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Report DRD MA-183TF

# SHUTTLE S-BAND HIGH GAIN SWITCHED BEAM BREADBOARD ANTENNAS

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## 1. INTRODUCTION AND DESCRIPTION

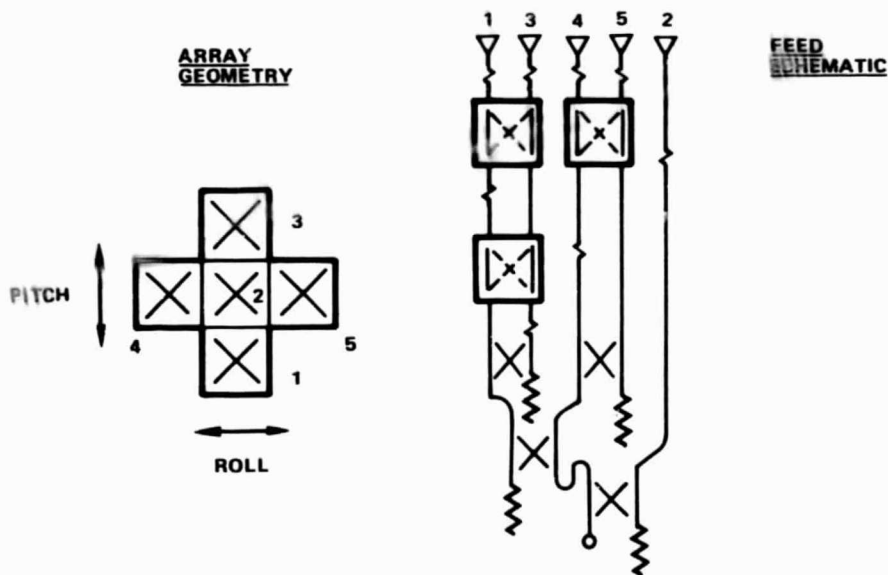
This is the final report for contract NAS9-17006, Shuttle High Gain Breadboard Antennas.

The two Shuttle High Gain Breadboard Antennas will demonstrate the performance of the proposed system, which consists of four of the five-element, eight-beam antennas designed to have improved performance over the existing two-element, two-beam antennas.

Each eight-beam antenna uses five closely spaced radiating elements in a cross formation, which are phase switchable to direct the beam. Power division is accomplished by an integrated stripline coupler assembly and phase tuning is accomplished through the use of precision RF cable lengths. Beam switching is done with three coaxial transfer switches.

The radiating elements are broad-banded crossed dipoles that are fed to provide righthand circular polarization.

The feed network and array geometry used for the eight beam antenna are as shown in the figure below.



## 2. FINAL FABRICATION AND ASSEMBLY

The upper flange was modified by the placement of additional layers of quartz disks over the radiating elements. This modification was successful in improving the performance.

The RF coaxial switches were originally received from the Novak Corporation in the beginning of August. They were found to have intermittent performance and were returned to the vendor for adjustments. Upon return from the vendor, one of the switches still exhibited intermittency, and the set was determined to be unacceptable for use. Transco Corporation's Engineering Group agreed to supply the program with three switches built from spare parts. These were delivered on October 19, 1984.

RF cable fabrication and phase trimming proved to be very time-consuming due to numerous iterations between proper phase length and mechanical fit.

After the final assembly integration, final bench tests were made and pattern testing was begun.

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### 3. TEST RESULTS

#### 3.1 COMPONENT TESTING (REFERENCE ATTACHED DATA SUMMARY SHEETS)

##### 3.1.1 Individual Components

Most of the individual components are common to both the upper and lower antennas. The only exceptions are the five cables which feed the elements and the input cables. The common components are exchanged between the upper and lower flanges and housings.

Two of the three coaxial switches had measured losses within the expected range. However, the third switch measured approximately twice as lossy as normal but was used anyway due to lack of time for the procurement of another switch.

All of the RF cables except for cable "e" (to the center element) measured well below their budgeted loss value. Cable "e" for both the upper and lower antennas measured only slightly more lossy than was predicted.

The stripline power divider network insertion loss measured approximately 0.5 dB better than was predicted through all RF paths. Its input VSWR and returned power to the load ports were low.

##### 3.1.2 Feed Subassembly

The feed subassembly consists of the power divider, the coaxial switches, and the RF cabling. This combination of components measured approximately 0.5 dB more lossy in some cases than was predicted. However, the input VSWR was good. Phase measurements, which were recorded at 2150 MHz only, demonstrated that phasing was held within 7° of design values.

##### 3.1.3 Radiating Subassembly

The radiating subassembly consists of the radiating elements with element couplers, combined with the antenna flange/radome. Input VSWR into both upper and lower units was low. Power at the load ports was reduced by the placement of additional layers of quartz over the apertures. Some values still spiked slightly higher than the target value.

#### 3.2 FINAL ASSEMBLY TESTING

##### 3.2.1 Final Bench Testing

Input VSWR of the complete assembly was generally lower than the budgeted value. Only in beam position 5 on the upper and lower antennas did the VSWR rise higher than the budgeted value. Power at the load ports of the power divider and radiating elements was measured at the complete assembly level. Values for some beam positions exceeded the budgeted values but the general trend was data close to those values.

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### 3.2.2 Radiation Patterns

Proper scan angles for each beam on both the upper and lower antennas were obtained by exciting only one row of elements in the array at a time. Patterns from a given plane were then obtainable with the opposing plane at boresight. The peak gain angles derived in this fashion were then used in testing the full five-element array.

The lower antenna was fully evaluated for gain and axial ratio. Gain measurements for 2041.9 and 2106.4 MHz are slightly less accurate than the other radiation data since the scan angles used at these frequencies were obtained at 2150 MHz. Scan angles typically varied less than 4° from frequency to frequency. However, gain measurements at 2217.5 and 2287.5 MHz, as well as all of the axial ratio measurements were measured using scan angles obtained at the appropriate frequencies.

At 2041.9 MHz, the pitch plane peak gain averaged 6.7 dB; 4.0 dB beamwidth averaged 132.0°; axial ratio at  $\pm 55^\circ$  averaged 4.8 dB. Roll plane peak gain averaged 6.8 dB; beamwidth averaged 93.5°; axial ratio at  $\pm 50^\circ$  averaged 5.2 dB.

At 2106.4 MHz, the pitch plane peak gain averaged 6.5 dB; beamwidth averaged 141.5°; axial ratio at  $\pm 55^\circ$  averaged 5.0 dB. Roll plane peak gain averaged 7.5 dB; beamwidth averaged 119.2°; axial ratio at  $\pm 50^\circ$  averaged 5.7 dB.

At 2217.5 MHz, the pitch plane peak gain averaged 7.4 dB; beamwidth averaged 123.5°; axial ratio at  $\pm 55^\circ$  averaged 6.2 dB. Roll plane peak gain averaged 7.2 dB; beamwidth averaged 95.8°; axial ratio at  $\pm 50^\circ$  averaged 5.2 dB.

At 2287.5 MHz, the pitch plane peak gain averaged 7.4 dB; beamwidth averaged 125.0°; axial ratio at  $\pm 55^\circ$  averaged 5.7 dB. Roll plane peak gain averaged 7.3 dB; beamwidth averaged 94°; axial ratio at  $\pm 50^\circ$  averaged 3.7 dB.

**4. COMPONENT TEST DATA SUMMARY SHEETS**

SPACE SHUTTLE S-BAND HIGH GAIN BREADBOARD ANTENNAS

UPPER \_\_\_\_\_ LOWER

DATA SHEET 1

COMPONENT (REF. SCHEMATIC)	TEST*	ACCEPT- ANCE CRITERIA		2041.9 MHz				2106.4 MHz				2177.5 MHz				2287.5 MHz				
				POS. 1		POS. 2		POS. 1		POS. 2		POS. 1		POS. 2		POS. 1		POS. 2		
				J1-J3	J4-J5	J1-J5	J4-J3	J1-J3	J4-J5	J1-J5	J4-J3	J1-J3	J4-J5	J1-J5	J4-J3	J1-J3	J4-J5	J1-J5	J4-J3	
RF SWITCH NO. 1	F.T.	> -15 dB		J1-J3	J4-J5	J1-J5	J4-J3	J1-J3	J4-J5	J1-J5	J4-J3	J1-J3	J4-J5	J1-J5	J4-J3	J1-J3	J4-J5	J1-J5	J4-J3	
NO. 2				-12	-12	-11	-10	-15	-12	-13	-10	-16	-13	-14	-13	-15	-13	-14	-14	-14
NO. 3				-11	-10	-11	-12	-13	-12	-13	-13	-15	-14	-14	-13	-15	-13	-14	-14	-14
INPUT CABLE	F.T.	> -15 dB		-11				-11				-14				-14				
INTERCONNECT CABLE	F.T.	UP.	LOW.																	
a.		>.21	>.21	.09				.08				.10				.10				
b.		.21	.21	.06				.06				.09				.09				
c.		.20	.20	.08				.08				.08				.09				
d.		.21	.21	.11				.12				.12				.13				
e.		.46	.46	.37				.43				.51				.47				
f.		.34	.35	.28				.29				.30				.30				
g.		.34	.34	.24				.23				.29				.27				
h.		.21	.21	.11				.10				.06				.08				
i.		.19	.19	.03				.04				.01				.03				
j.		.27	.27	.18				.17				.17				.19				
k.	.27	.27	.12				.11				.12				.15					
PWR. DIVIDER NETWORK	F.T.	> -9.0 dB																		
PORT A				- 8.4				- 8.4				- 8.6				- 8.6				
B				- 8.4				- 8.3				- 8.4				- 8.4				
C				- 8.5				- 8.4				- 8.4				- 8.5				
D				- 8.7				- 8.8				- 8.8				- 8.8				
E	> -4.0				- 3.8				- 3.7				- 3.6				- 3.6			
INPUT	R.L.	> 14.0 dB		23.5				24.0				20.1				17.7				
COUPLER NO. 1	P/L	< -14.0 dB		-26.8				-30.0				-42.5				-34.0				
NO. 2		< -16.4		-27.8				-26.6				-23.8				-21.8				
NO. 3		< -19.5		-22.1				-22.3				-22.8				-22.9				
NO. 4		< -19.5		-27.9				-28.3				-29.3				-29.2				

\*TEST CODES

F. T. = FORWARD TRANSMISSION, INCLUDING LOSSES

R. L. = RETURN LOSS

P/L = POWER AT LOAD PORTS (ISOLATION)

ALL MEAS. ARE RELATIVE TO INPUT



**LOWER ANTENNA  
CABLE PHASE MEASUREMENTS  
DATA SHEET 2**

NOTE: All cable phase measurements relative to cable J (element C). @ 2150 MHz.

CABLE F (ELEMENT A)			
BEAM	EXPERIMENTAL	DESIGN	ERROR
1	lag 142.8	lag 140.0	F long by 2.8
2	lag 52.1	lag 50.0	F long by 2.1
3	lead 34.3	lead 40.0	F long by 5.7
4	lead 124.5	lead 130.0	F long by 5.5
5	lag 7.1	lag 8.0	F short by 0.9
6	lead 83.6	lead 82.0	F short by 1.6
7	lead 170.0	lead 172.0	F long by 2.0
8	lead 260.2	lead 262.0	F long by 1.8
CABLE G (ELEMENT B)			
BEAM	EXPERIMENTAL	DESIGN	ERROR
1	lead 48.2	lead 50.0	G long by 1.8
2	lead 135.4	lead 140.0	G long by 4.6
3	lead 224.5	lead 230.0	G long by 5.5
4	lead 313.0	lead 320.0	G long by 7.0
5	lag 83.3	lag 82.0	G long by 1.3
6	lead 3.7	lead 8.0	G long by 4.3
7	lead 92.6	lead 98.0	G long by 5.4
8	lead 181.4	lead 188.0	G long by 6.6
CABLE K (ELEMENT D)			
BEAM	EXPERIMENTAL	DESIGN	ERROR
1	lag 274.6	lag 270.0	K long by 4.6
2	lag 89.8	lag 90.0	K short by 0.2
3	lead 88.9	lead 90.0	K long by 1.1
4	lead 270.0	lead 270.0	-
5	lag 273.9	lag 270.0	K long by 3.9
6	lag 92.8	lag 90.0	K long by 2.8
7	lead 88.2	lead 90.0	K long by 1.8
8	lead 269.3	lead 270.0	K long by 1.7



SPACE SHUTTLE S-BAND HIGH GAIN BREADBOARD ANTENNAS

UPPER LOWER

DATA SHEET 4

FINAL ASSEMBLY (REF. SCHEMATIC)	ACCEPTANCE CRITERIA	2041.9 MHz								2108.4 MHz								2217.8 MHz								2287.8 MHz							
		POS.								POS.								POS.								POS.							
TEST*		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
INPUT	R.L. > 9.5 dB	12.8	14.1	22.1	12.6	9.4	17.5	17.2	10.2	16.2	11.0	13.9	26.1	15.6	32.0	16.2	15.7	10.5	13.0	17.1	11.0	9.0	14.2	13.6	9.0	23.5	13.6	14.5	26.2	23.6	19.6	16.3	22.4
PWR DIVIDER NETWORK																																	
COUPLER NO. 1	P.L. < -14.0 dB	26.7	24.6	18.8	21.4	23.3	20.8	25.1	31.2	20.1	22.4	20.6	18.2	16.9	17.9	19.7	18.2	21.3	21.2	15.7	16.8	18.4	18.3	21.6	25.3	15.2	16.3	20.8	19.4	14.9	17.5	14.9	13.8
NO. 2	< -18.4	13.5	16.9	18.4	21.9	20.8	18.1	18.7	14.4	14.9	18.8	12.6	11.8	17.0	12.8	16.0	14.5	18.4	13.5	17.1	22.1	25.0	16.0	14.5	18.9	21.2	21.6	15.5	18.7	19.5	17.7	19.6	21.6
NO. 3	< -19.0	14.9	15.5	15.6	14.9	18.9	19.8	15.0	14.8	15.2	15.8	16.0	15.7	21.4	23.4	19.2	18.5	16.9	17.0	17.2	17.0	38.5	30.6	25.0	25.1	19.8	19.8	19.6	19.2	27.2	25.2	45.5	33.4
NO. 4	< -19.5	11.8	16.4	16.1	12.1	14.4	19.8	18.7	15.9	21.7	23.7	21.6	20.5	37.6	16.7	18.1	44.9	14.9	29.3	27.3	15.3	15.4	35.0	22.5	16.6	21.1	15.5	14.0	22.7	19.8	14.6	13.3	
ELEM COUPLER A	P.L. < -23.1 dB	22.9	25.4	29.9	23.6	18.5	17.0	17.9	20.4	20.9	23.5	25.4	23.6	18.2	19.6	21.3	20.5	17.2	18.6	20.3	18.0	24.8	31.5	27.6	24.7	15.6	17.4	18.0	16.4	29.6	28.0	26.5	29.6
B	< -22.3	15.4	16.3	14.9	14.1	34.4	20.7	20.6	34.9	16.0	18.3	17.1	15.2	30.6	21.3	20.0	24.7	20.9	26.2	24.0	19.9	22.2	25.2	22.2	21.3	28.5	26.9	25.4	25.7	21.5	28.2	25.9	
C	< -23.6	17.7	18.2	20.7	21.2	22.7	20.8	21.2	32.4	18.0	18.8	20.6	19.7	23.2	22.9	23.4	25.1	19.2	25.3	21.2	18.3	23.9	34.5	28.6	21.3	18.0	35.2	26.9	16.1	19.9	28.9	34.6	
D	< -22.6	23.0	23.0	20.8	19.0	25.4	21.2	19.0	20.0	24.6	24.3	21.4	20.0	24.3	21.0	20.2	21.2	20.8	22.3	24.3	26.2	18.1	20.0	25.9	20.8	18.3	22.9	28.6	23.1	16.2	24.7	44.5	
E	< -18.4	16.2	18.9	18.8	17.0	17.3	14.9	15.0	17.4	20.3	20.7	20.4	20.7	20.7	20.7	20.7	20.7	22.3	19.2	18.8	21.5	25.5	16.3	15.5	25.4	16.4	17.7	16.9	16.9	19.4	16.0	16.1	

\*TEST CODES

F.T. = FORWARD TRANSMISSION, INCLUDING LOSSES

R.L. = RETURN LOSS

P.L. = POWER AT LOAD PORTS (ISOLATION)

ALL MEASURES ARE RELATIVE TO INPUT

SPACE SHUTTLE S-BAND HIGH GAIN BREADBOARD ANTENNAS

UPPER  LOWER

DATA SHEET 1

COMPONENT (REF. SCHEMATIC)	TEST*	ACCEPT- ANCE CRITERIA	2041.9 MHz		2106.4 MHz		2217.5 MHz		2287.5 MHz									
			POS 1	POS 2	POS 1	POS 2	POS 1	POS 2	POS 1	POS 2								
			J1-J3 J4-J5	J1-J5 J4-J3	J1-J3 J4-J5	J1-J5 J4-J3	J1-J3 J4-J5	J1-J5 J4-J3	J1-J3 J4-J5	J1-J5 J4-J3								
RF SWITCH NO. 1	F.T.	> -15 dB	-.12	-.12	-.11	-.10	-.15	-.12	-.13	-.10	-.16	-.13	-.14	-.13	-.15	-.13	-.14	-.14
NO. 2			-.11	-.10	-.11	-.12	-.13	-.12	-.13	-.13	-.15	-.14	-.14	-.15	-.15	-.13	-.14	-.14
NO. 3			-.17	-.29	-.20	-.19	-.17	-.29	-.19	-.19	-.19	-.32	-.20	-.20	-.19	-.32	-.21	-.21
INPUT CABLE	F.T.	> -15 dB	-.09		-.08		-.08		-.08		-.09							
INTERCONNECT CABLE	F.T.	UP LOW																
a.		> .21 > .21	.09		.08		.10		.10		.10		.10		.10		.10	
b.		.21 .21	.06		.06		.09		.09		.09		.09		.09		.09	
c.		.20 .20	.08		.08		.08		.08		.08		.08		.08		.08	
d.		.21 .21	.11		.12		.12		.12		.12		.12		.12		.12	
e.		.46 .46	.40		.43		.42		.42		.42		.42		.42		.42	
f.		.34 .35	.20		.19		.28		.28		.28		.28		.28		.28	
g.		.34 .34	.21		.20		.23		.23		.23		.23		.23		.23	
h.		.21 .21	.11		.10		.06		.06		.06		.06		.06		.06	
i.		.19 .19	.03		.04		.01		.01		.01		.01		.01		.01	
j.		.27 .27	.17		.17		.19		.19		.19		.19		.19		.19	
k.		.27 .27	.13		.12		.12		.12		.12		.12		.12		.12	
PWR DIVIDER NETWORK																		
PCRT	A	F.T.	> 9.0 dB		8.4		8.4		8.6		8.6		8.6		8.6		8.6	
	B		> 9.0		8.4		8.3		8.4		8.4		8.4		8.4		8.4	
	C		> 9.0		8.5		8.4		8.4		8.4		8.4		8.4		8.4	
	D		> 9.0		8.7		8.8		8.8		8.8		8.8		8.8		8.8	
	E		> 4.0		3.8		3.7		3.6		3.6		3.6		3.6		3.6	
INPUT	R.L.	> 14.0 dB	23.5		24.0		20.1		20.1		20.1		20.1		20.1		20.1	
COUPLER NO. 1	P/L	< 14.0 dB	26.8		30.0		42.5		42.5		42.5		42.5		42.5		42.5	
NO. 2		< 16.4	27.8		26.6		23.0		23.0		23.0		23.0		23.0		23.0	
NO. 3		< 19.5	22.1		22.3		22.8		22.8		22.8		22.8		22.8		22.8	
NO. 4		< 19.5	27.9		28.3		29.3		29.3		29.3		29.3		29.3		29.3	

\*TEST CODES

F. T. = FORWARD TRANSMISSION, INCLUDING LOSSES

R. L. = RETURN LOSS

P/L = POWER AT LOAD PORTS (ISOLATION)

ALL MEAS. ARE RELATIVE TO INPUT

**UPPER ANTENNA  
CABLE PHASE MEASUREMENTS  
DATA SHEET 2**

NOTE: All cable phase measurements relative to cable J (element C). @ 2150 MHz.

