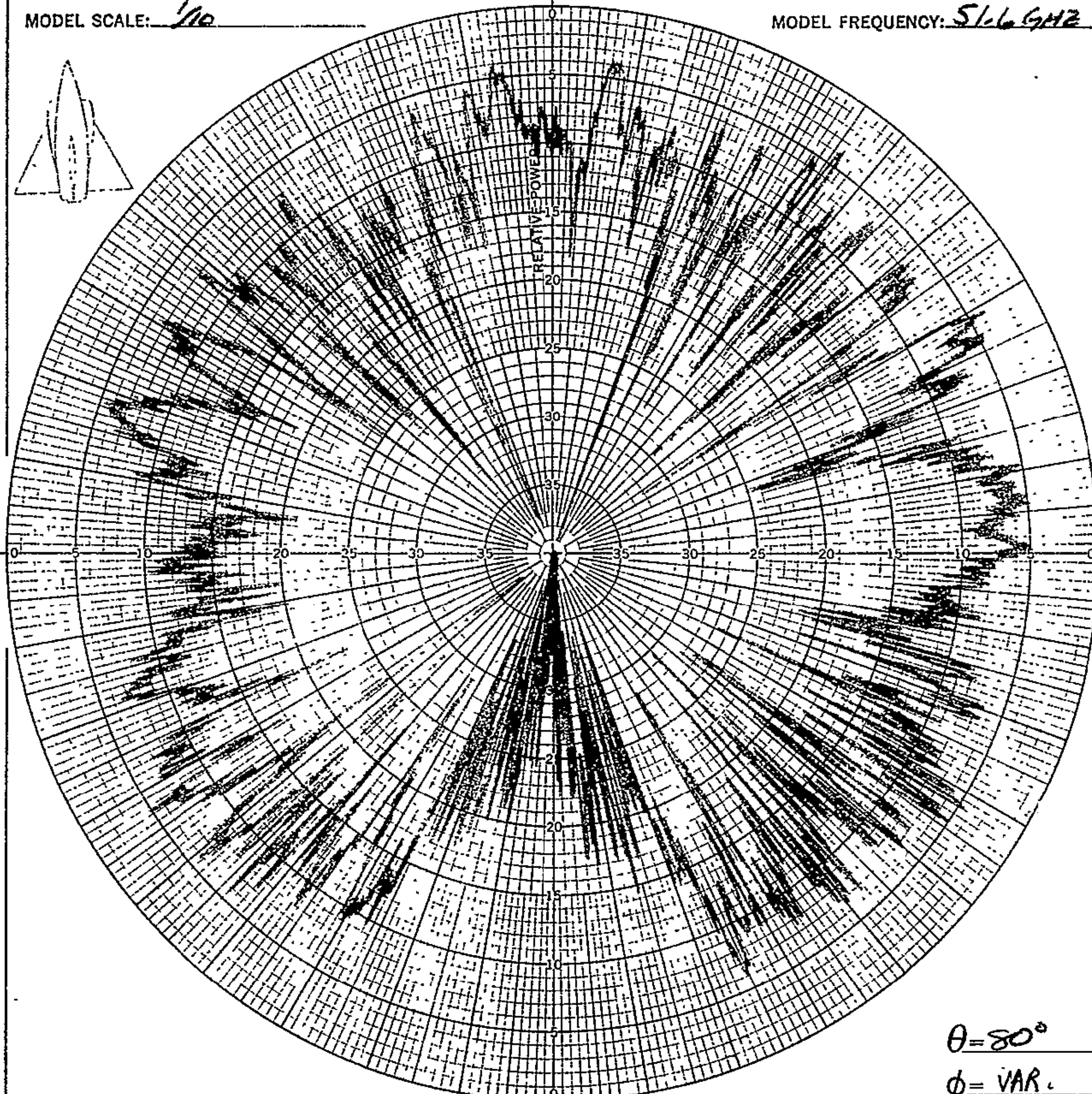
REPORT
MODEL

ANTENNA: C-BAND BEACON
ANTENNA LOCATION: LOWER ¢
MODEL SCALE: 1/10

VEHICLE: SHUTTLE
FULL SCALE FREQUENCY: 5.16GHZ
MODEL FREQUENCY: 51.6GHZ



$\theta = 80°$
$\phi =$ VAR.
CONICAL CUT

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: DR-DM-DF DATE: 4-21-75

MAC 231YL (7 MAY 64) K&E CO.

Figure 65. Lower Antenna with Tank θ = 80°

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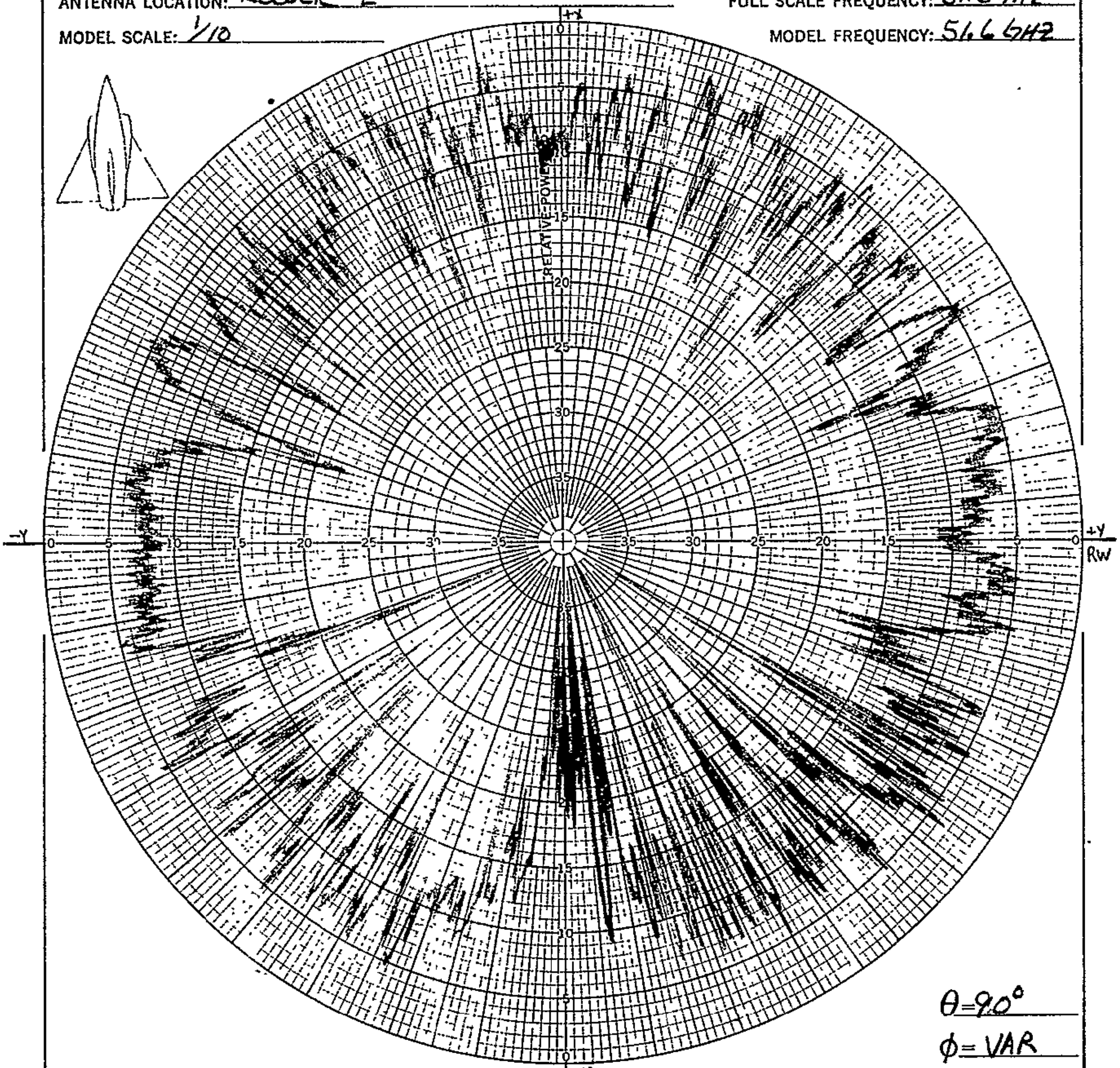
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: LOWER ℄
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHZ



CONFIGURATION: TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER:
DATE: 4-18-75

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Figure 66. Lower Antenna with Tank X-Y plane

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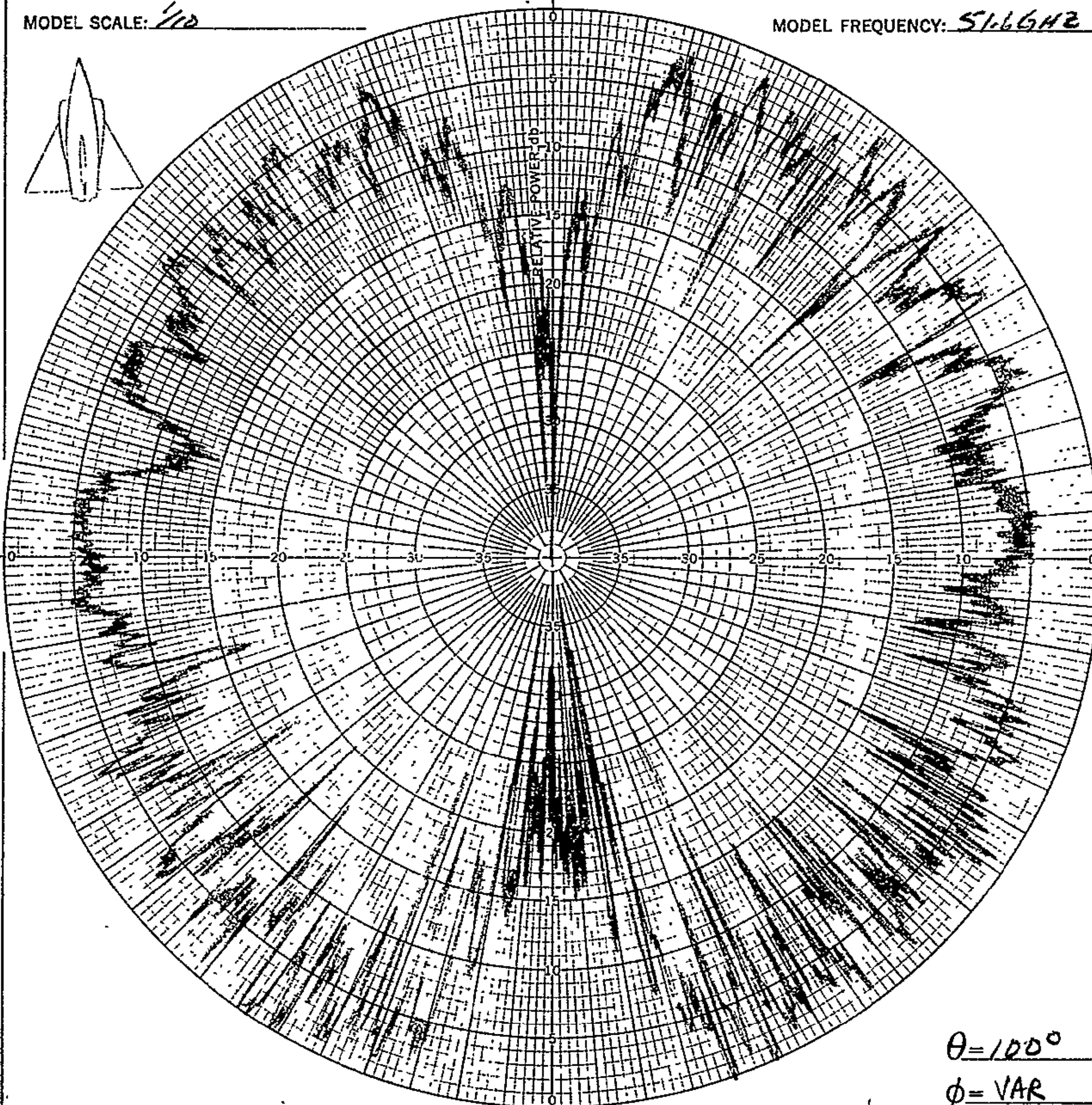
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE

ANTENNA LOCATION: LOWER ¢
FULL SCALE FREQUENCY: 5.16 GHZ

MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHZ



CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: [illegible]
DATE: 4/21-75

MAC 231YL (7 MAY 64)
K&E CO.

Figure 67. Lower Antenna with Tank θ = 100°

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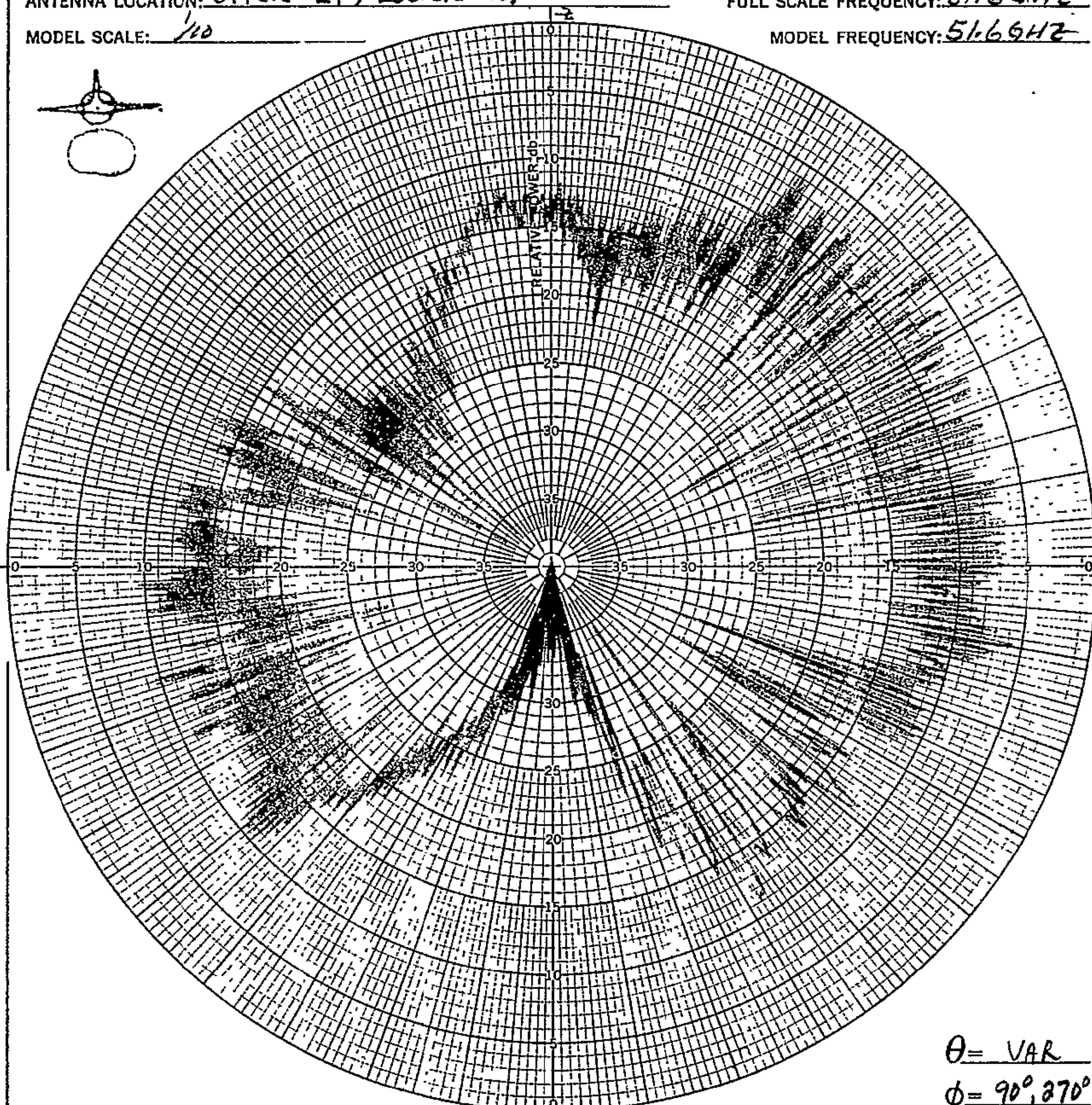
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER LT/LOWER RT
FULL SCALE FREQUENCY: 5.16 GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHZ



CONFIGURATION: W/TANK
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: [illegible]
DATE: 4-22-75

MAC 231YL (7 MAY 64)

Figure 68. Lower Right/Upper Left with Tank Y-Z plane

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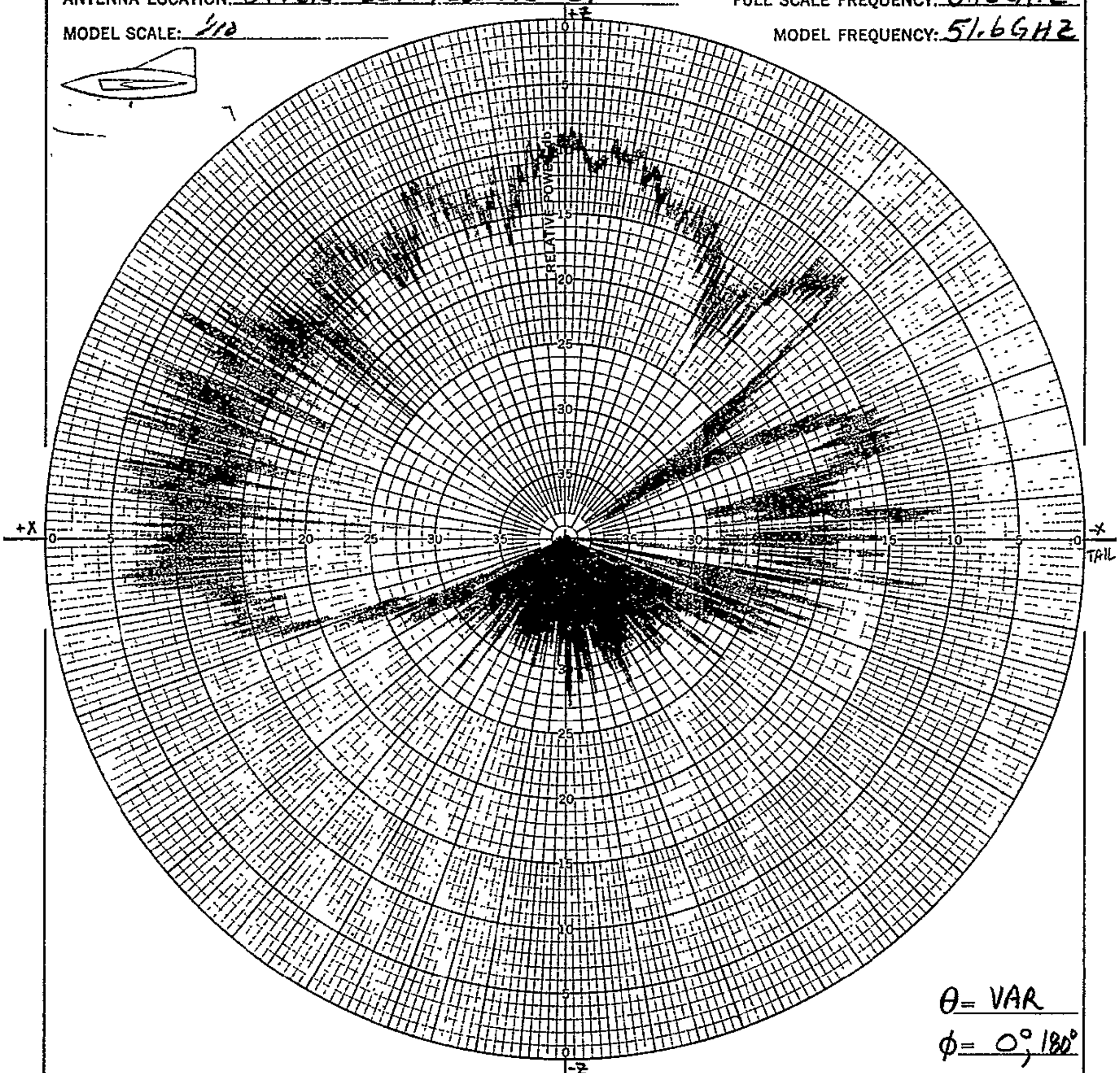
ANTENNA: C-BAND BCN
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER LEFT/LOWER RT
FULL SCALE FREQUENCY: 5.16GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHZ



θ= VAR
φ= 0°, 180°

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: DC. JM. DF
DATE: 4-22-75

MAC 231YL (7 MAY 64)