CABLE F (ELEMENT A)			
EEAM	EXPERIMENTAL	DESIGN	ERROR
1	lag 119.0	lag 122.0	F short by 2.8
2	lag 31.6	lag 32.0	F short by 0.4
3	lead 61.7	lead 58.0	F short by 3.7
4	lead 146.1	lead 148.0	F long by 1.9
5	lead 13.7	lead 10.0	F short by 3.7
6	lead 100.8	lead 100.0	F short by 0.8
7	lead 195.3	lead 190.0	F short by 5.3
8	lead 279.9	lead 280.0	F long by 0.1
CABLE G (ELEMENT B)			
BEAM	EXPERIMENTAL	DESIGN	ERROR
1	lead 33.0	lead 32.0	G short by 1.0
2	lead 120.5	lead 122.0	G long by 1.5
3	lead 213.4	lead 212.0	G short by 1.4
4	lead 298.6	lead 302.0	G long by 3.4
5	lag 98.2	lag 100.0	G short by 1.8
6	lag 10.9	lag 10.0	G long by 0.9
7	lead 82.1	lead 80.0	G short by 2.1
8	lead 166.8	lead 170.0	G long by 3.2
CABLE K (ELEMENT D)			
BEAM	EXPERIMENTAL	DESIGN	ERROR
1	lag 266.5	lag 270.0	K short by 3.5
2	lag 93.6	lag 90.0	K long by 3.6
3	lead 92.3	lead 90.0	K short by 2.3
4	lead 265.4	lead 270.0	K long by 4.6
5	lag 266.1	lag 270.0	K short by 3.9
6	lag 93.0	lag 90.0	K long by 3.0
7	lead 92.4	lead 90.0	K short by 2.4
8	lead 264.2	lead 270.0	K long by 5.8

SPACE SHUTTLE S-BAND BREADBOARD ANTENNAS  
 UPPER ✓ LOWER

DATA SHEET 3

FEED SUBASSEMBLY (REF. SCHEMATIC) PORT	ACCEPTANCE CRITERIA	2041.9 MHz								2108.7 MHz								2217.5 MHz								2287.8 MHz							
		POS.								POS.								POS.								POS.							
		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
NO 1	F.T. > -9.7 dB	92	91	91	90	89	89	89	89	93	92	92	92	91	90	91	91	93	93	93	93	93	91	91	91	94	94	94	94	94	92	92	92
NO 2	> -9.7	90	91	90	90	91	91	91	91	90	92	90	90	91	91	91	91	91	91	91	91	91	90	92	92	91	92	91	91	93	92	92	93
NO 3	> -10.0	110	92	104	97	110	104	97	104	92	104	92	104	96	104	96	101	94	113	96	101	94	113	96	104	95	112	98	104	95	111	98	100
NO 4	> -10.0	97	102	94	106	97	102	94	107	96	102	92	101	96	103	92	101	99	107	95	97	99	107	95	97	99	107	98	100	99	108	98	100
NO 5	> -4.5	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	41	41	41	41	41	41	41	41	42	42	42	42	42	42	42	42
INPUT	R.L. > -12.0 dB	177	210	194	171	173	200	186	179	208	242	214	200	210	206	222	181	222	205	184	224	207	204	157	160	149	168	168	171	159	180	180	
RADIATING SUBASSEMBLY																																	
ELEM COUPLER A	R.L. > -14.0 dB	18.3																															
B		19.5																															
C		25.9																															
D		21.8																															
E		21.3																															
ELEM COUPLER A	P/L < -14.0 dB	-16.1																															
B		-14.4																															
C		-16.7																															
D		-14.9																															
E		-16.1																															
ELEM COUPLER A		-22.3																															
B		-19.2																															
C		-22.6																															
D		-18.9																															
E		-21.7																															
ELEM COUPLER A		-18.8																															
B		-19.9																															
C		-21.3																															
D		-23.6																															
E		-20.3																															

\*TEST CODES

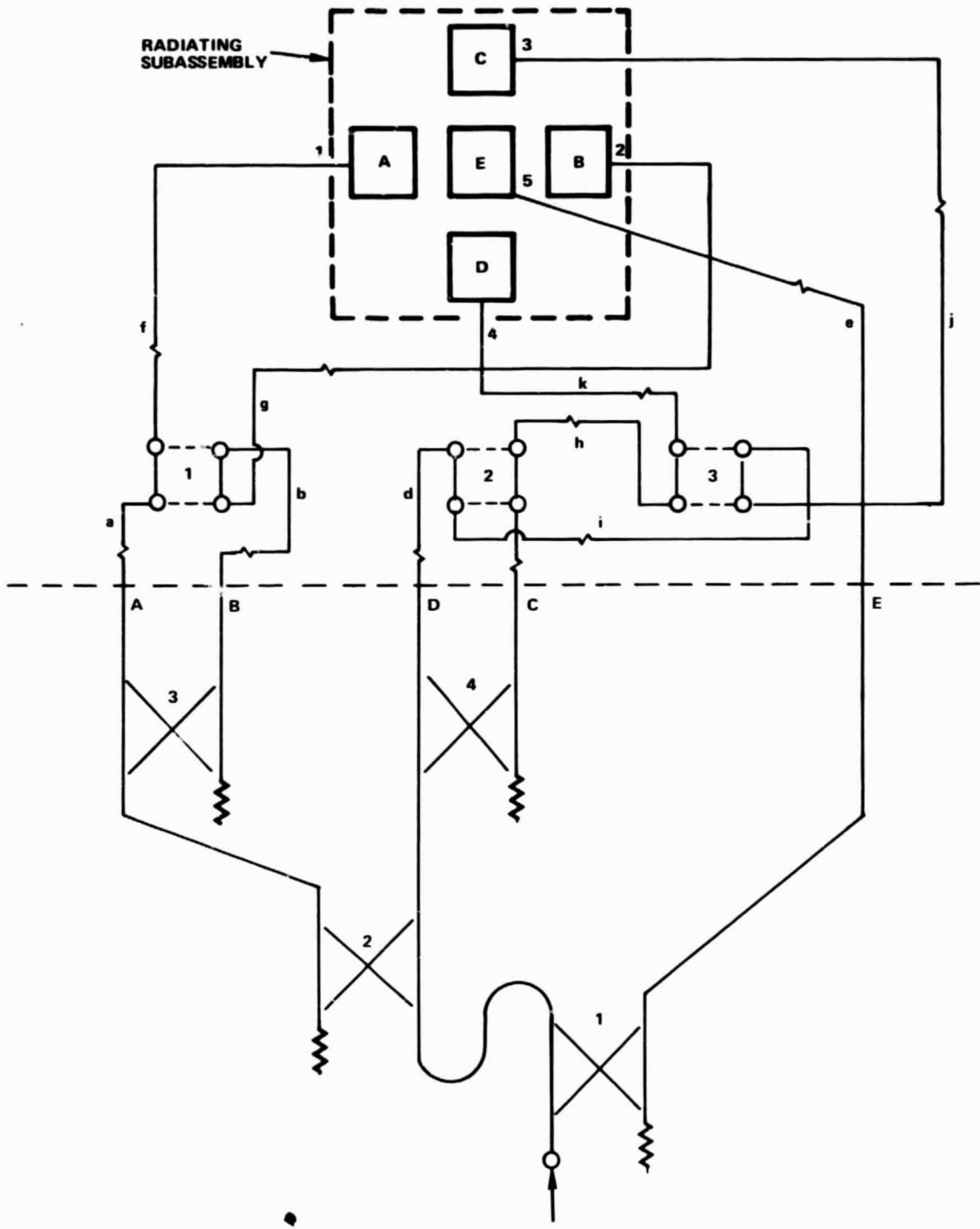
F.T. \* FORWARD TRANSMISSION, INCLUDING LOSSES  
 R.L. \* RETURN LOSS  
 P.L. \* POWER AT LOAD PORTS (ISOLATION)  
 ALL MEASURES ARE RELATIVE TO INPUT

SPACE SHUTTLE S-BAND HIGH GAIN BREADBOARD ANTENNAS  
 UPPER ✓ LOWER

DATA SHEET 4

FINAL ASSEMBLY (REF. SCHEMATIC) INPUT	TEST* R/L	ACCEPTANCE CRITERIA	2041.9 MHz							2106.4 MHz							2217.5 MHz							2287.2 MHz										
			POS.							POS.							POS.							POS.										
PWR DIVIDER NETWORK	NO 1	P/L <-14.0 dB	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
			-25.7	-28.9	-23.1	-34.6	-27.7	-25.3	-30.3	-24.0	-25.3	-35.3	-23.0	-23.5	-20.1	-21.4	-27.4	-26.1	-25.3	-27.7	-18.2	-20.2	-20.1	-20.2	-25.8	-35.5	-14.5	-15.9	-19.0	-17.6	-16.8	-19.9	-16.2	-14.6
			13.6	17.2	35.0	17.7	10.8	26.8	21.6	12.9	21.2	14.0	18.2	20.8	20.0	21.6	15.9	20.8	10.0	15.7	15.4	10.0	9.4	16.8	14.9	10.3	26.0	16.8	15.7	18.0	16.0	20.0	18.2	22.0
			-12.5	-20.0	-18.4	-13.5	-13.4	-20.9	-19.2	-5.3	23.3	-19.6	-17.6	-22.6	-32.4	-18.2	-16.8	-29.9	-16.4	-31.4	-35.9	-18.7	-16.2	-28.2	-36.2	-19.2	-20.6	-15.4	-14.1	-23.5	-19.0	-14.8	-13.6	-22.2
			-15.3	-14.9	-16.5	-16.2	-16.4	-16.5	-14.3	-14.4	-15.1	-15.8	-16.7	-16.0	-18.9	-20.0	-17.6	-17.1	-22.7	-23.7	-24.8	-24.4	-28.1	-27.6	-28.1	-29.5	-26.2	-23.6	-25.3	-24.8	-23.4	-22.3	23.9	-24.7
NO 2	P/L <-16.4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
NO 3	P/L <-19.5	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
NO 4	P/L <-19.5	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
ELEM. COUPLER A	P/L <-23.3 dB	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
B	P/L <-23.3	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
C	P/L <-23.6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
D	P/L <-23.6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
E	P/L <-18.4	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	

\*TEST CODES  
 F.T. = FORWARD TRANSMISSION, INCLUDING LOSSES  
 R/L = RETURN LOSS  
 P/L = POWER AT LOAD PORTS ISOLATION  
 ALL MEASURES ARE RELATIVE TO INPUT.



SCHEMATIC

SPACE SHUTTLE S-BAND HIGH GAIN ANTENNA



**5. RADIATION PATTERN DATA SUMMARY SHEETS**

16

~~15A~~

LOWER PITCH PLANE 2041.9 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1	4.0	4.5	138°	142°
2	5.2	7.1		
3	5.4	7.3		
4	6.2	5.4		
5	6.2	6.3	126°	132°
6	4.3	8.2		
7	2.8	8.6		
8	2.9	6.3		

LOWER PITCH PLANE 2106.4 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1	4.6	2.9	142°	148°
2	6.0	6.6		
3	4.5	7.6		
4	6.8	5.6		
5	6.5	5.0	141°	147°
6	4.4*	8.3		
7	3.2	9.3		
8	2.0	6.8		

\* At  $50^\circ$

LOWER ROLL PLANE 2041.9 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1 5	4.7 9.4	5.4 7.6	116°	124°
2 6	3.2 4.4	8.2 8.2	120°	126°
3 7	3.0 2.4	7.9 7.7	112°	117°
4 8	10.4 4.0	4.7 4.4	26°	45°

LOWER ROLL PLANE 2106.4 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1 5	3.0 14.1	6.3 8.2	123°	128°
2 6	2.8 4.4	8.6 8.4	119°	123°
3 7	2.6 3.8	8.2 9.0	119°	123°
4 8	11.4 3.2	5.5 5.9	116°	123°

LOWER PITCH PLANE 2217.5 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1	5.5	4.4	123°	136°
2	6.2	8.1		
3	6.0	8.5		
4	8.7	5.8		
5	8.6	6.6	124°	129°
6	4.1	9.4		
7	2.1	9.6		
8	1.9	6.8		

LOWER PITCH PLANE 2287.5 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1	4.0	4.7	129°	135°
2	4.4	7.6		
3	5.7	6.8		
4	3.2	5.2		
5	8.8	7.6	121°	127°
6	4.2	9.6		
7	2.6	9.5		
8	1.7	7.9		

LOWER ROLL PLANE 2217.5 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1 5	5.9 10.0	3.8 6.1	49°	56°
2 6	3.4 5.9	8.1 9.4	114°	118°
3 7	2.7 3.2	8.4 9.8	113°	118°
4 8	8.2 2.0	6.2 5.6	107°	111°

LOWER ROLL PLANE 2287.5 MHz			BEAMWIDTH	
BEAM	A.R. AT $\pm 50^\circ$	GAIN dBci	4.0 dBci	3.5 dBci
1 5	3.3 8.2	4.7 6.2	56°	62°
2 6	1.7 3.0	8.7 9.8	109°	113°
3 7	1.7 3.0	8.8 9.4	106°	111°
4 8	6.8 2.1	5.3 5.5	105°	112°

## **6. OFFSITE TEST INSTALLATION REPORT**

The upper and lower antennas are mounted into their respective mock-ups in the same fashion as the presently used two beam antennas.

The scan angles determined at Rockwell - Anaheim are listed in the following pages. They can be used to approximately locate beam peaks. Variations from these angles will occur due to mock-up and range differences.

## EIGHT BEAM ANTENNA SCAN ANGLES

### UPPER ANTENNA

2041.9 MHz

BEAMS	SCAN ANGLE
R 1 and 5	54.5° down
O 2 and 6	19.0° down
L 3 and 7	17.0° up
L 4 and 8	55.5° up
P 1 thru 4	39.5° down
I 5 thru 8	33.5° up
T	
C	
H	

2106.4 MHz

BEAMS	SCAN ANGLE
R 1 and 5	55.5° down
O 2 and 6	18.5° down
L 3 and 7	17.0° up
L 4 and 8	57.0° up
P 1 thru 4	38.0° down
I 5 thru 8	32.0° up
T	
C	
H	

EIGHT BEAM ANTENNA SCAN ANGLES (UPPER ANTENNA) (Continued)

2217.5 MHz

BEAMS	SCAN ANGLE
R 1 and 5	53.5° down
O 2 and 6	14.5° down
L 3 and 7	21.5° up
L 4 and 8	53.5° up
P 1 thru 4	32.5° down
I 5 thru 8	27.0° up
T	
C	
H	

2287.5 MHz

BEAMS	SCAN ANGLE
R 1 and 5	54.0° down
O 2 and 6	15.0° down
L 3 and 7	13.0° up
L 4 and 8	53.5° up
P 1 thru 4	32.5° down
I 5 thru 8	27.5° up
T	
C	
H	



## EIGHT BEAM ANTENNA SCAN ANGLES

### LOWER ANTENNA

2041.9 MHz

	BEAMS	SCAN ANGLE
R O L L	1 and 5	53.0° down
	2 and 6	21.5° down
	3 and 7	17.5° up
	4 and 8	53.0° up
P I T C H	1 thru 4	38.5° down
	5 thru 8	19.5° up

2106.4 MHz

	BEAMS	SCAN ANGLE
R O L L	1 and 5	57.0° down
	2 and 6	19.0° down
	3 and 7	18.0° up
	4 and 8	54.0° up
P I T C H	1 thru 4	40.0° down
	5 thru 8	20.5° up

EIGHT BEAM ANTENNA SCAN ANGLES (LOWER ANTENNA) (Continued)

2217.5 MHz

BEAMS	SCAN ANGLE
R 1 and 5	52.5° down
O 2 and 6	17.5° down
L 3 and 7	13.5° up
L 4 and 8	48.5° up
P 1 thru 4	46.0° down
I 5 thru 8	14.5° up
T	
C	
H	

2287.5 MHz

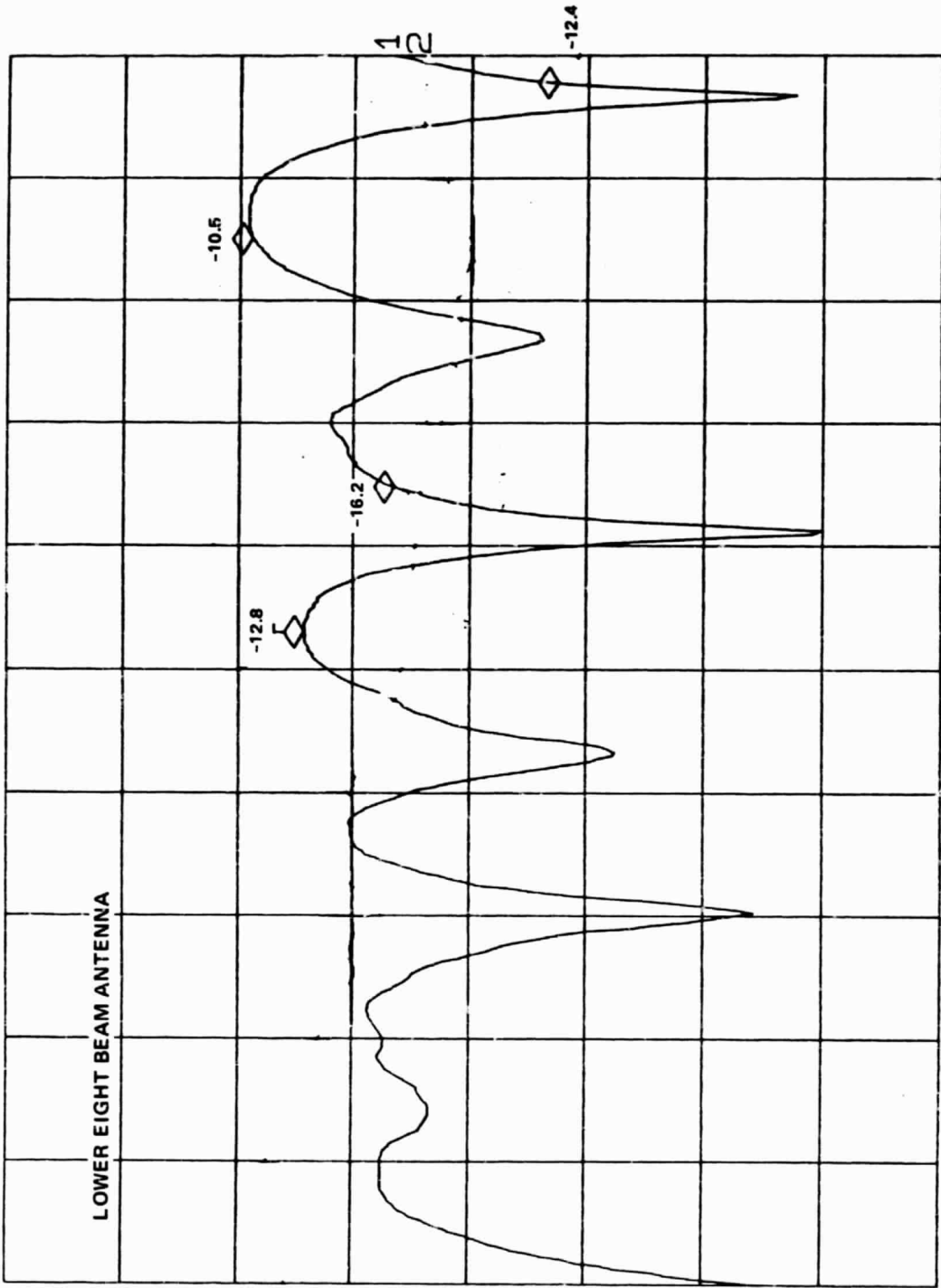
BEAMS	SCAN ANGLE
R 1 and 5	53.5° down
O 2 and 6	11.5° down
L 3 and 7	11.0° up
L 4 and 8	52.5° up
P 1 thru 4	43.0° down
I 5 thru 8	13.0° up
T	
C	
H	

**7. RETURN LOSS PLOTS**

24A

CH1: A -12.84 dB  
5.0dB/ REF + .00 dB

REF 1



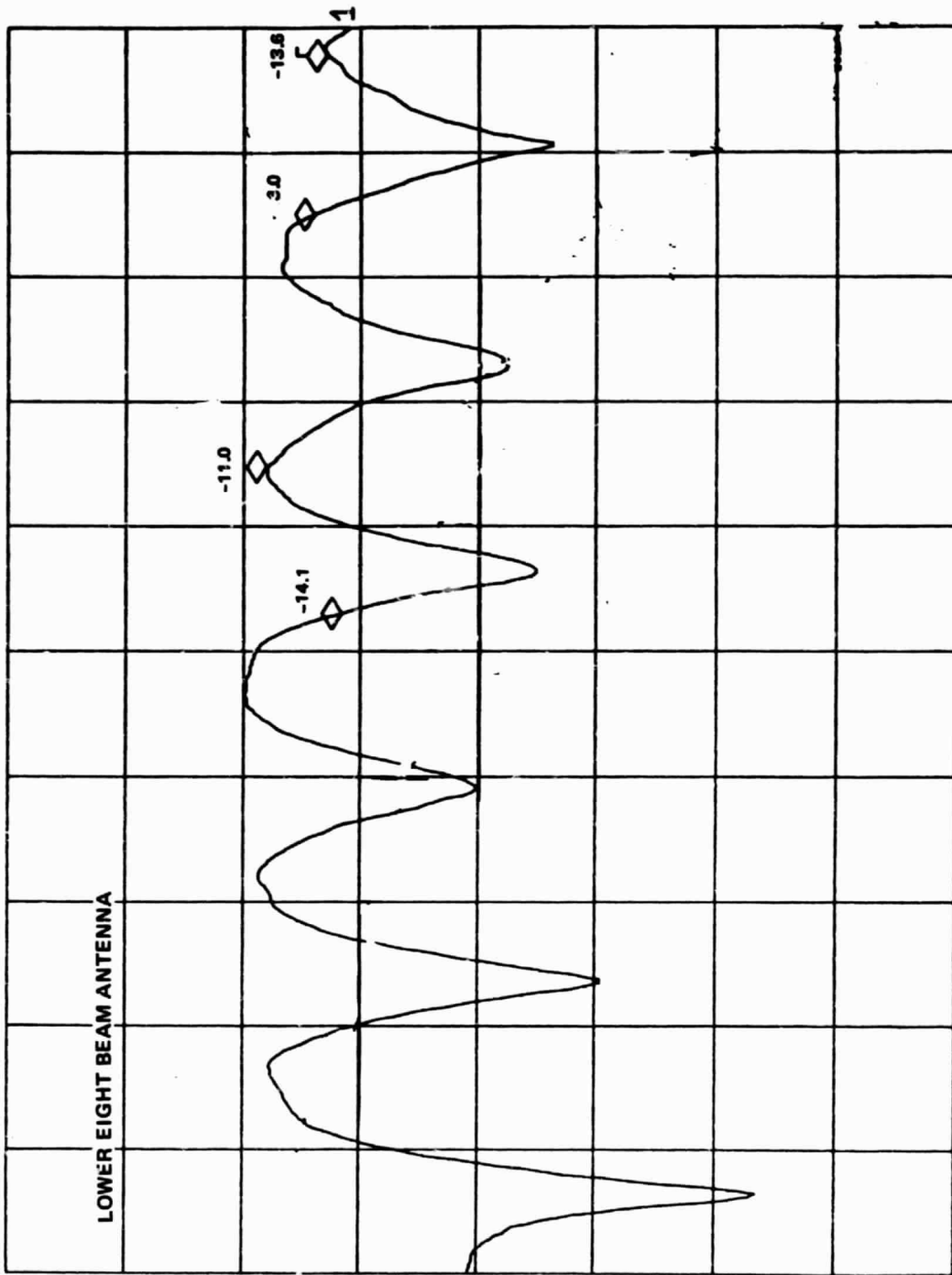
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 1

CH1: A -13.56 dB  
5.0dB/ REF + .00 dB

REF 1



LOWER EIGHT BEAM ANTENNA

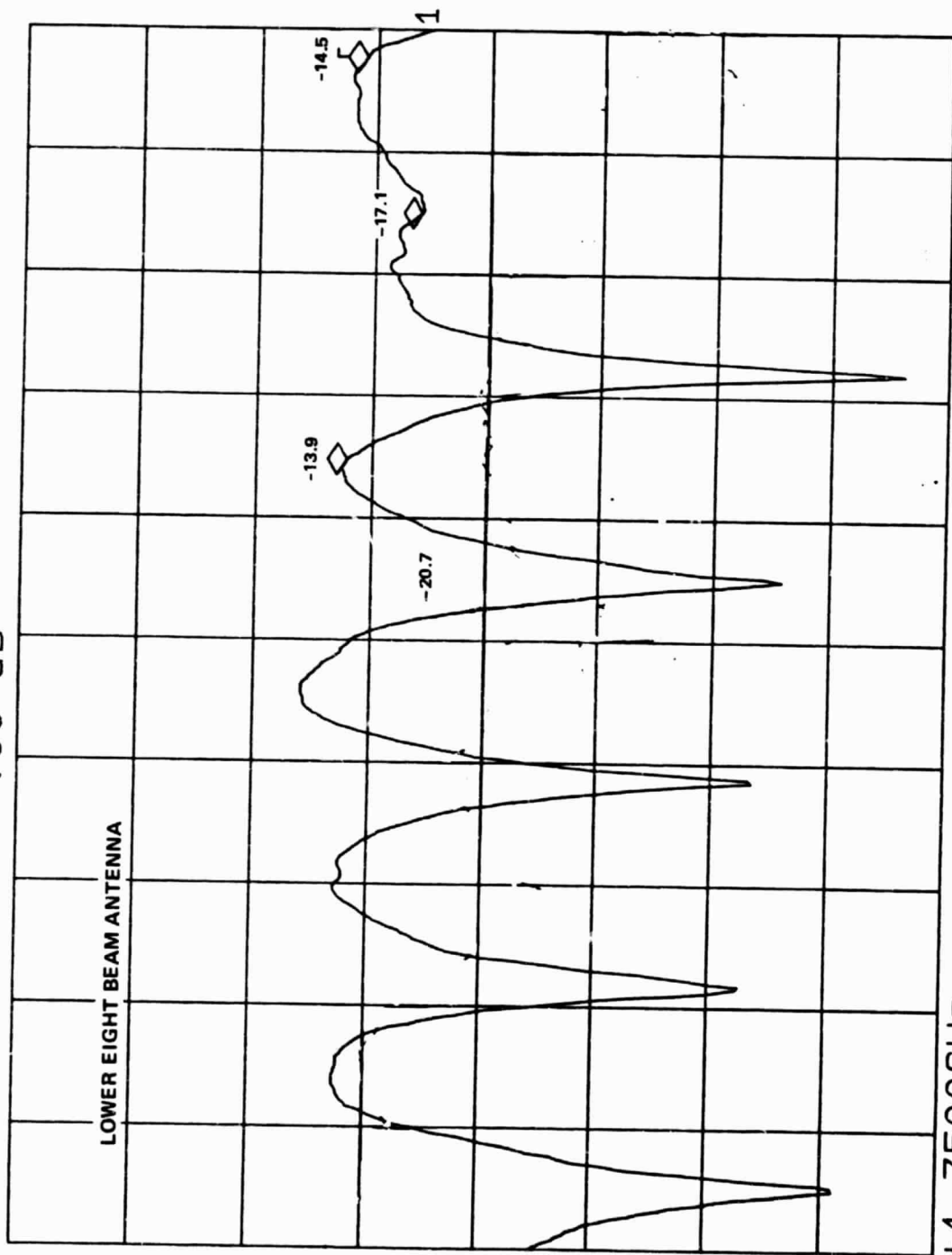
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 2

CH1: A - 14.58 dB  
5.0dB / REF + .00 dB

REF 1



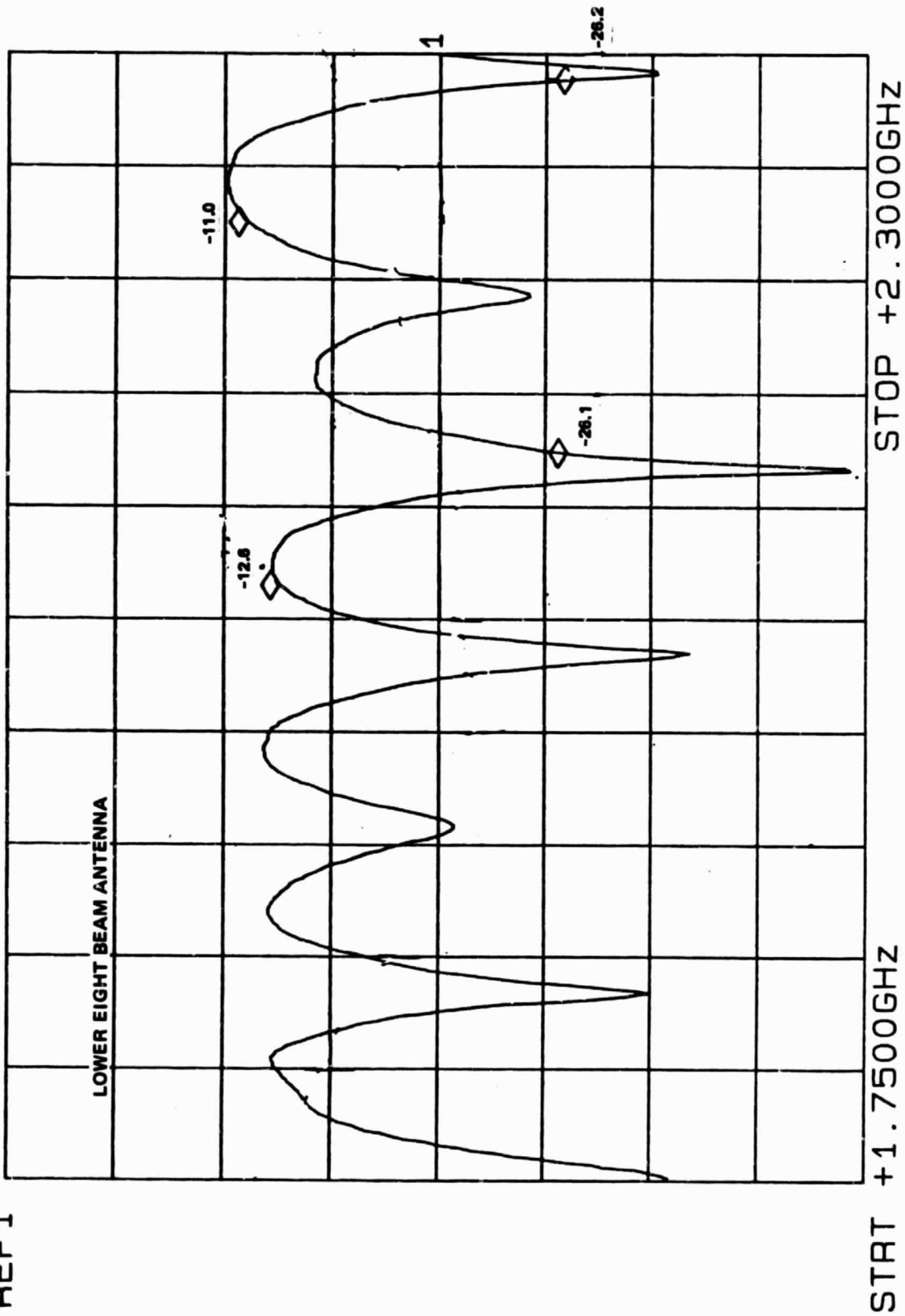
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 3