Figure 69. Lower Right/Upper Left with Tank X-Z plane

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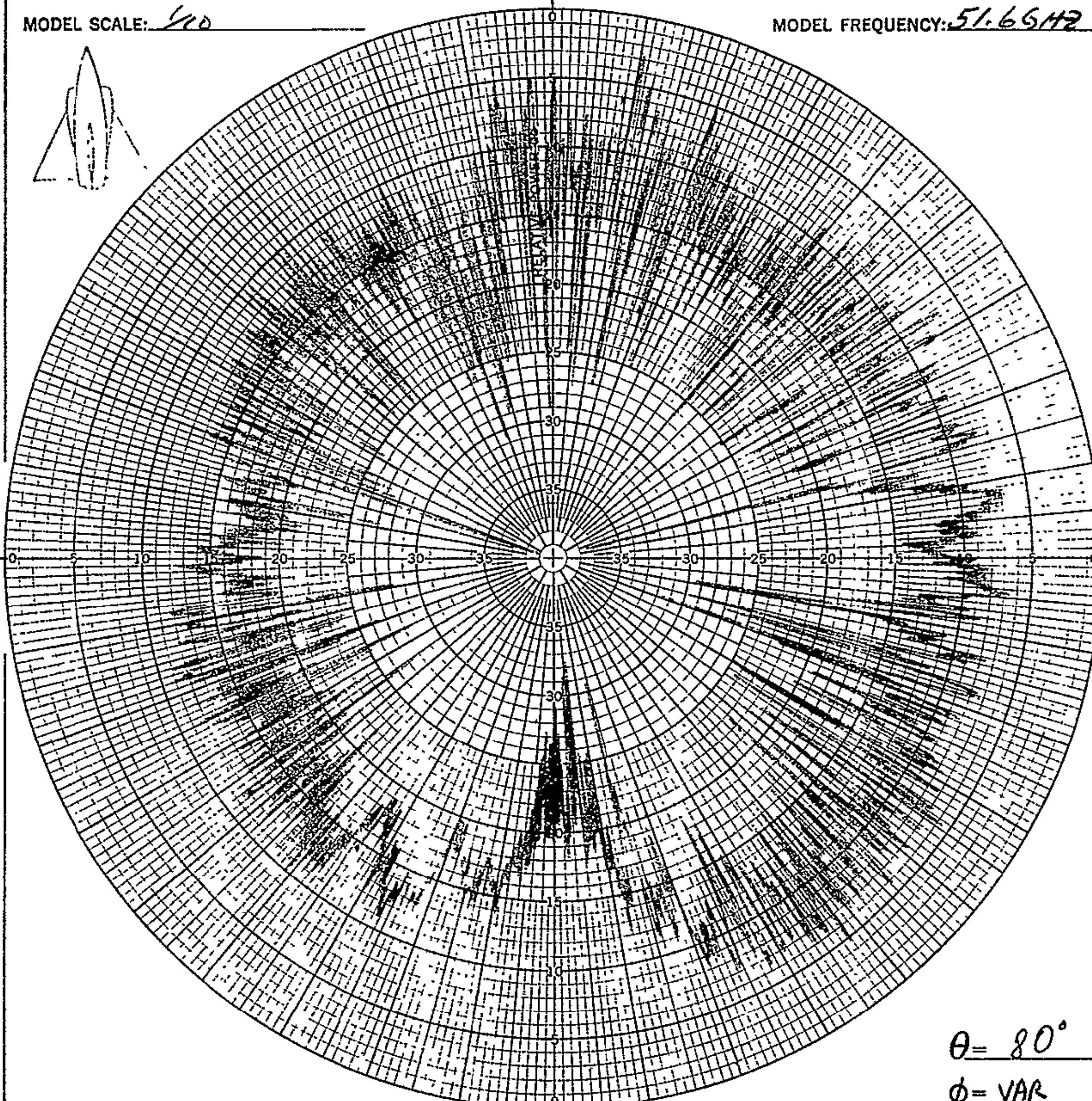
REPORT
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER LT/LOWER RT.
FULL SCALE FREQUENCY: 5.16 GHz
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHz



θ = 80°
φ = VAR
CONICAL CUT

CONFIGURATION: W/TANK
INTEGRATOR COUNT:
POLARIZATION: Eφ [ ] Eθ [ ] OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: AR-AM-DE
DATE: 4-22-75

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Figure 70. Lower Right/Upper Left with Tank θ = 80°

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MODEL

ANTENNA: C-BAND BEACON

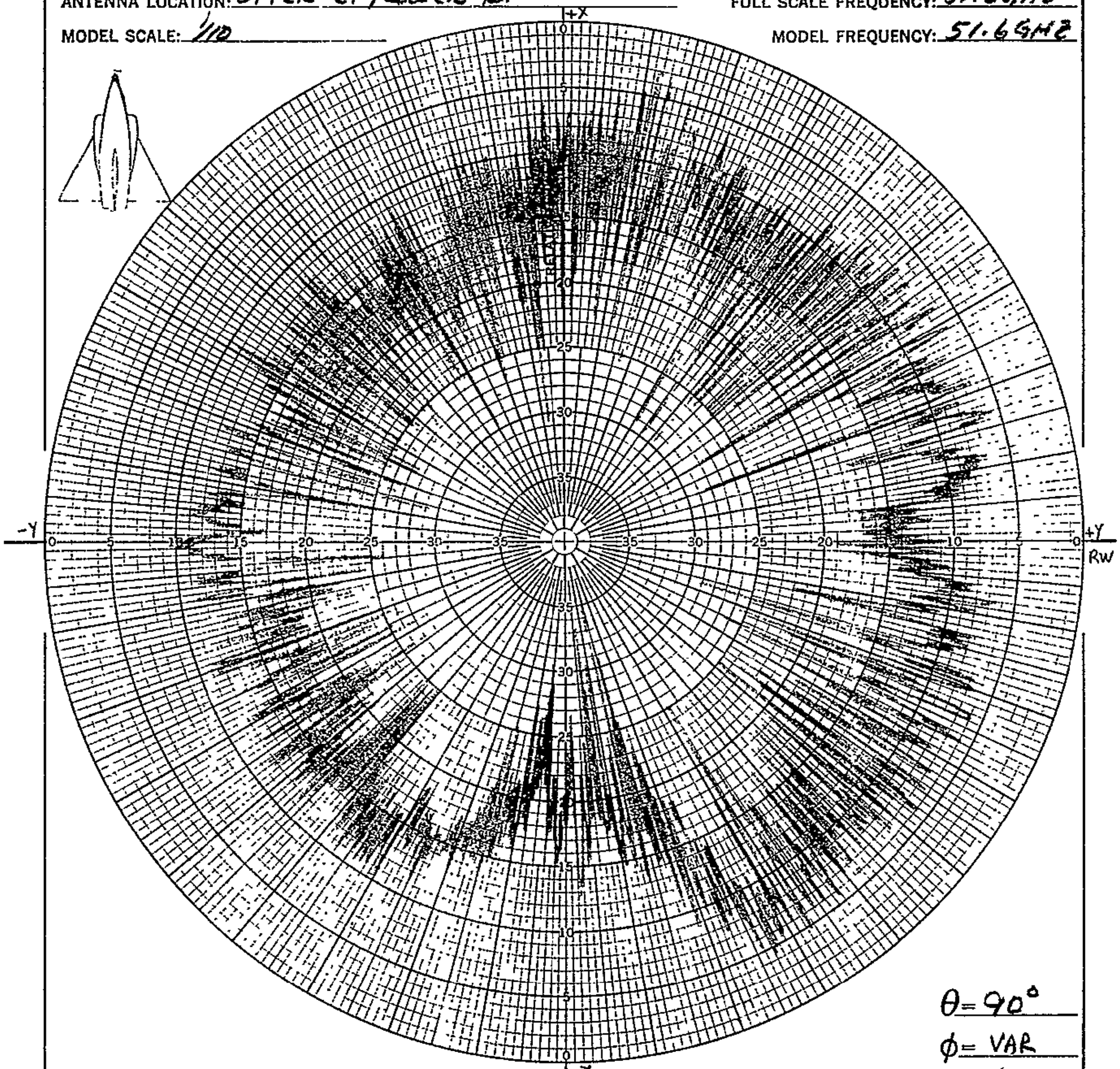
VEHICLE: SHUTTLE

ANTENNA LOCATION: UPPER LT/LOWER RT

FULL SCALE FREQUENCY: 5.16 GHZ

MODEL SCALE: 1/10

MODEL FREQUENCY: 51.6 GHZ



θ = 90°

φ = VAR

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:

POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC

PLOTTED IN: RELATIVE POWER db

TRANSMISSION DISTANCE: 110'

OBSERVER: DR-JM-DF

DATE: 4-22-75

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Figure 71. Lower Right/Upper Left with Tank X-Y plane

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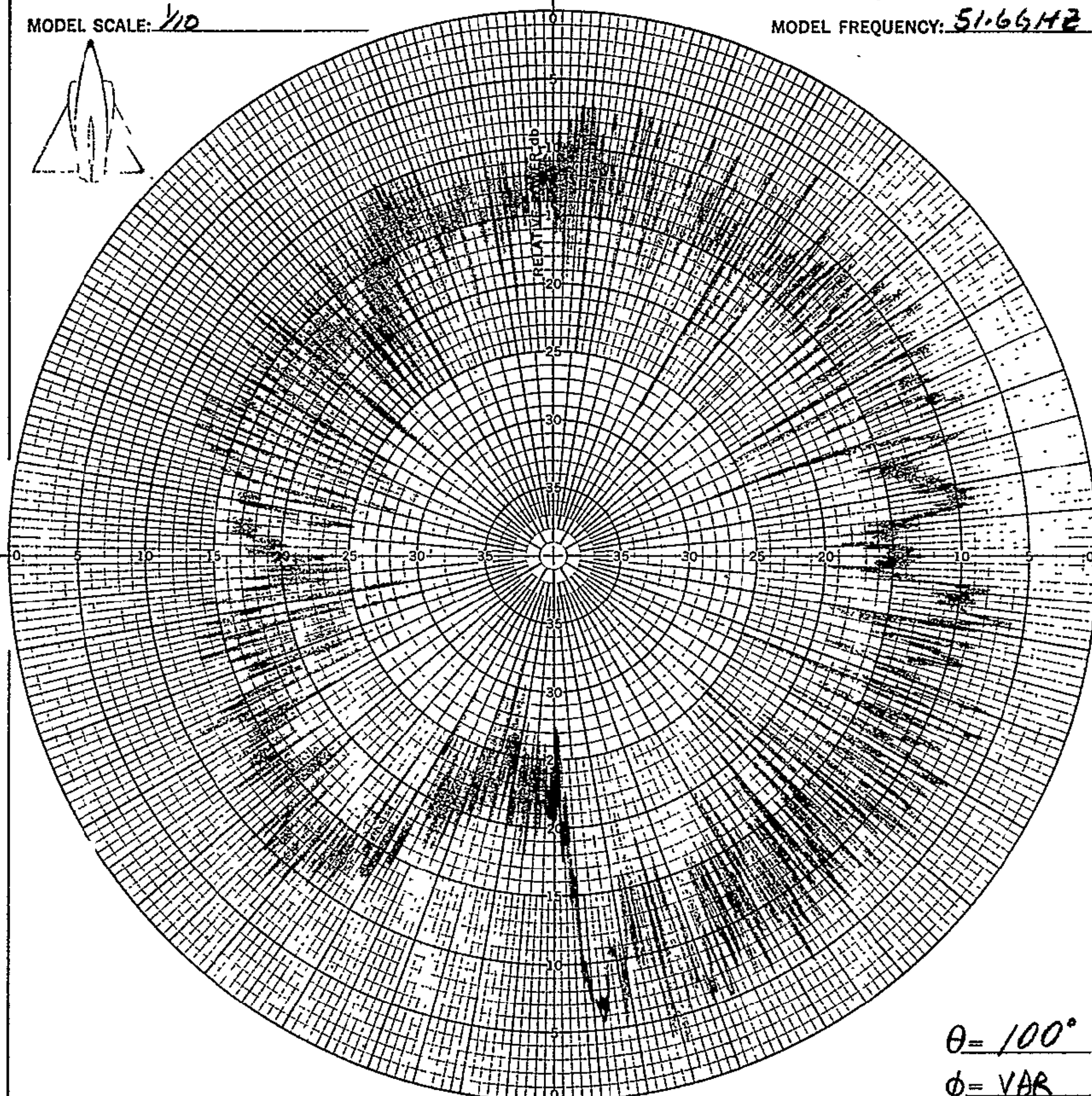
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER LT / LOWER RT
FULL SCALE FREQUENCY: 5.16GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHZ



θ = 100°
φ = VAR
CONICAL CUT

CONFIGURATION: w/TANK

REMARKS:

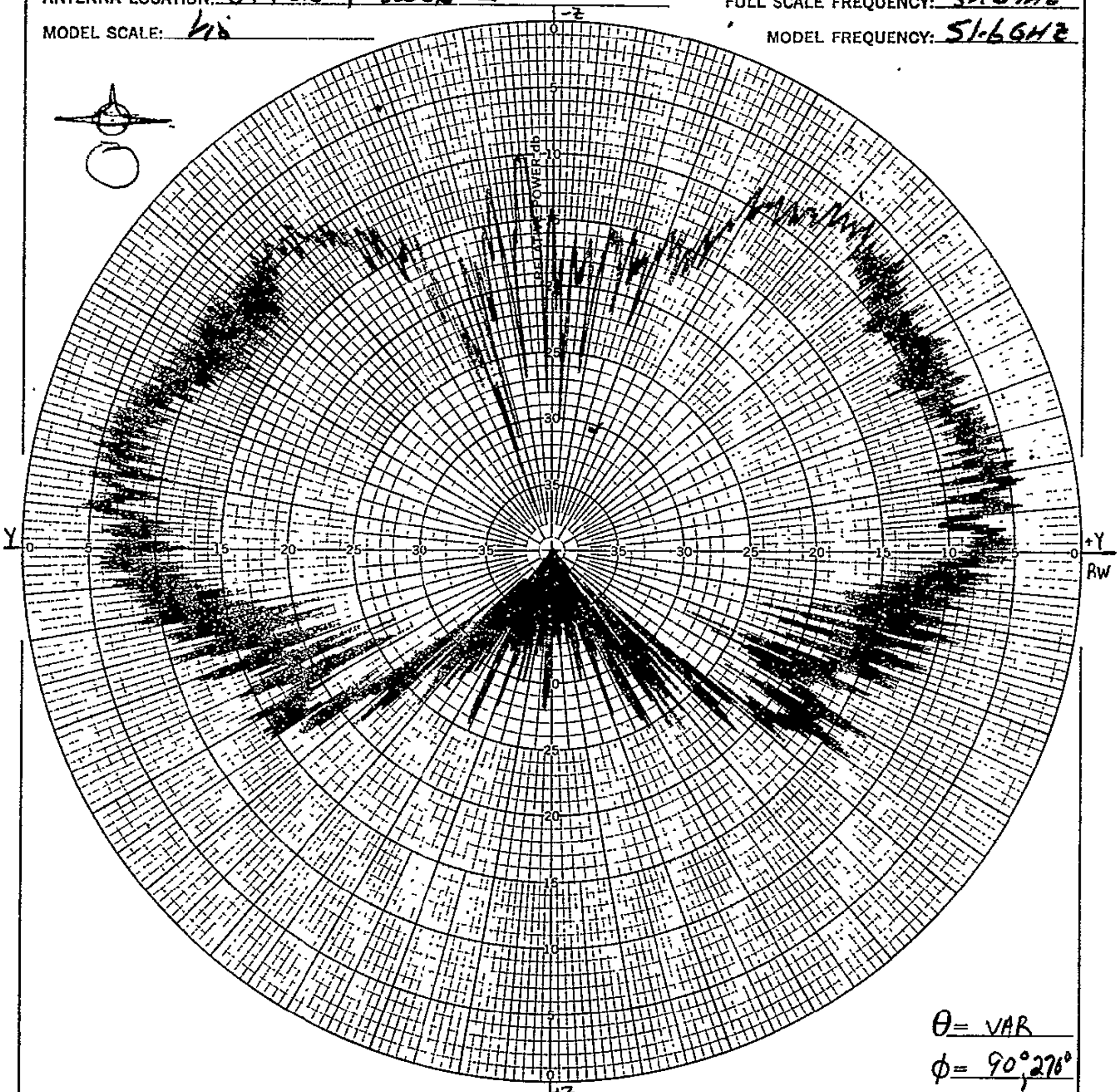
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: AGR - DM - DF
DATE: 4-22-75

MAC 231YL (7 MAY 64)

Figure 72. Lower Right/Upper Left with Tank θ = 100°

K&E CO.