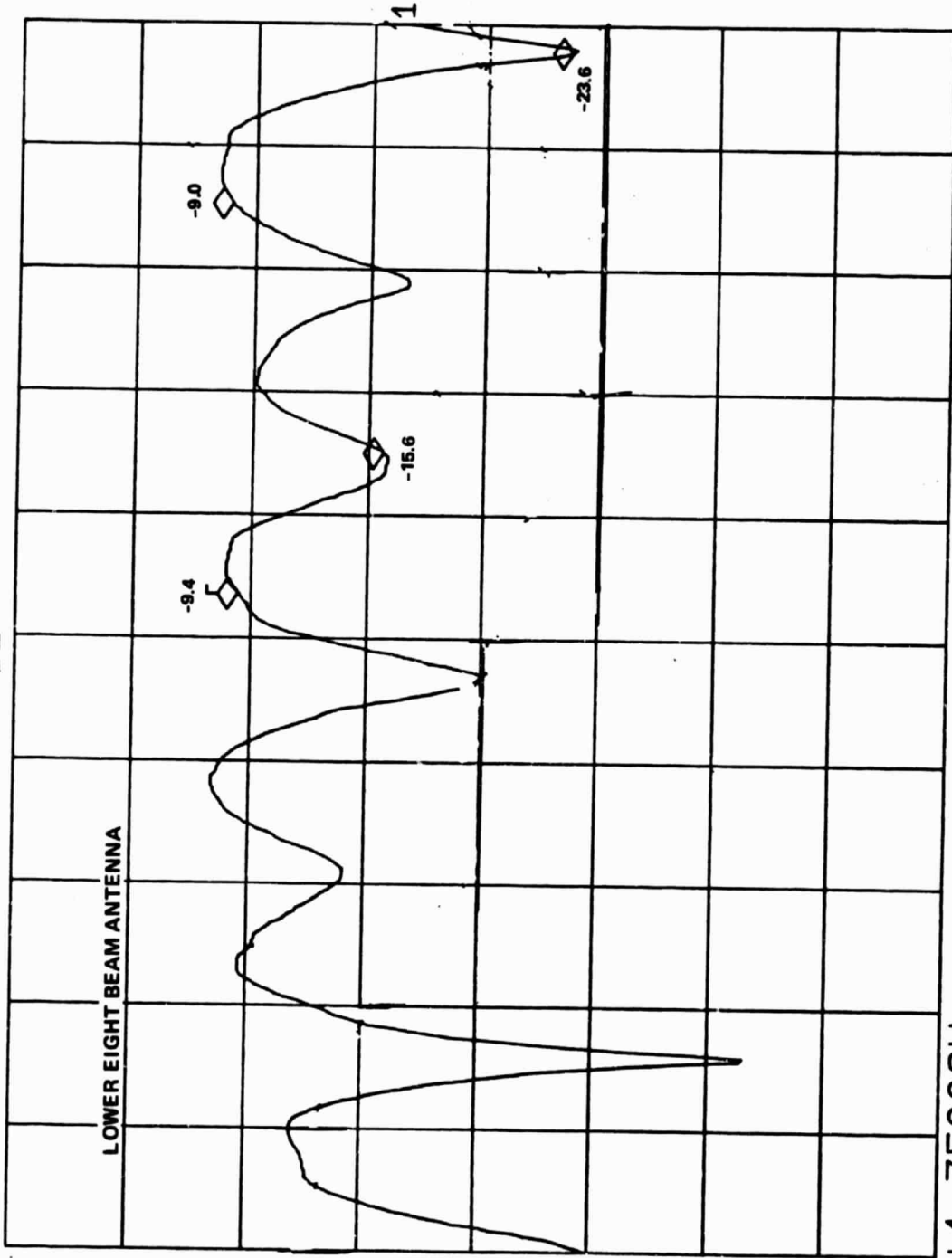
CH1: A -26.25 dB  
5.0dB/ REF +.00 dB

REF 1



CH1: A - 9.40 dB  
5.0dB/ REF + .00 dB

REF 1



START +1.7500GHZ

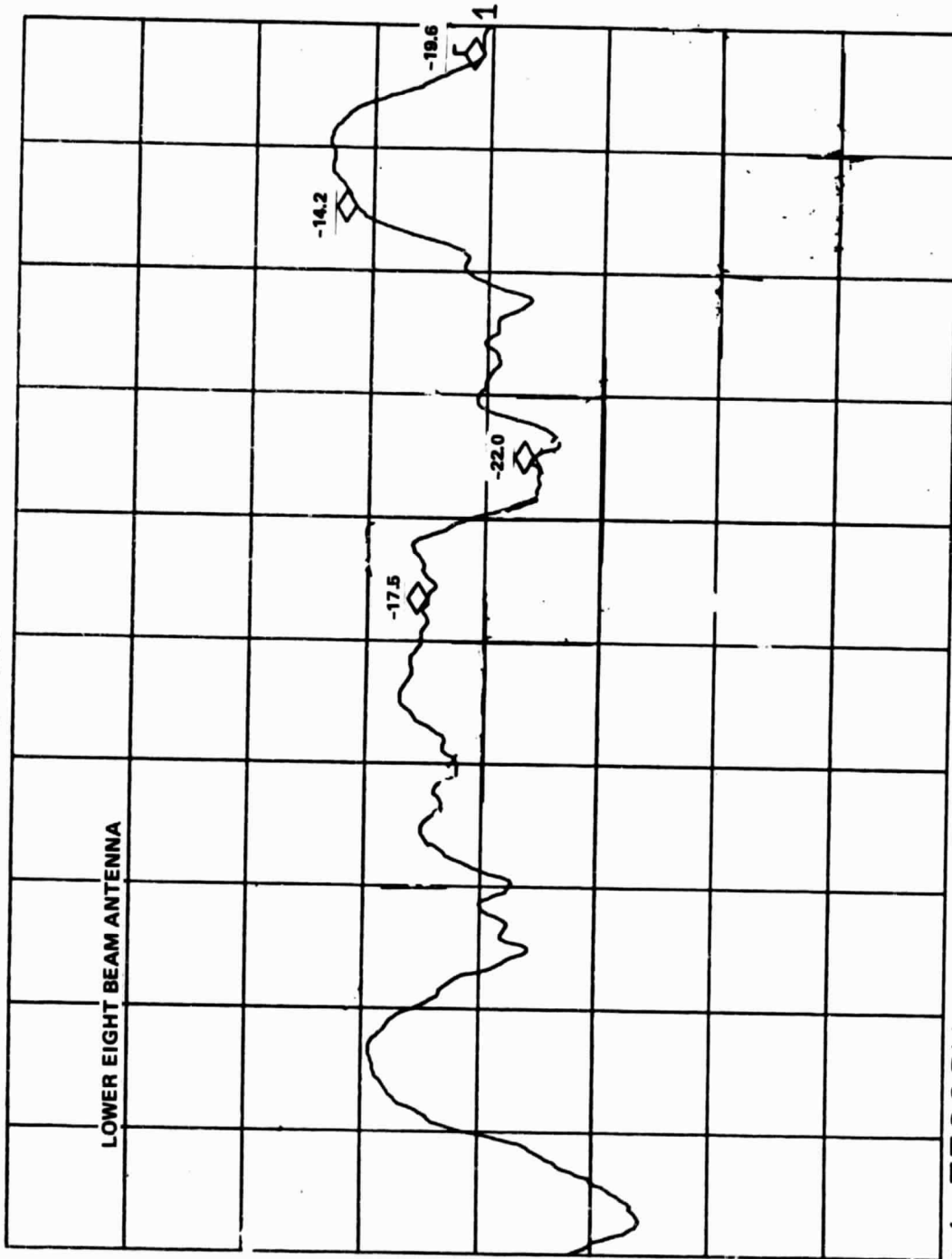
RETURN LOSS - BEAM 5

STOP +2.3000GHZ



CH1: A -19.59 dB  
5.0dB/ REF + .00 dB

REF 1



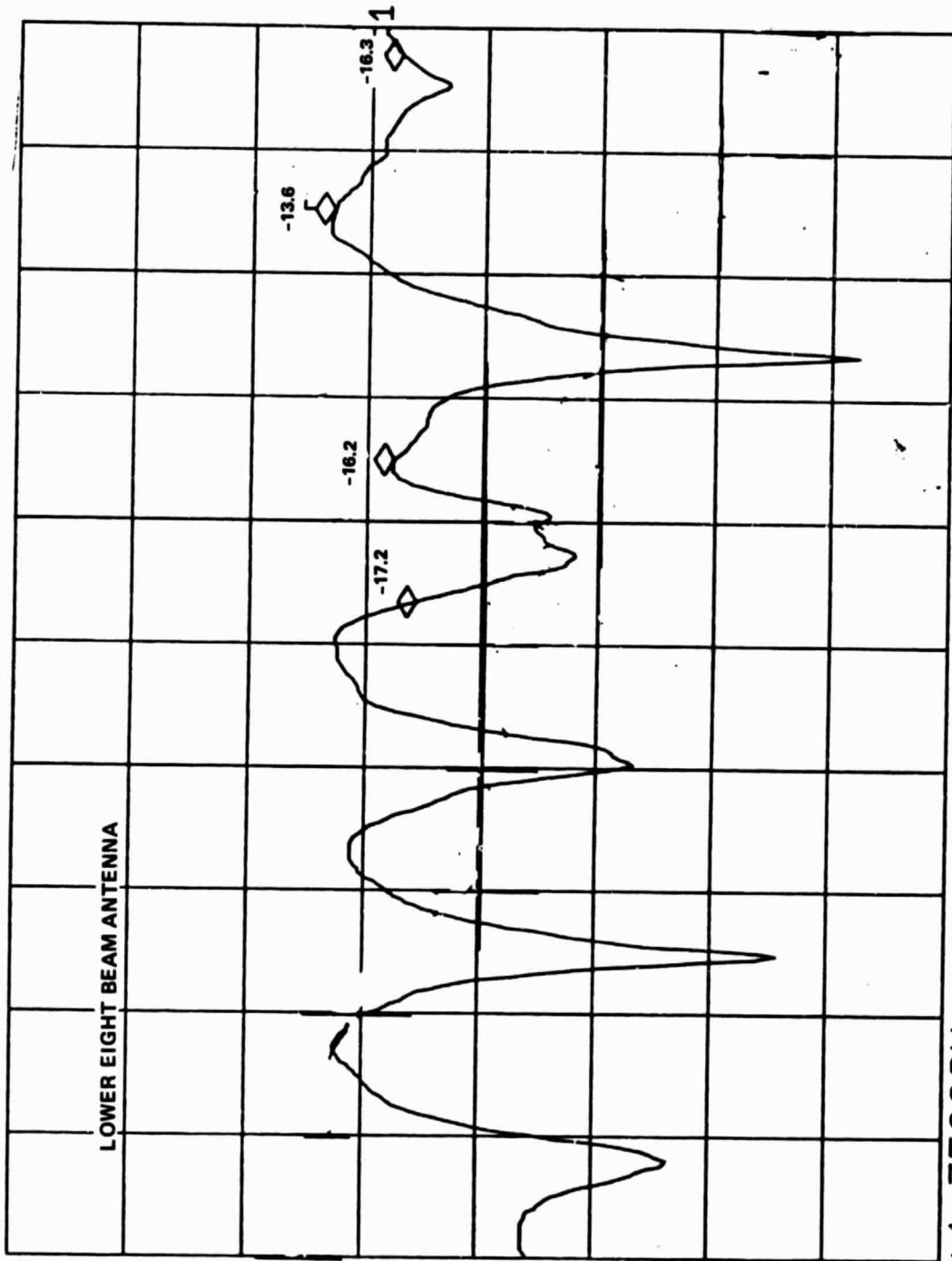
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 6

CH1: A - 13.58 dB  
5.0dB/ REF + .00 dB

REF 1



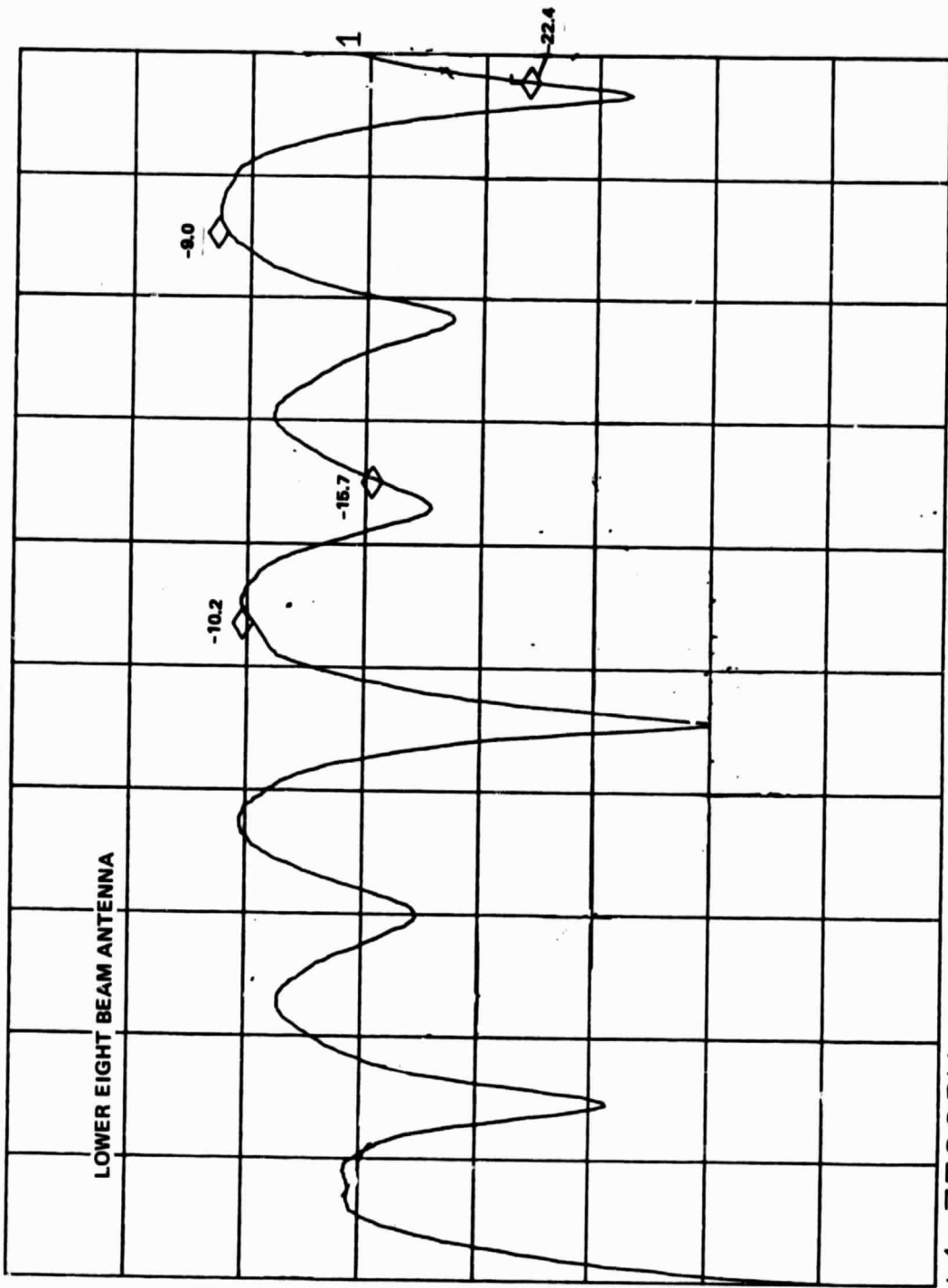
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 7

CH1: A - 22.53 dB  
5.0dB/ REF + .00 dB

REF 1



LOWER EIGHT BEAM ANTENNA

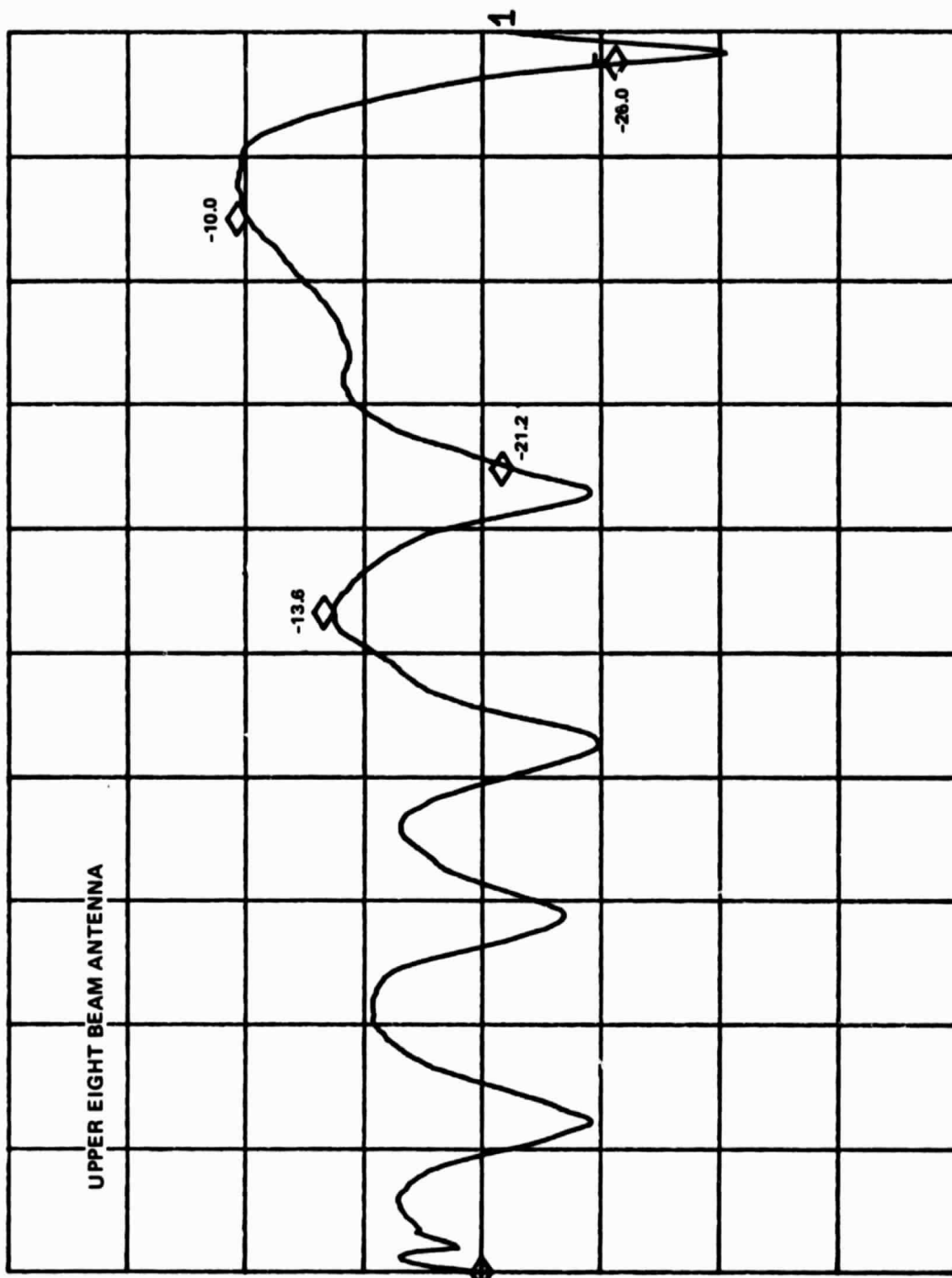
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS -- BEAM 8

CH1: B -20.37 dB  
5.0dB/ REF +.00 dB

REF1



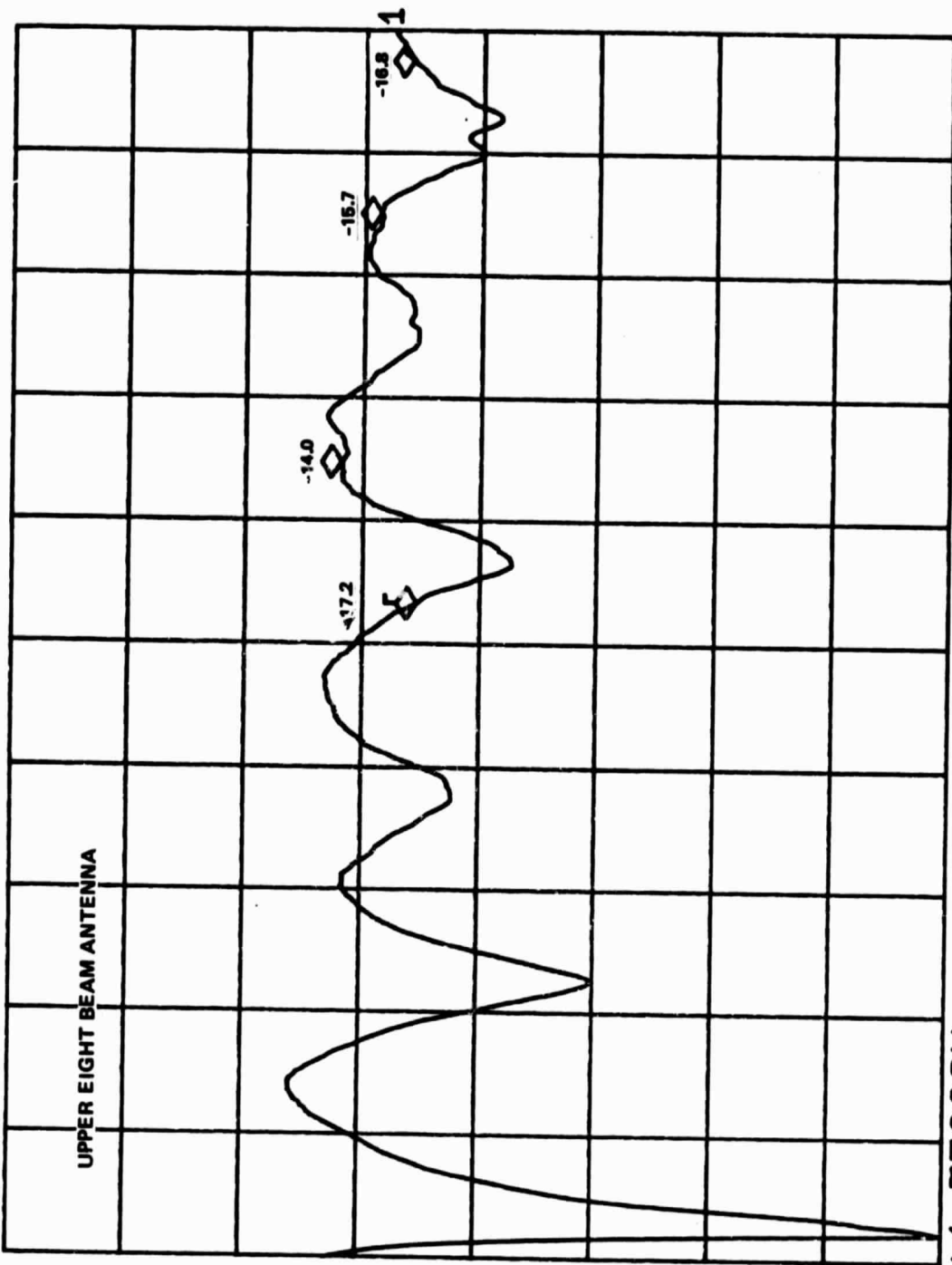
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 1

CH1: B -17.35 dB  
5.0dB/ REF +.00 dB

REF 1



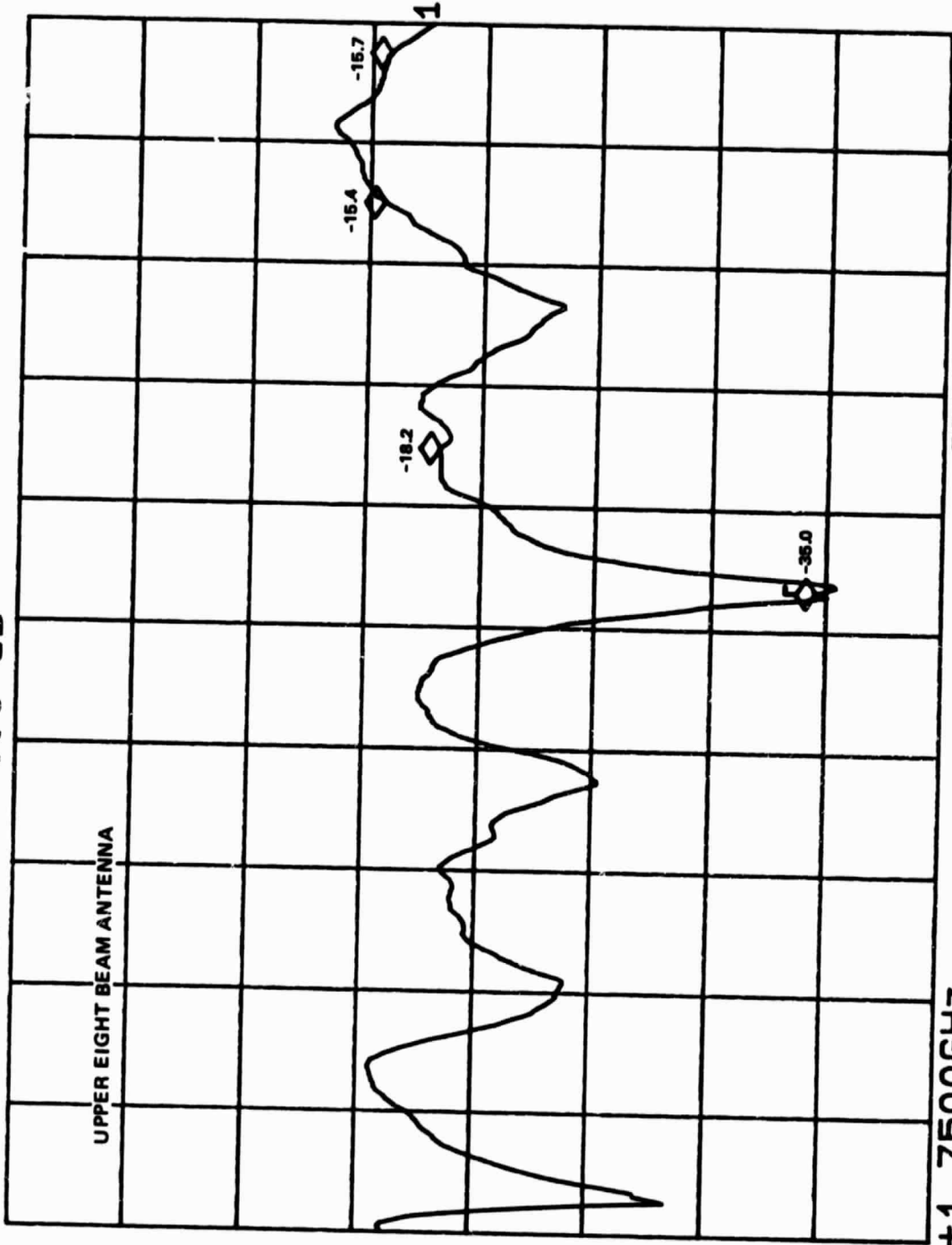
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 2