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER & LOWER ℄
FULL SCALE FREQUENCY: 5.16GHZ
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6GHZ



CONFIGURATION: W/ TANK
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: KC-JM
DATE: 4-18-75

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Figure 73. Lower/Upper with Tank Y-Z plane

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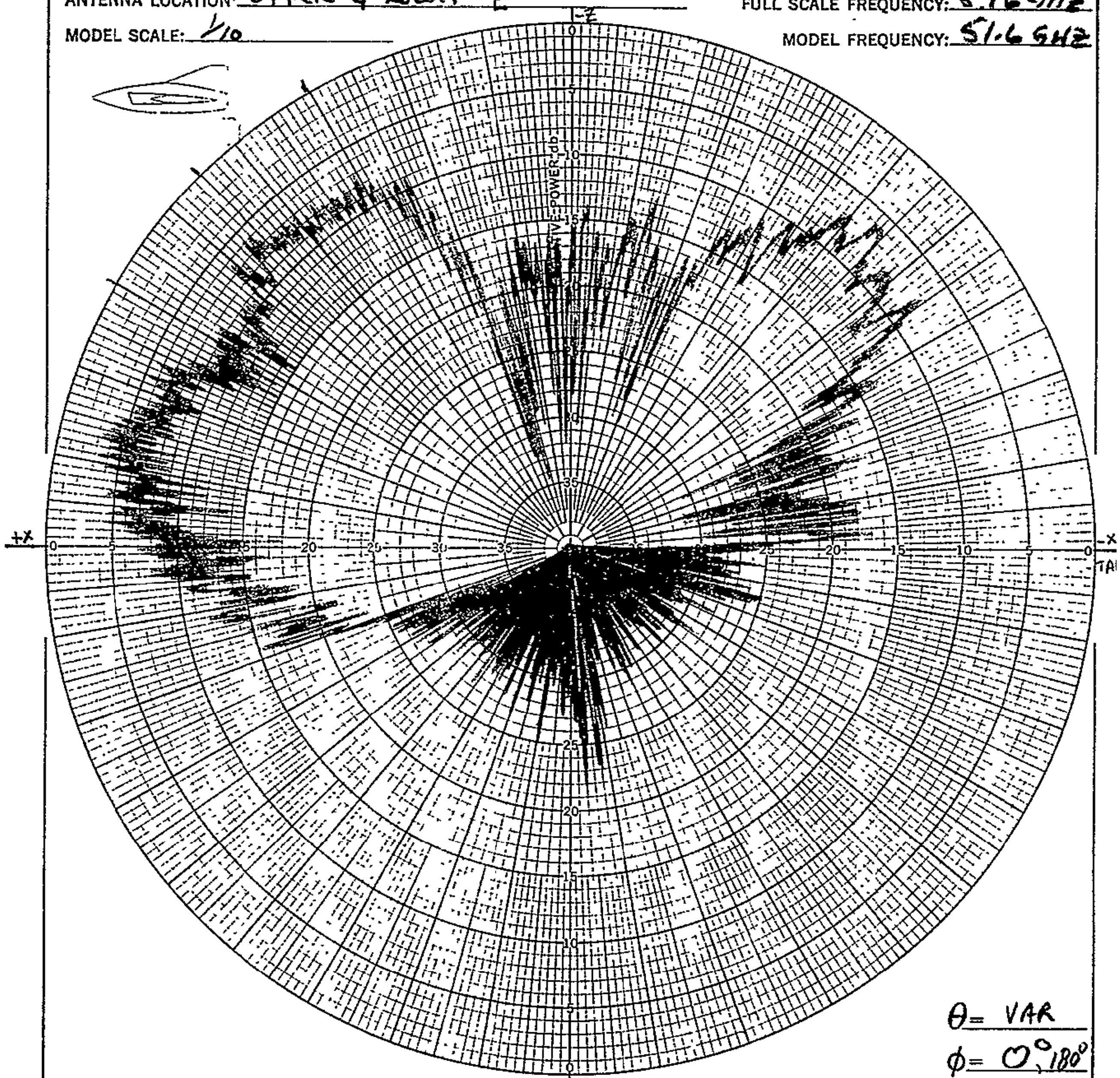
MODEL

ANTENNA: C-BAND BEACON
VEHICLE: SHUTTLE
ANTENNA LOCATION: UPPER & LOWER ℄
FULL SCALE FREQUENCY: 5.16 GHz
MODEL SCALE: 1/10
MODEL FREQUENCY: 51.6 GHz



CONFIGURATION: W/ TANK
INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
REMARKS:
TRANSMISSION DISTANCE: 110'
OBSERVER: QR-JSH
DATE: 4-18-75

MAC 231YL (7 MAY 64)

Figure 74. Lower/Upper with Tank. X-Z plane

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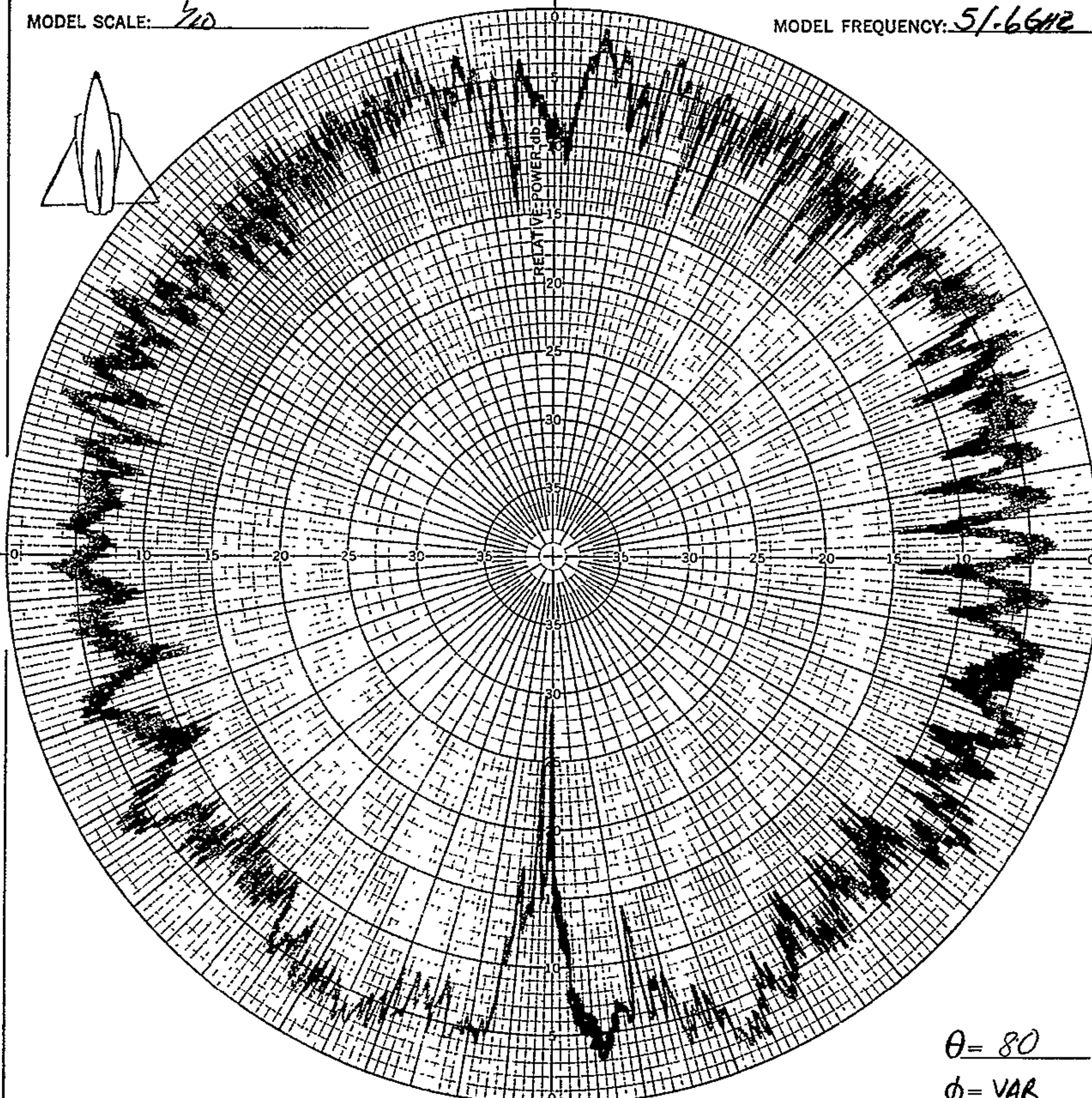
MODEL:

ANTENNA: C-BAND BEACON
ANTENNA LOCATION: UPPER & LOWER ℄
MODEL SCALE: 1/10

VEHICLE: SHUTTLE
FULL SCALE FREQUENCY: 5.16 GHz
MODEL FREQUENCY: 5.16 GHz



θ = 80
φ = VAR
CONICAL CUT

CONFIGURATION: W/TANK

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ [ ] Eθ [ ] OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 710'
OBSERVER: OR-AM
DATE: 4-18-75

MAC 231YL (7 MAY 64)

Figure 75. Lower Upper with Tank θ = 80°

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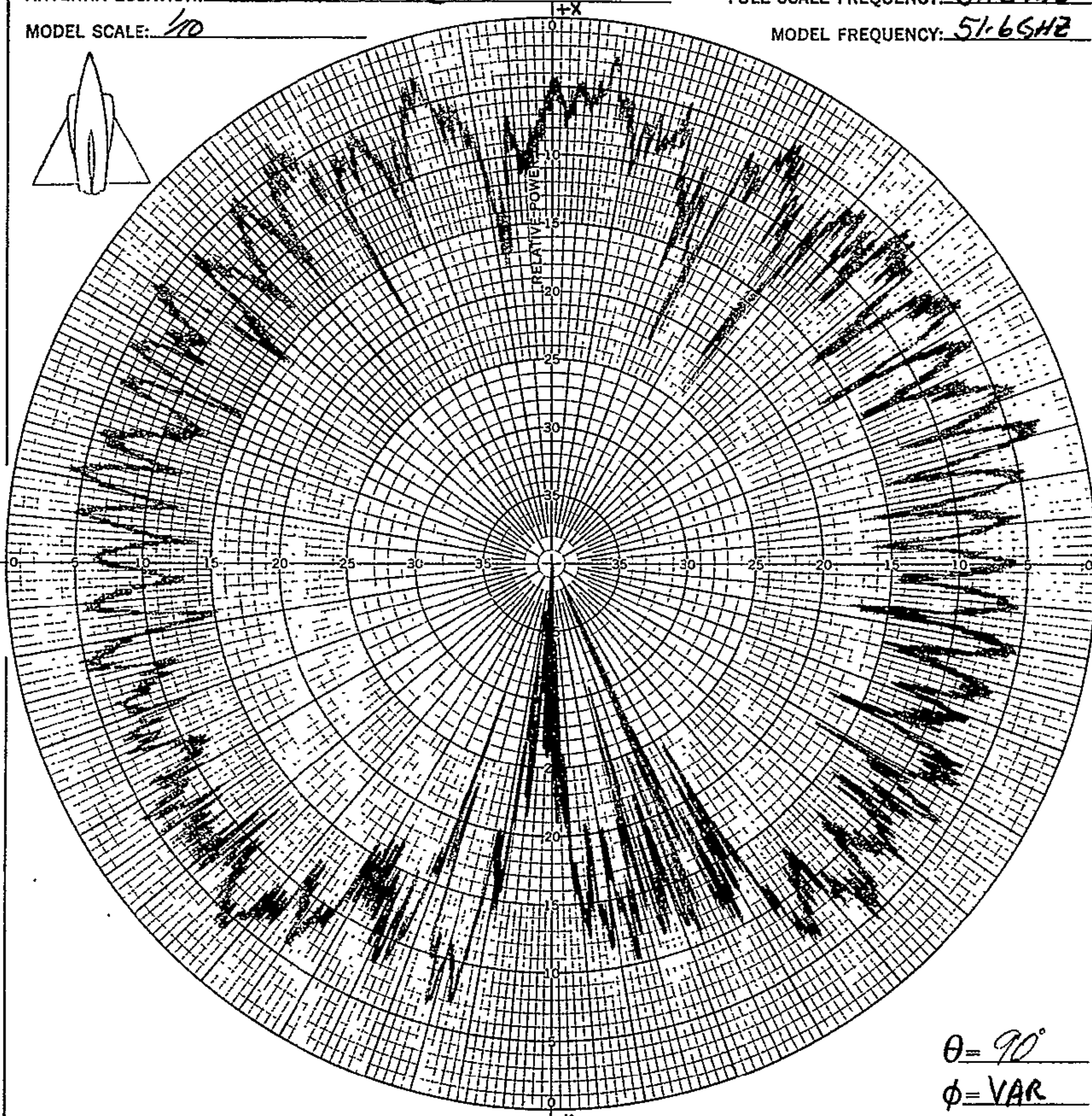
REPORT
MODEL

ANTENNA: C-BAND BEACON
ANTENNA LOCATION: UPPER & LOWER ℄
MODEL SCALE: 1/10

VEHICLE: SHUTTLE
FULL SCALE FREQUENCY: 5.16GHZ
MODEL FREQUENCY: 51.6GHZ



CONFIGURATION: W/TAN

REMARKS:

INTEGRATOR COUNT:
POLARIZATION: Eφ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: DR-JM DATE: 4-18-75

MAC 231YL (7 MAY 64)