CH1: B - 34.49 dB  
5.0dB/ REF + .00 dB

REF 1



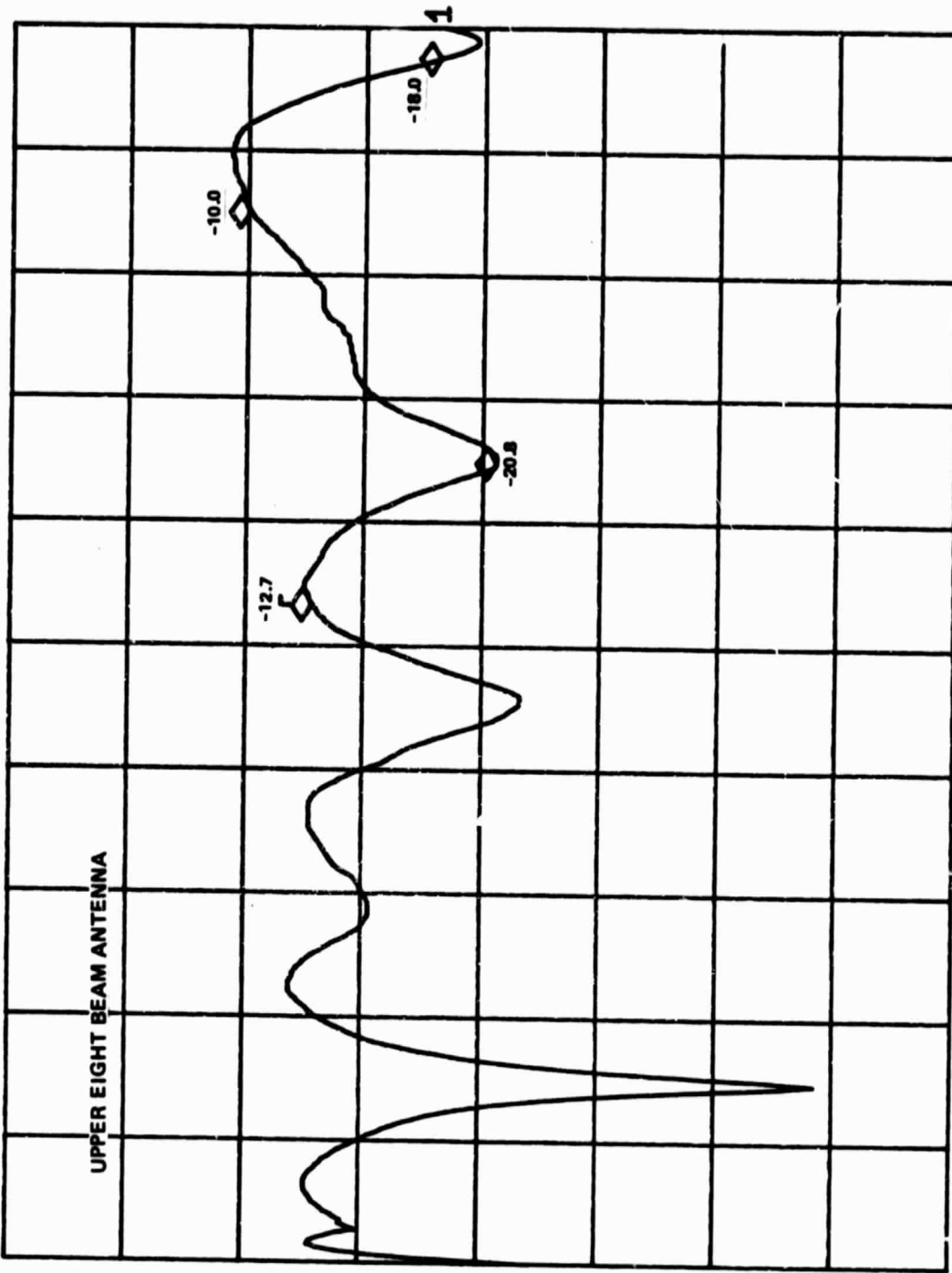
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 3

CH1: B -12.79 dB  
5.0dB/ REF + .00 dB

REF 1



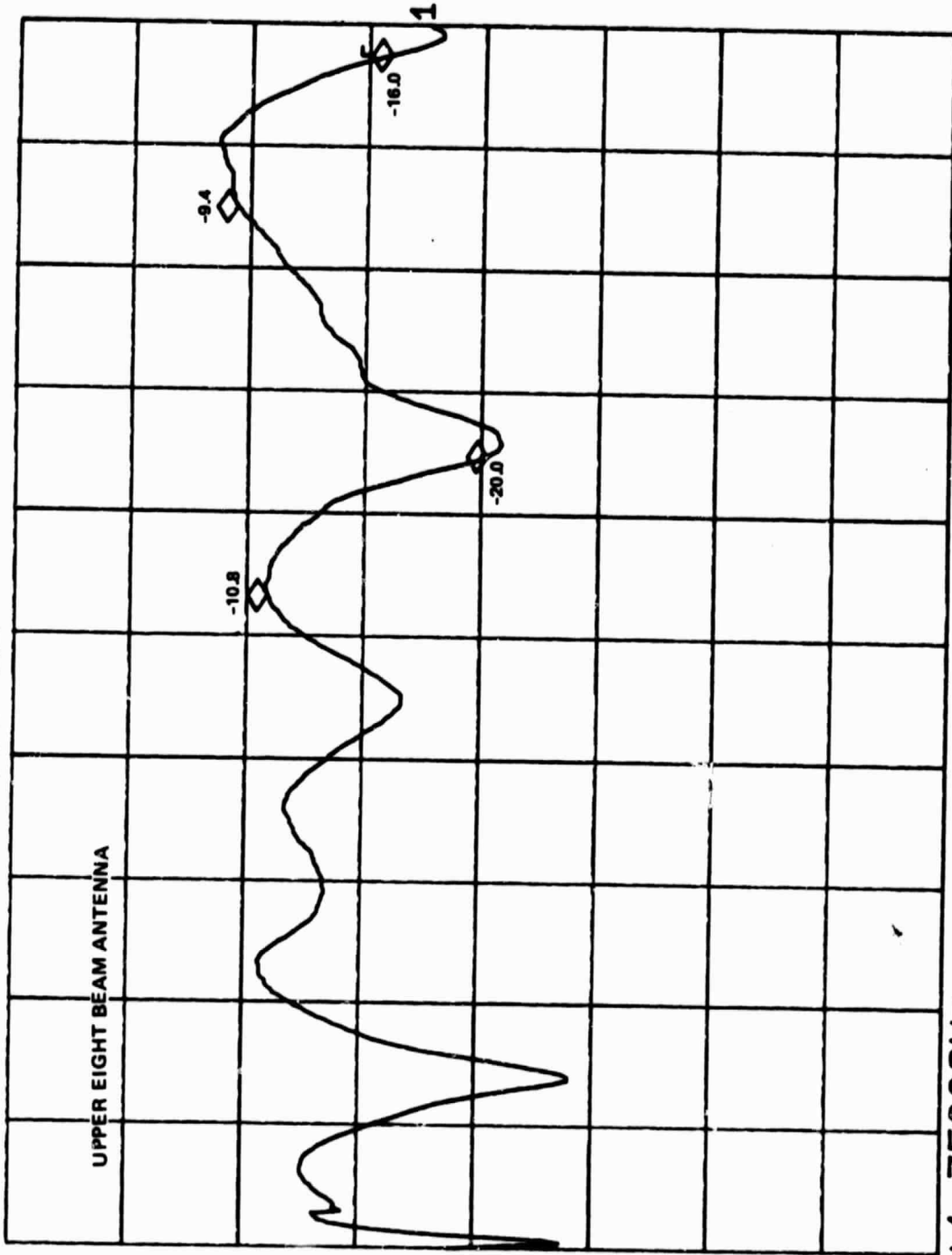
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 4

CH1: B - 15.86 dB  
5.0dB/ REF + .00 dB

REF1



START +1.7500GHZ

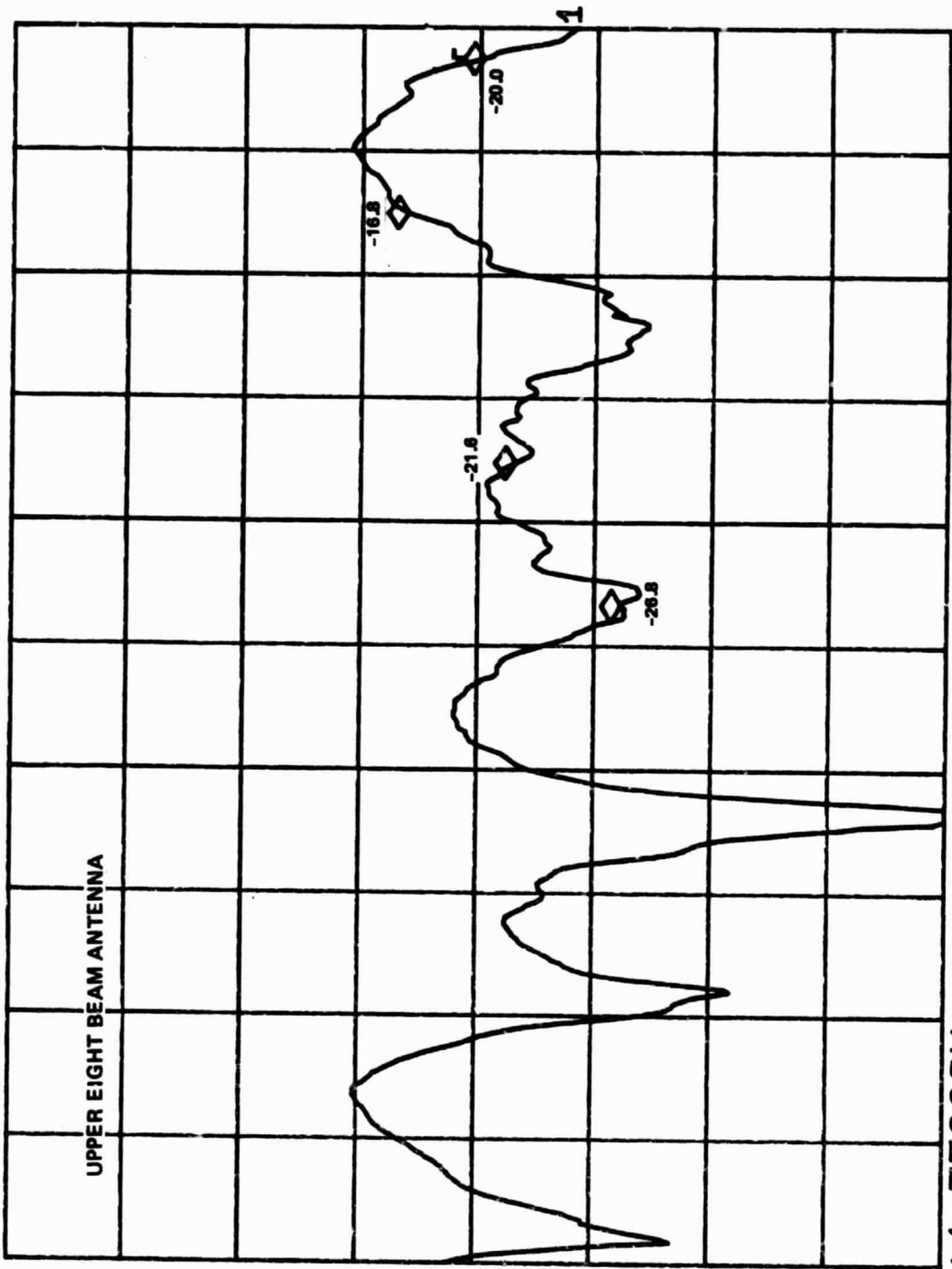
STOP +2.3000GHZ

RETURN LOSS - BEAM 5



CH1: B -20.16 dB  
5.0dB/ REF + .00 dB

REF1



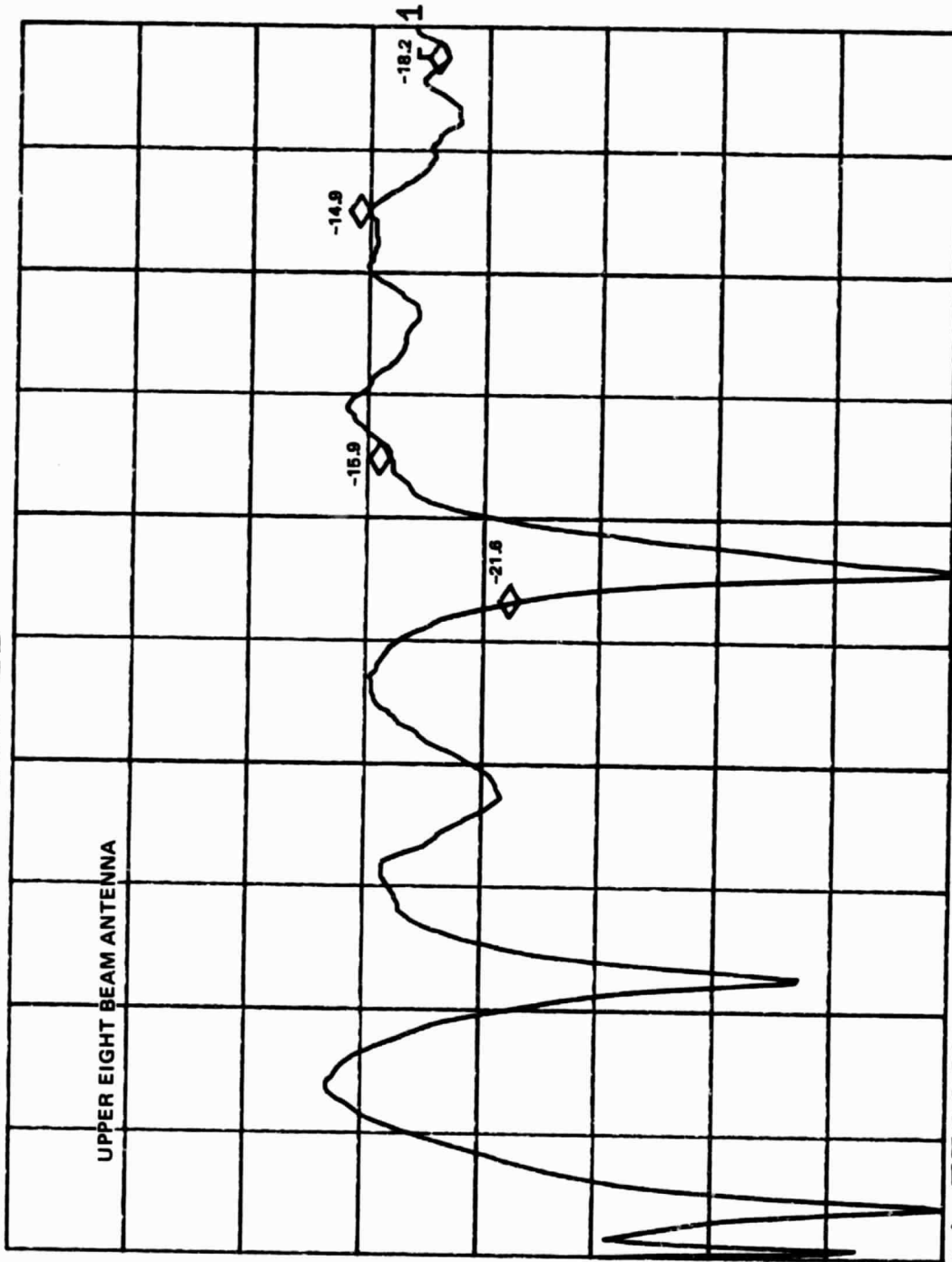
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 6