Figure 76. Lower/Upper with Tank X-Y plane

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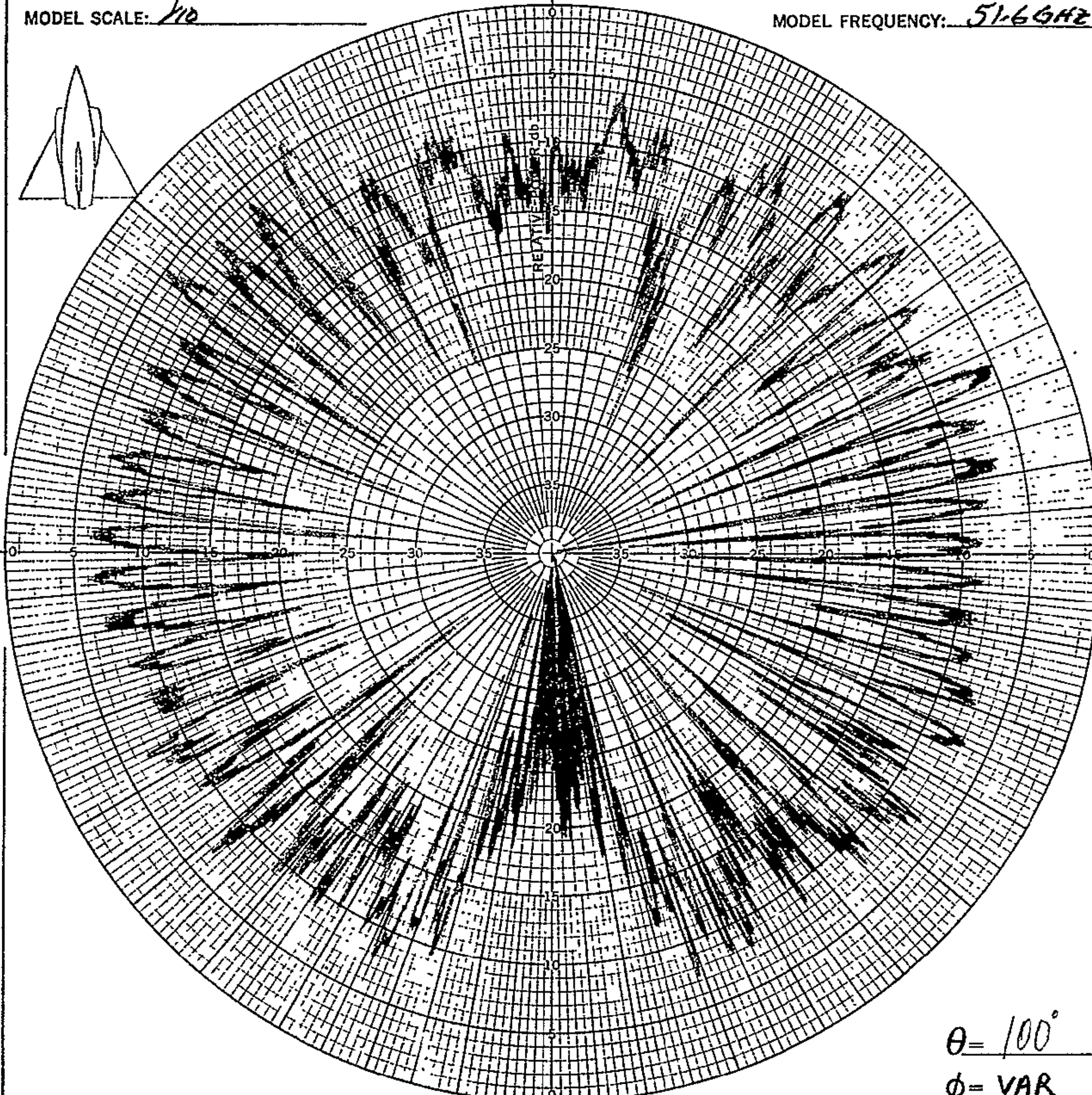
REPORT
MODEL

ANTENNA: GRAND BEACON
ANTENNA LOCATION: UPPER ¢ LOWER ¢
MODEL SCALE: 1/10

VEHICLE: SHUTTLE
FULL SCALE FREQUENCY: 5.16GHZ
MODEL FREQUENCY: 51.6GHZ



θ= 100°
ϕ= VAR
CONICAL CUT

CONFIGURATION: TPI

INTEGRATOR COUNT:
POLARIZATION: Eϕ ☐ Eθ ☐ OTHER: RHC
PLOTTED IN: RELATIVE POWER db
TRANSMISSION DISTANCE: 110'
OBSERVER: DR-DM DATE: 4-18-75

REMARKS:

MAC 231YL (7 MAY 64)

Figure 77. Lower/Upper with Tank θ = 100°

K&E CO.

reference it is necessary to know the maximum gain level and set its value equal to the peak gain of the antenna under test. For example in Figure 47 the printout of a "0" represents a gain of 5 dB over isotropic and a printout of "20" is a level 15 dB below isotropic.

4.0 RESULTS

This section discusses the look angle calculations, vehicle shadowing evaluation and antenna patterns as they apply to the use of the C-Band Beacon during Approach and Landing Tests.

A previous calculation in Reference G has shown the C-Band Beacon circuit margin to vary from 30.6 dB to 45.8 dB for slant ranges of 64.3 nautical miles and 11.1 nautical miles respectively assuming a 0dB beacon antenna power gain. The longer slant range represents a typical maximum and the shorter slant range is typical for separation of the Orbiter from the 747. Careful examination of the look angles of Figures 6 and 7 show that the required coverage is near the X-Y plane for both reference missions and that coverage off the right wing and nose is required from immediately before separation through landing. Examination of the antenna patterns in areas around the X-Y plane (i.e. θ - 80°, 90° and 100°) show that severe interferometer effects as high as 80dB per degree occur in this region for two antennas in parallel. Also, examination of the patterns (Figures 37, 49, 65, 66 and 67) associated with the lower antenna alone show that significantly better coverage is obtained from this antenna.

As far as vehicle shadowing is concerned it is interesting to note that the sine wave type variation from Quad locations which appear in the vehicle blockage patterns also appear in the actual antenna patterns (See Figures 47 and 48). It should also be observed that the blockage effect of the tank is significantly greater than that for the 747.

Figure 36 shows the tank blockage in the Y-Z plane to be approximately 105°, whereas the 747 blockage angle is only 64° with an inclination angle of 5° between the 747 and the Orbiter. In the X-Z plane the coverage with the tank is limited to about 5° below the X-axis (see Figure 37), however the 747 blockage is approximately 20° for the 5° inclination.

5.0 CONCLUSIONS

Based on the results of this study it is recommended that a single C-Band Beacon Antenna be used in the Lower Hemi S-Band cutout location instead of the presently planned locations of lower left and upper right S-Band Quad cutouts. The single antenna will eliminate the need for antenna switching by the ground and will eliminate interferometer nulling effects of two antennas in parallel.

The present arrangement for the C-Band Beacon will probably provide adequate information for the Approach and Landing Tests; however, it should be pointed out that the simpler system involving only one antenna provides better coverage and is operationally simpler since no switching is required. The two antenna arrangment is required only for aircraft with significant changes in attitude.

To further substantiate the recommendation of a single lower antenna plots of the look angles from immediately before separation to landing are superimposed on the single lower radiation distribution printout for landing on runways 17 and 22 in Figure 78. The lowest gain level encountered is 20 dB below isotropic and most of the gain levels are near isotropic.

6.0 REFERENCES

(A) Symonds, R. J., "Orbiter/C-Band Beacon Antenna", Rockwell ICD-3-0061-02, Jan. 7, 1975.

(B) Elder, W. C., "Orbiter/C-Band Beacon", Rockwell ICD-3-0061-01, Jan. 31, 1975

(C) Fitch, M., "Schematic Diagram-Communication and Tracking C-Band Beacon", Rockwell Drawing No. VS70-740301, June 28, 1974

(D) Carman, G. L. "Approach and Landing Test Preliminary Reference Mission Trajectory Data Tape No. 2" Johnson Space Center No. FM42(75-2), January 10, 1975

(E) AFFTC Instrumentation Map AIM-1, Edition 3, Defense Mapping Agency Aerospace Center, Missouri 63118, June 3, 1974

(F) Smith, B. A. "Carrier Aircraft Modification Configuration Baseline Document," Boeing No. 81205, August 14, 1975

(G) Lindsey, J. F. "Evaluation of ALT Flight and Trajectory Profile for C-Band Beacon Antenna Coverage", MDTSCO No. 1.2-WP-B0203-019, February 26, 1975