CH1: B -18.21 dB  
5.0dB/ REF + .00 dB

REF 1



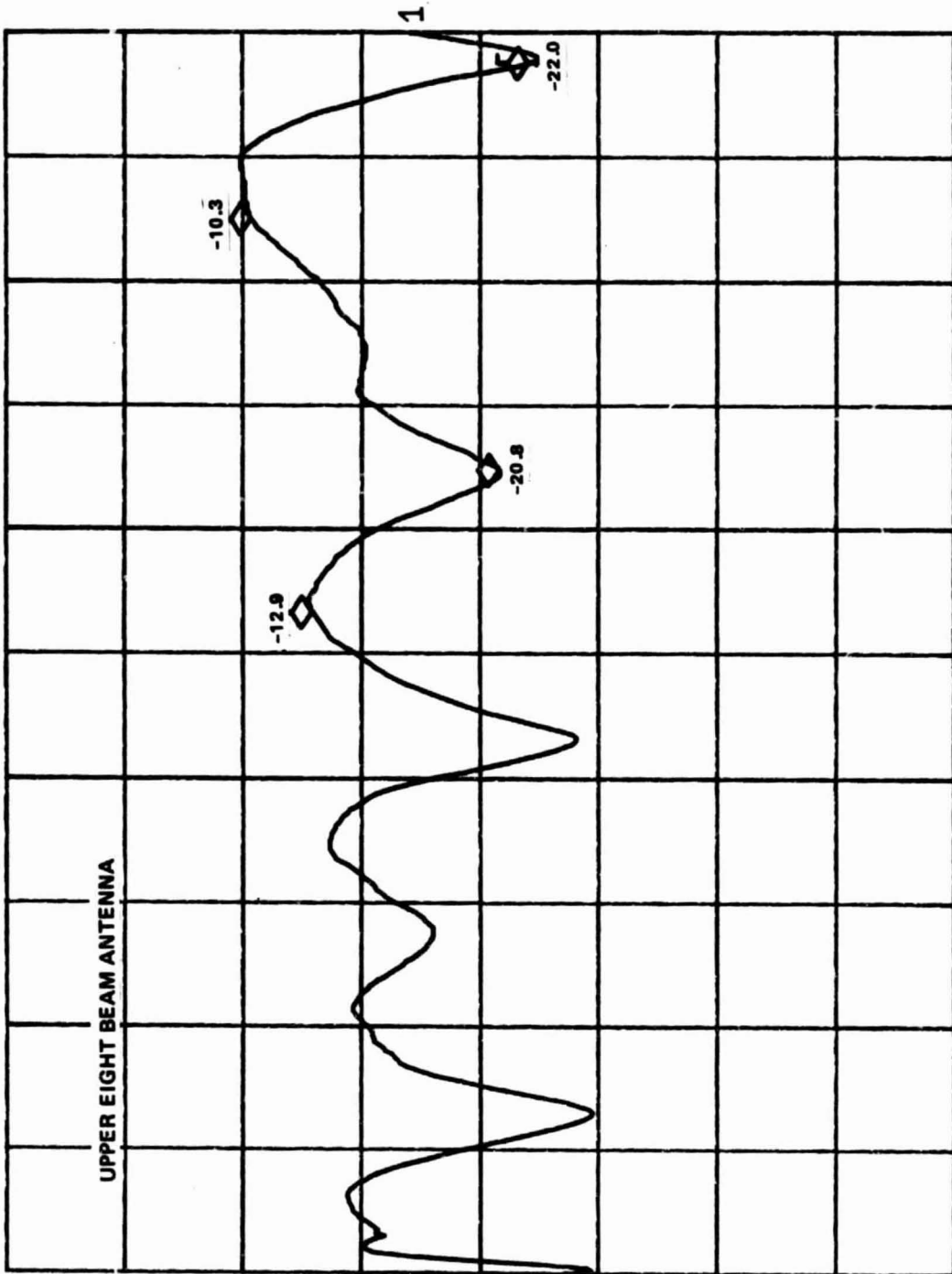
START +1.7500GHZ

STOP +2.3000GHZ

RETURN LOSS - BEAM 7

CH1: B - 22.04 dB  
5.0dB/ REF + .00 dB

REF 1



STRT +1.7500GHZ

STOP +2.3000GHZ

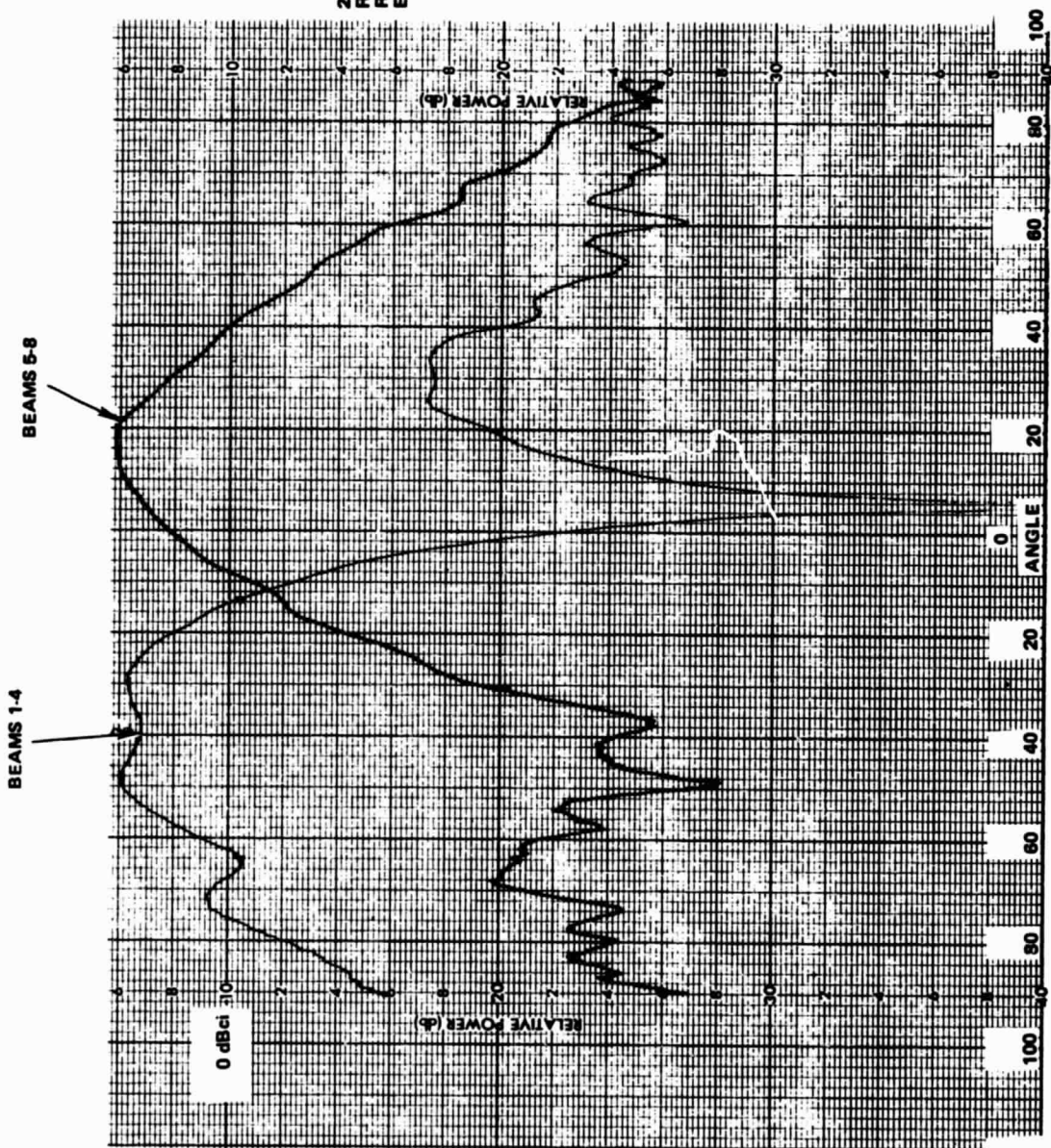
RETURN LOSS - BEAM 8

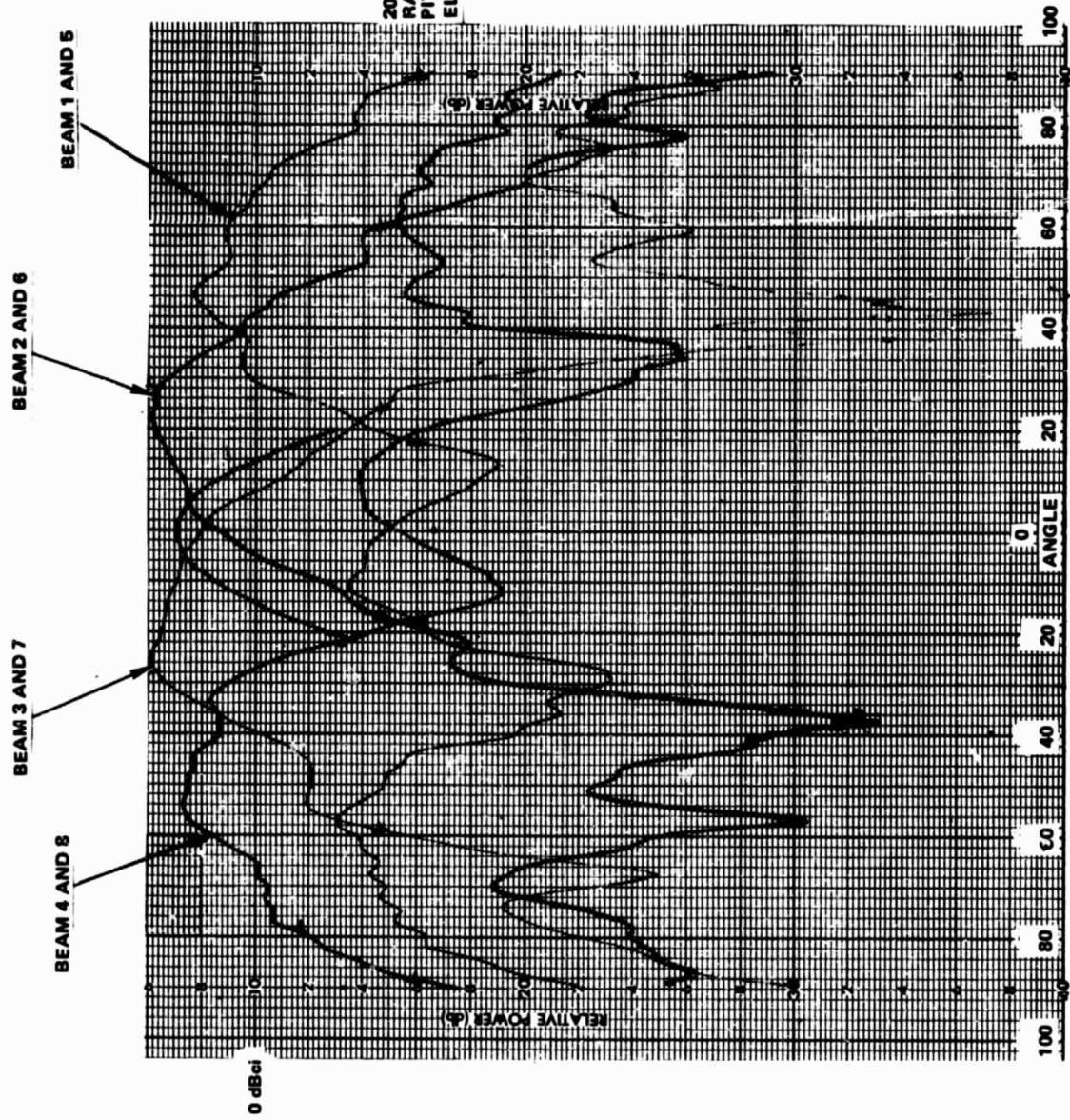
**8. GAIN PATTERNS**

40A

2041.9 MHz  
RADIATING ELEMENTS: A-E-B  
ROLL PLANE  
ELEVATION: 0°

LOWER ANTENNA

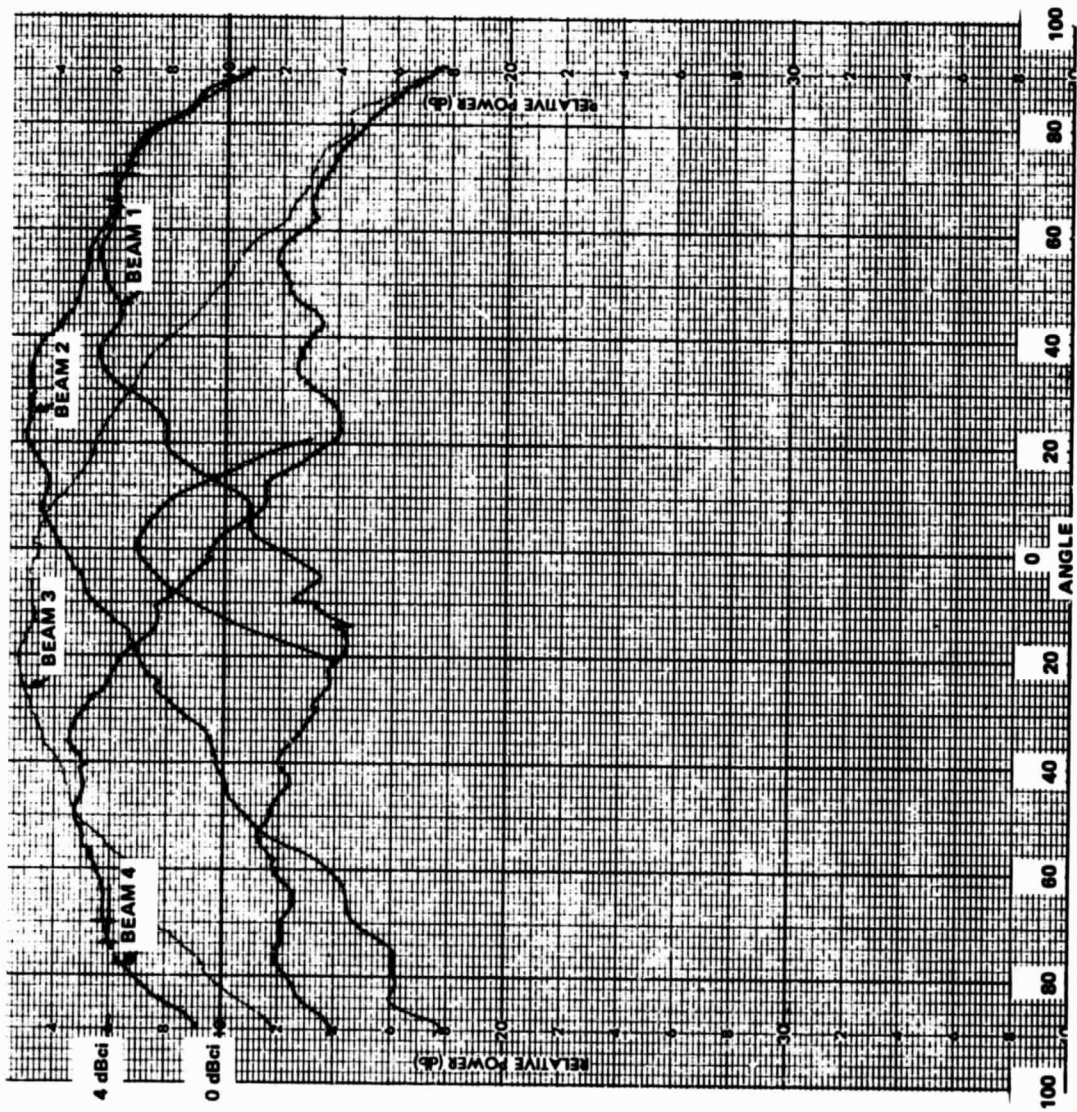




2041.9 MHz  
 RADIATING ELEMENTS: C-E-D  
 PITCH PLANE  
 ELEVATION: 0°

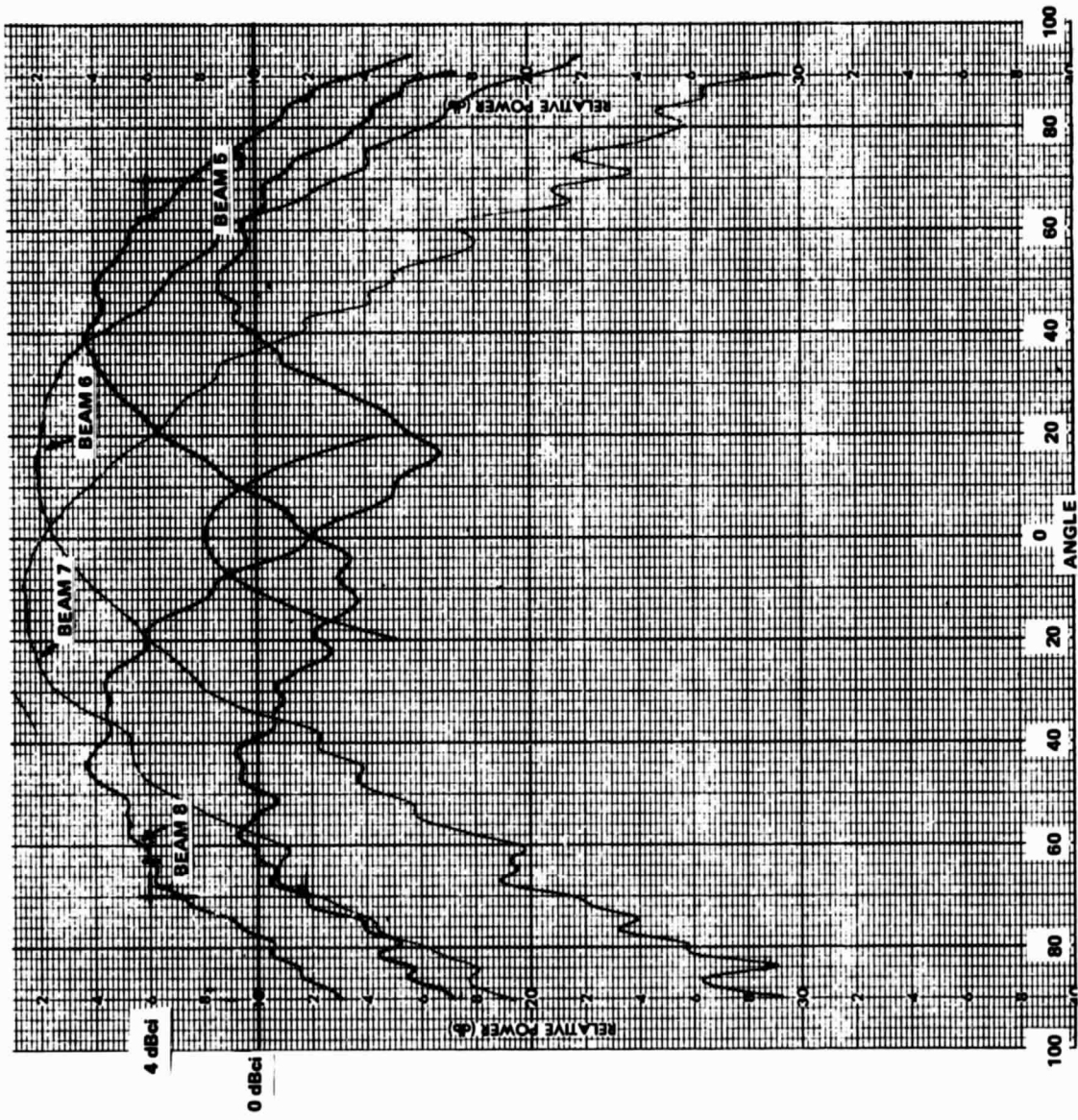
LOWER ANTENNA

2041.9 MHz  
BEAMS 1 THRU 4 (PITCH)  
ELEVATION: 48.3° DOWN  
MEASURED USING  
SCAN ANGLES  
FROM 2160 MHz  
LOWER ANTENNA



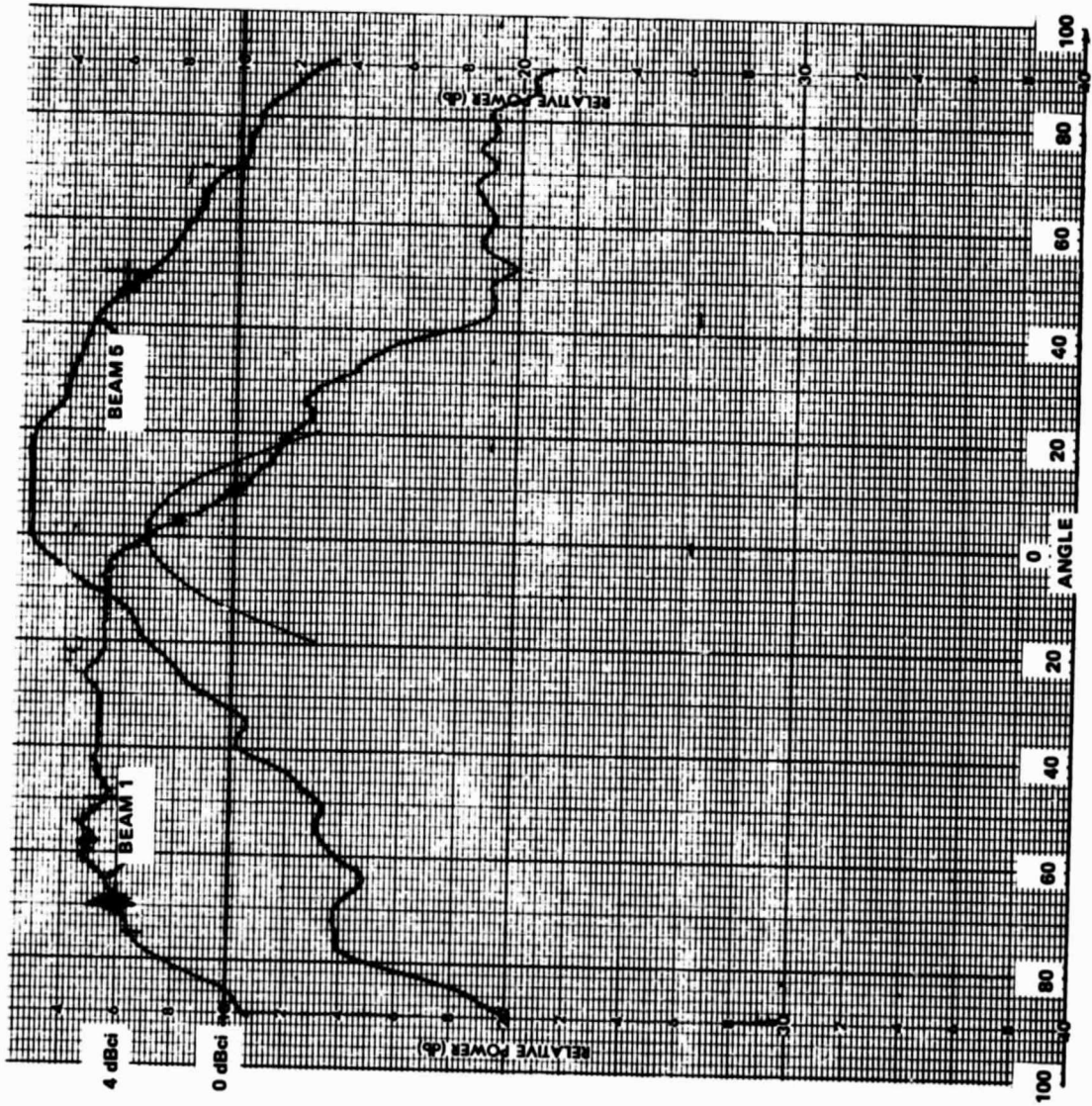


2041.9 MHz  
BEAMS 5 THRU 8 (PITCH)  
ELEVATION: 6.0° UP  
MEASURED USING  
SCAN ANGLES  
FROM 2150 MHz  
LOWER ANTENNA

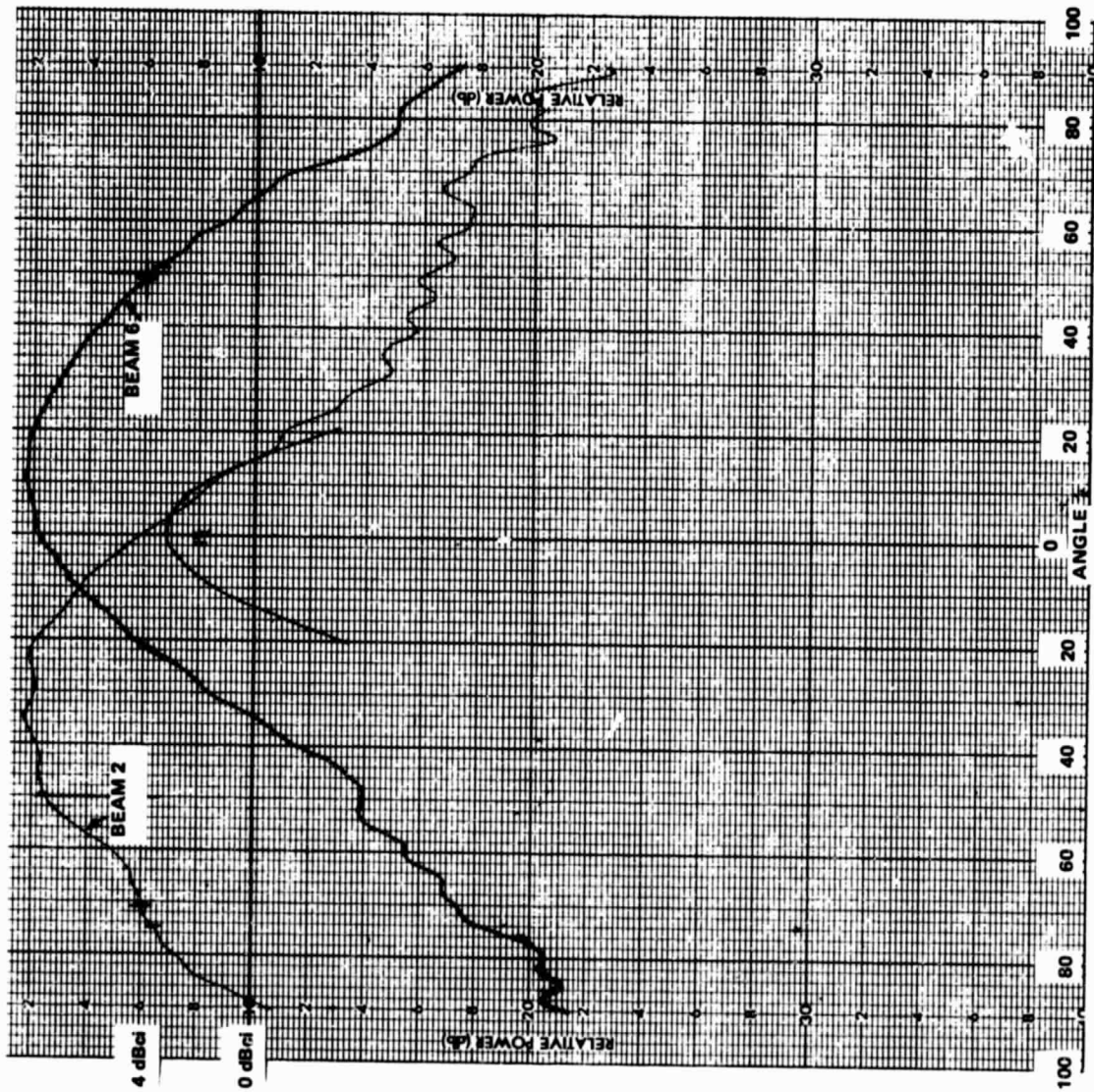




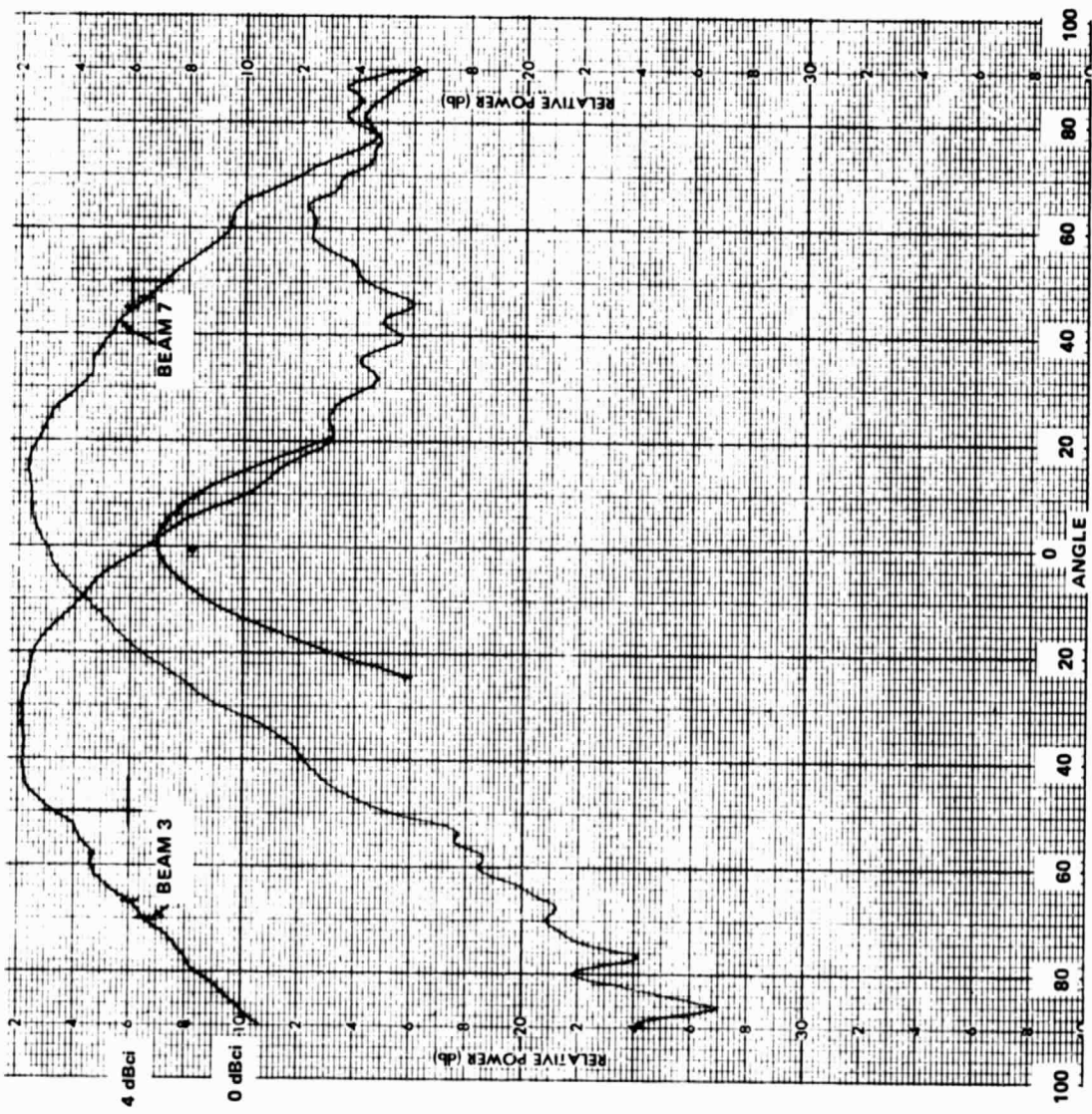
2041.9 MHz  
BEAMS 1 AND 5 (ROLL)  
ELEVATION: 46.4° DOWN  
MEASURED USING  
SCAN ANGLES  
FROM 2160 MHz  
LOWER ANTENNA



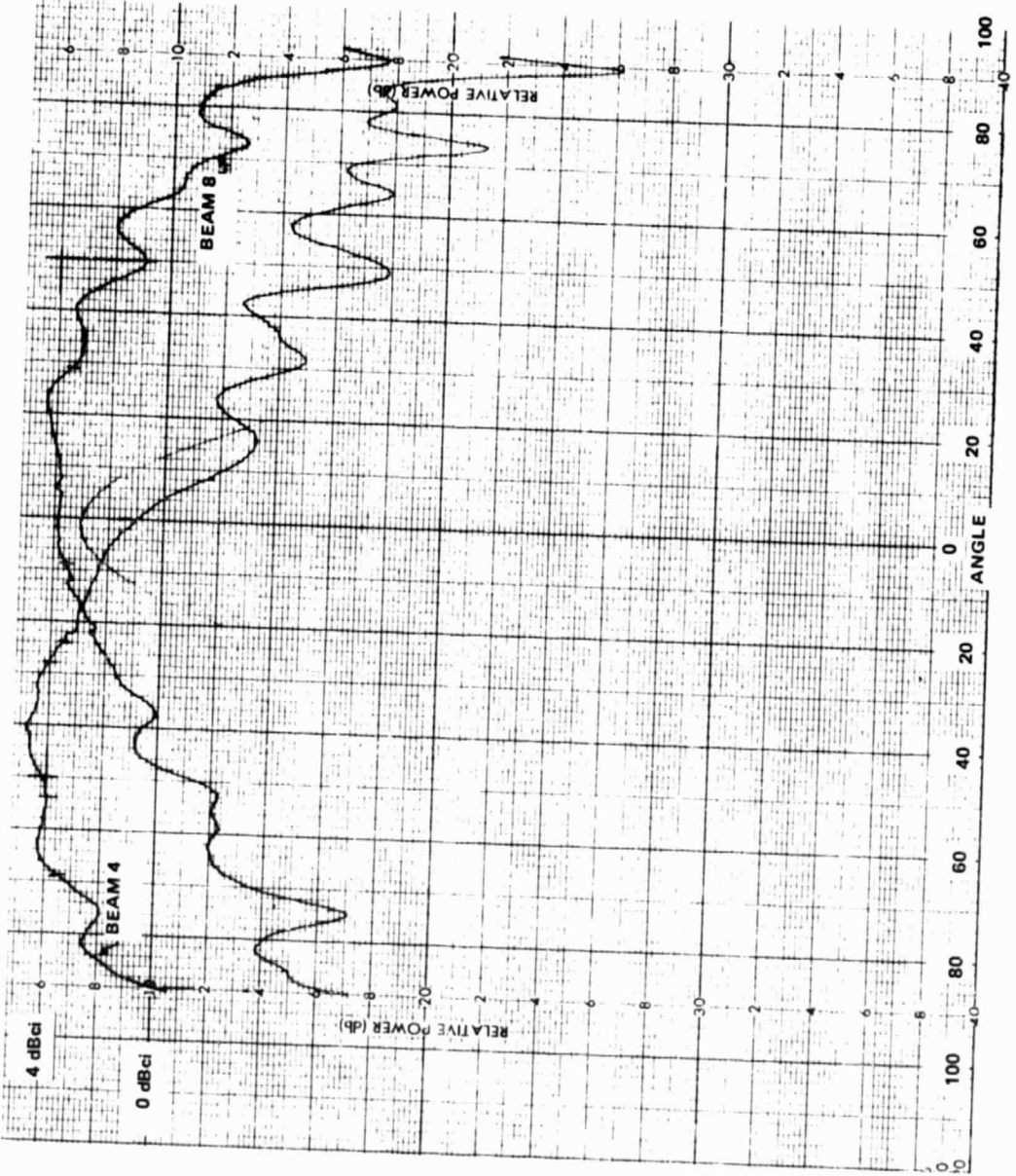
2041.9 MHz  
BEAMS 2 AND 6 (ROLL)  
ELEVATION: 13.5° DOWN  
MEASURED USING  
SCAN ANGLES  
FROM 2150 MHz  
LOWER ANTENNA



2041.9 MHz  
BEAMS 3 AND 7 (ROLL)  
ELEVATION: 12.5° UP  
MEASURED USING  
SCAN ANGLES  
FROM 2150 MHz  
LOWER ANTENNA

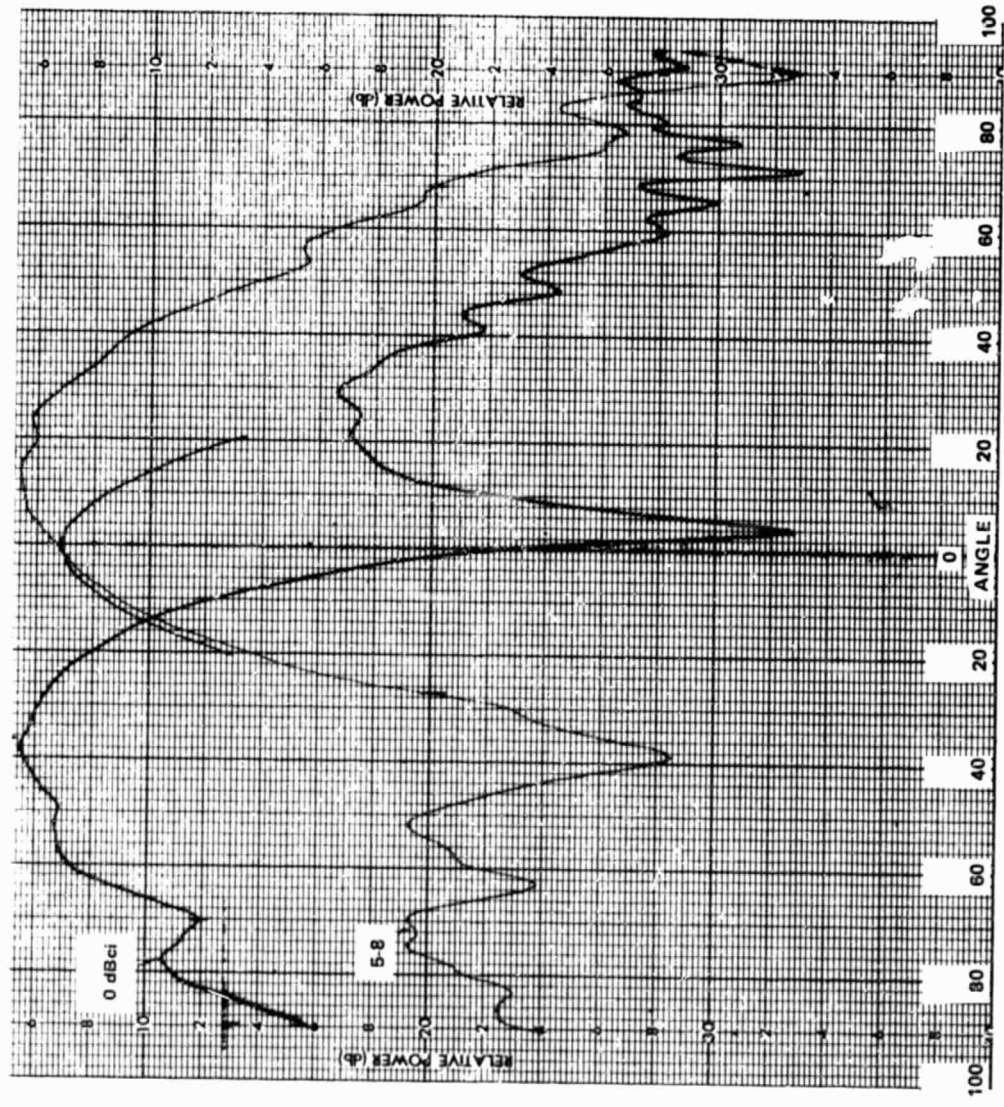


2041.9 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 52.0° UP  
MEASURED USING  
SCAN ANGLES  
FROM 2150 MHz  
LOWER ANTENNA

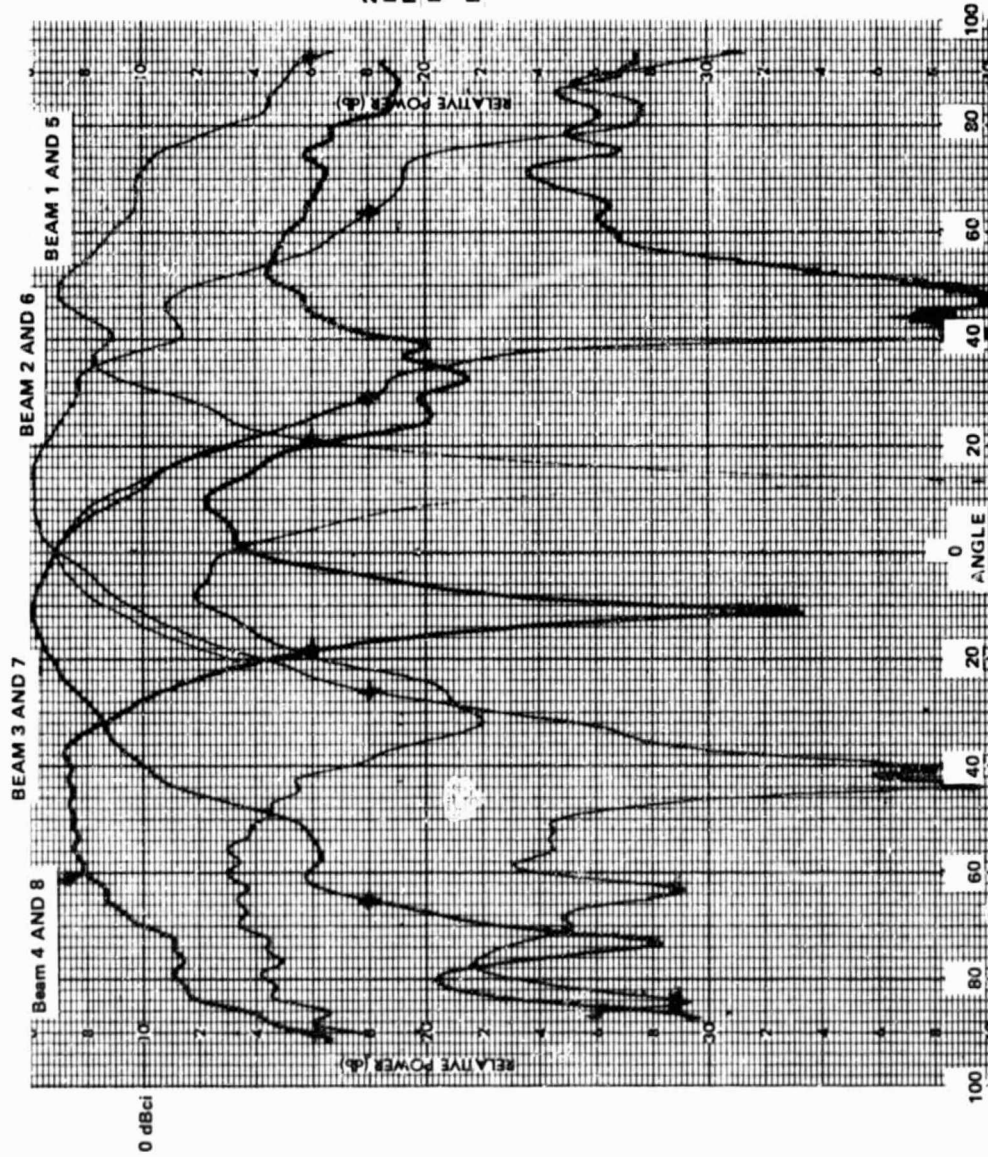


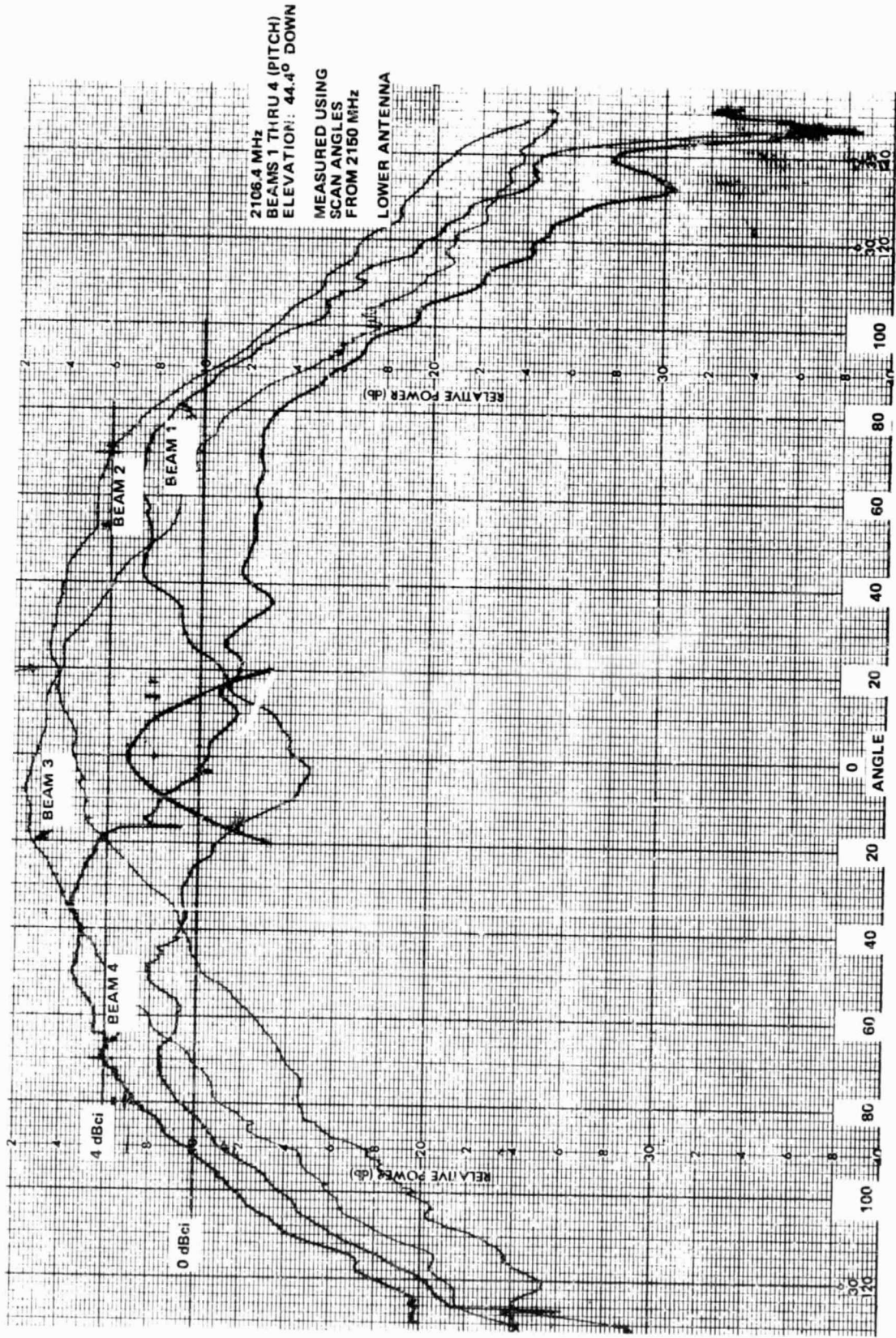


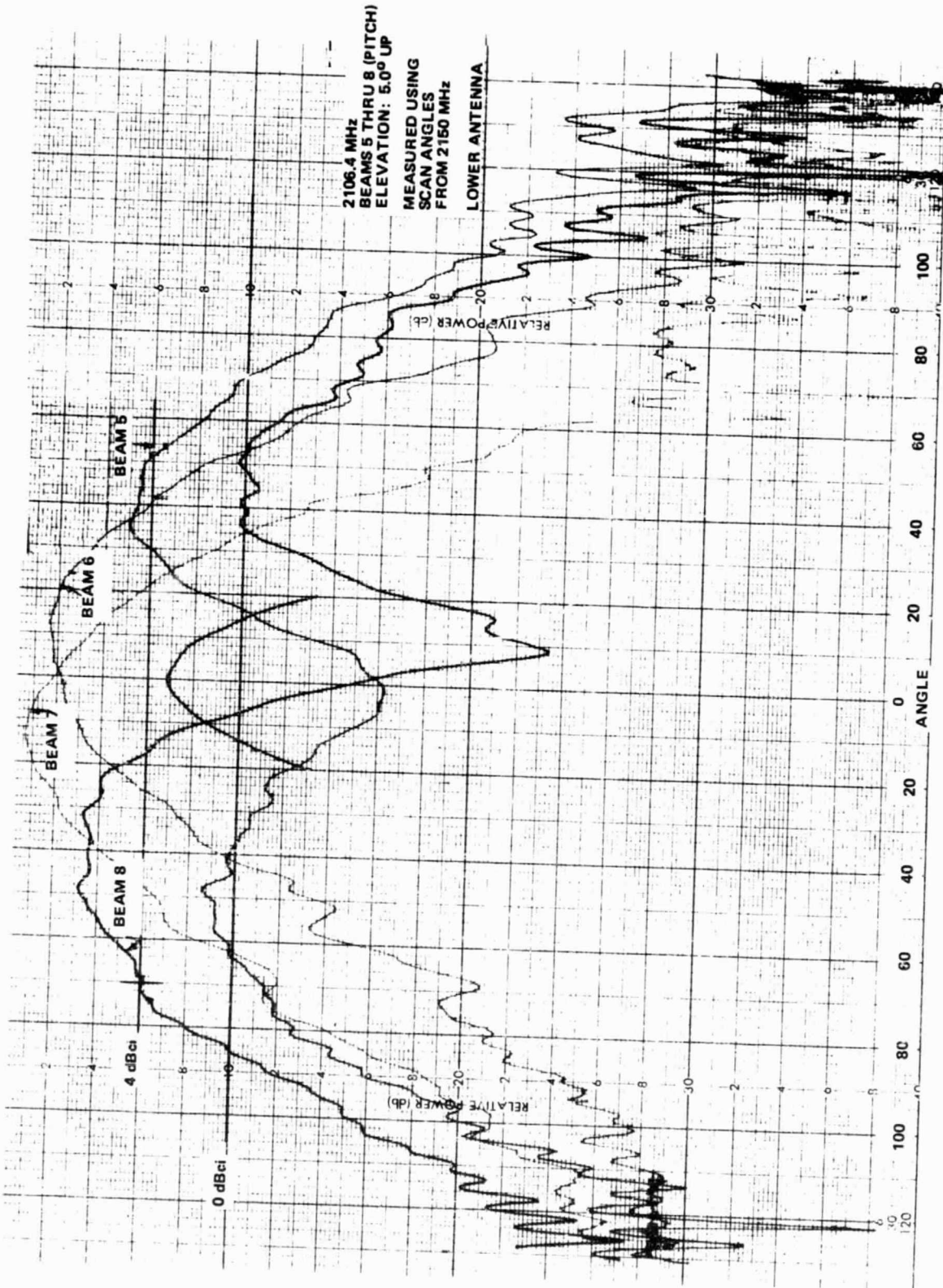
2106.4 MHz  
RADIATING ELEMENTS: A-E-B  
ROLL PLANE  
ELEVATION: 0°  
LOWER ANTENNA



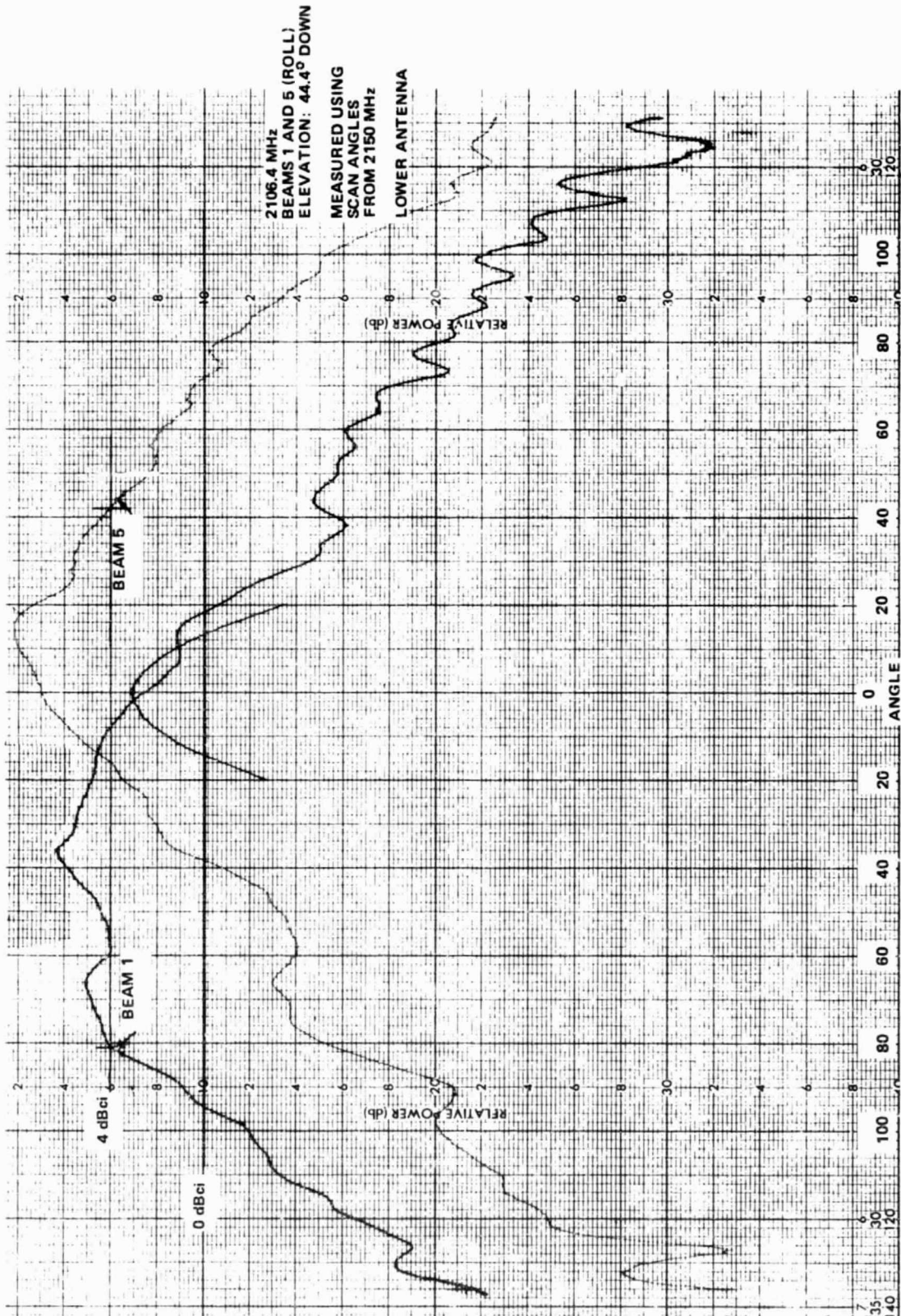
2106.4 MHz  
RADIATING ELEMENTS: C-E-D  
PITCH PLANE  
ELEVATION: 0°  
LOWER ANTENNA

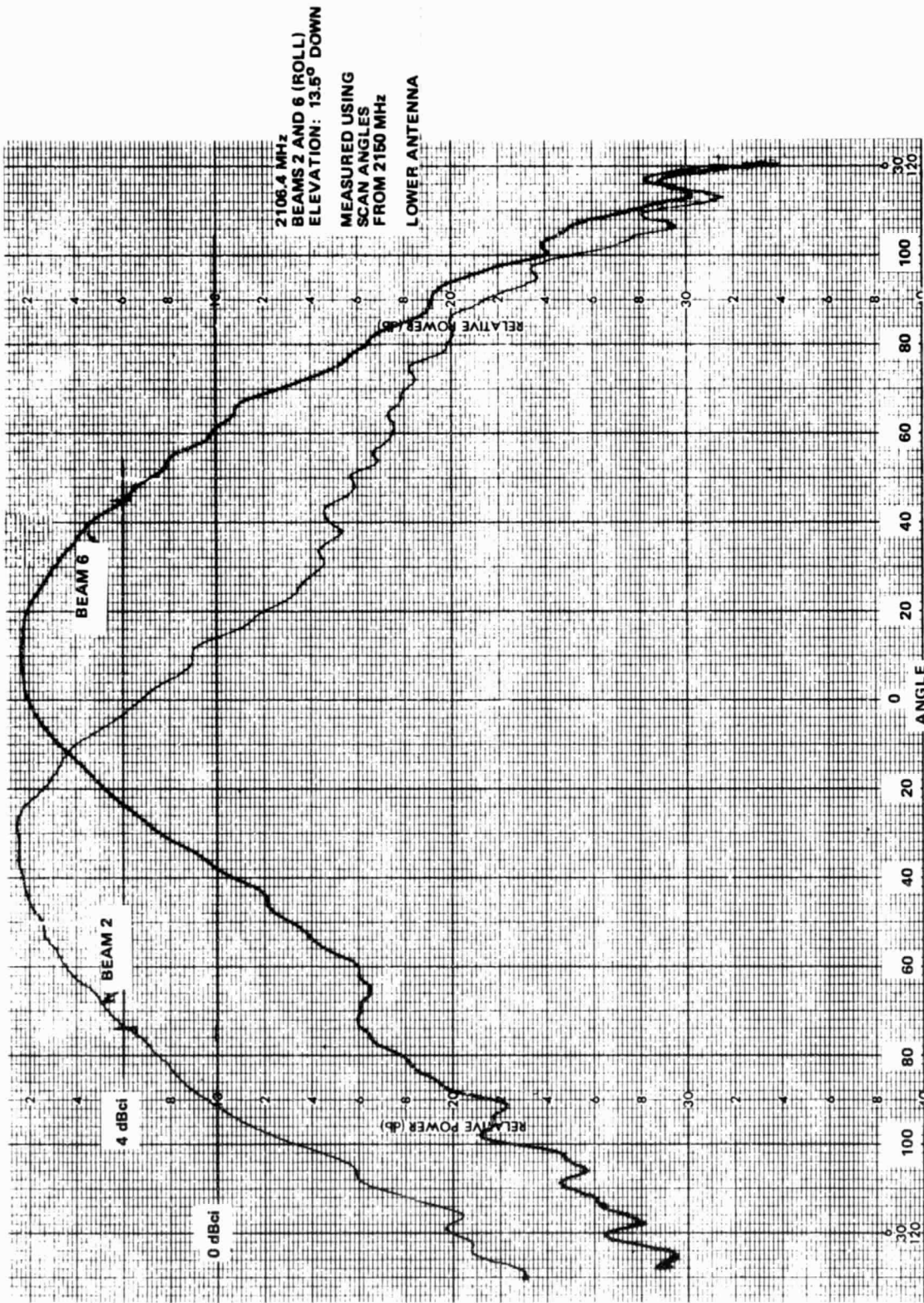




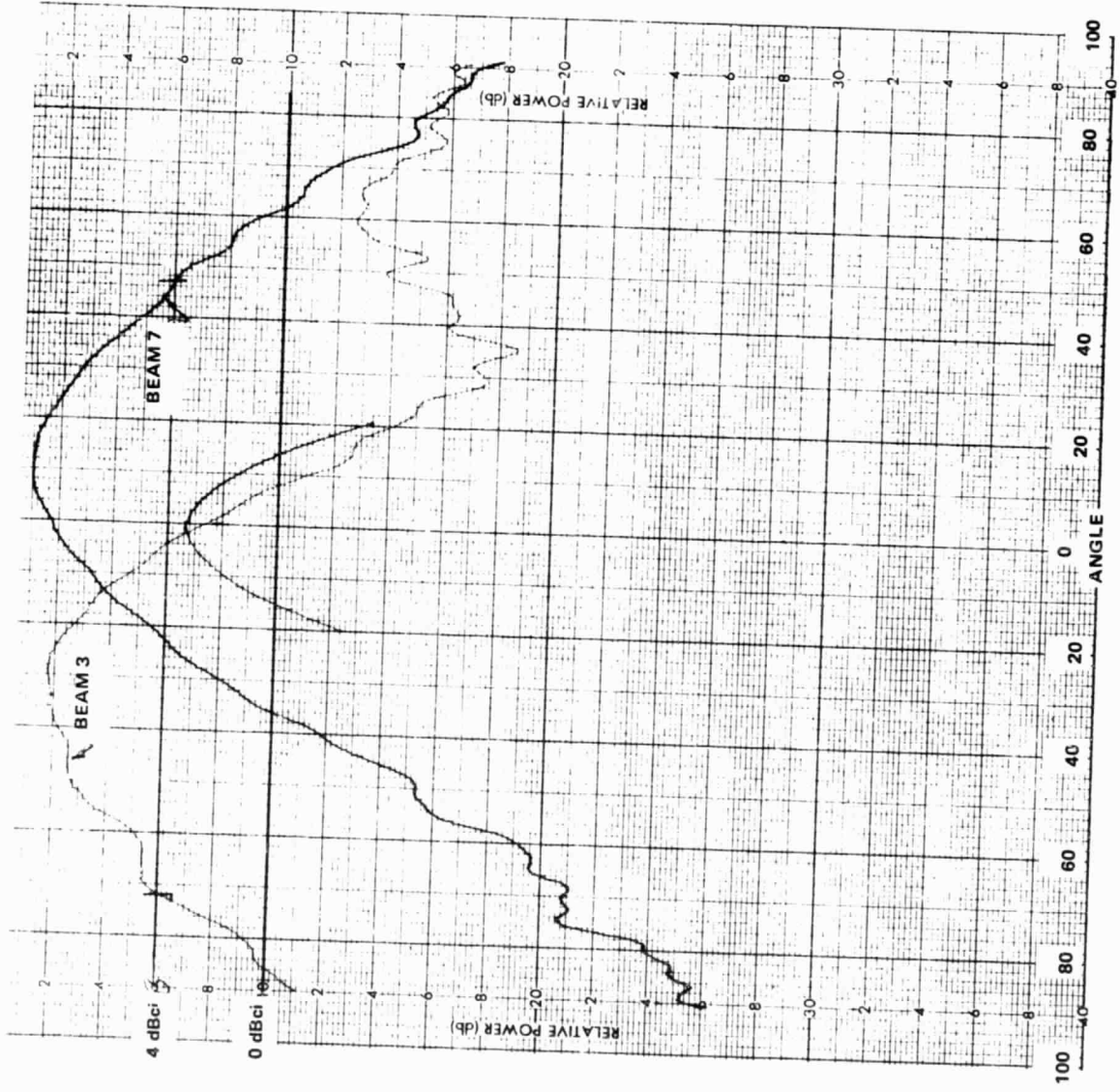




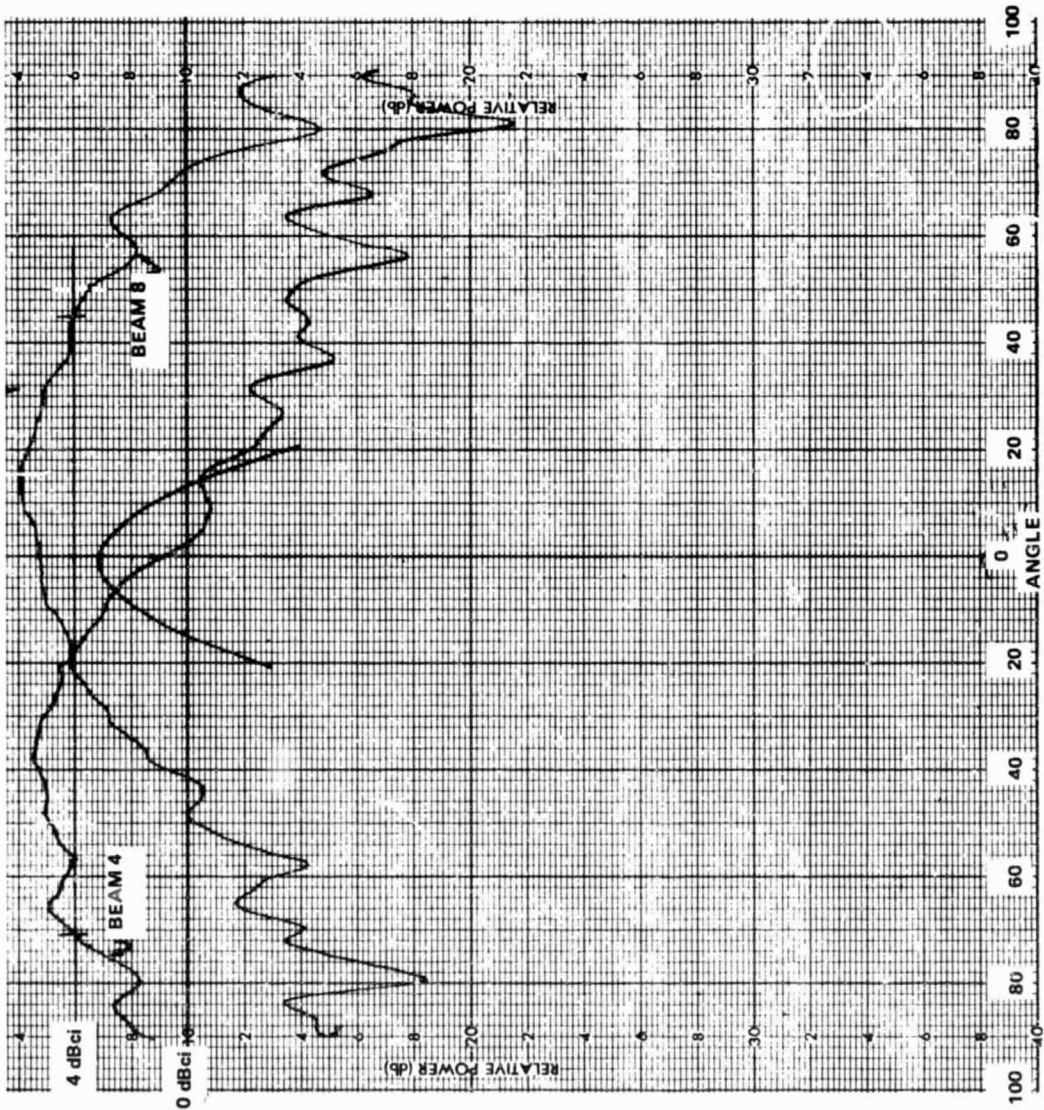




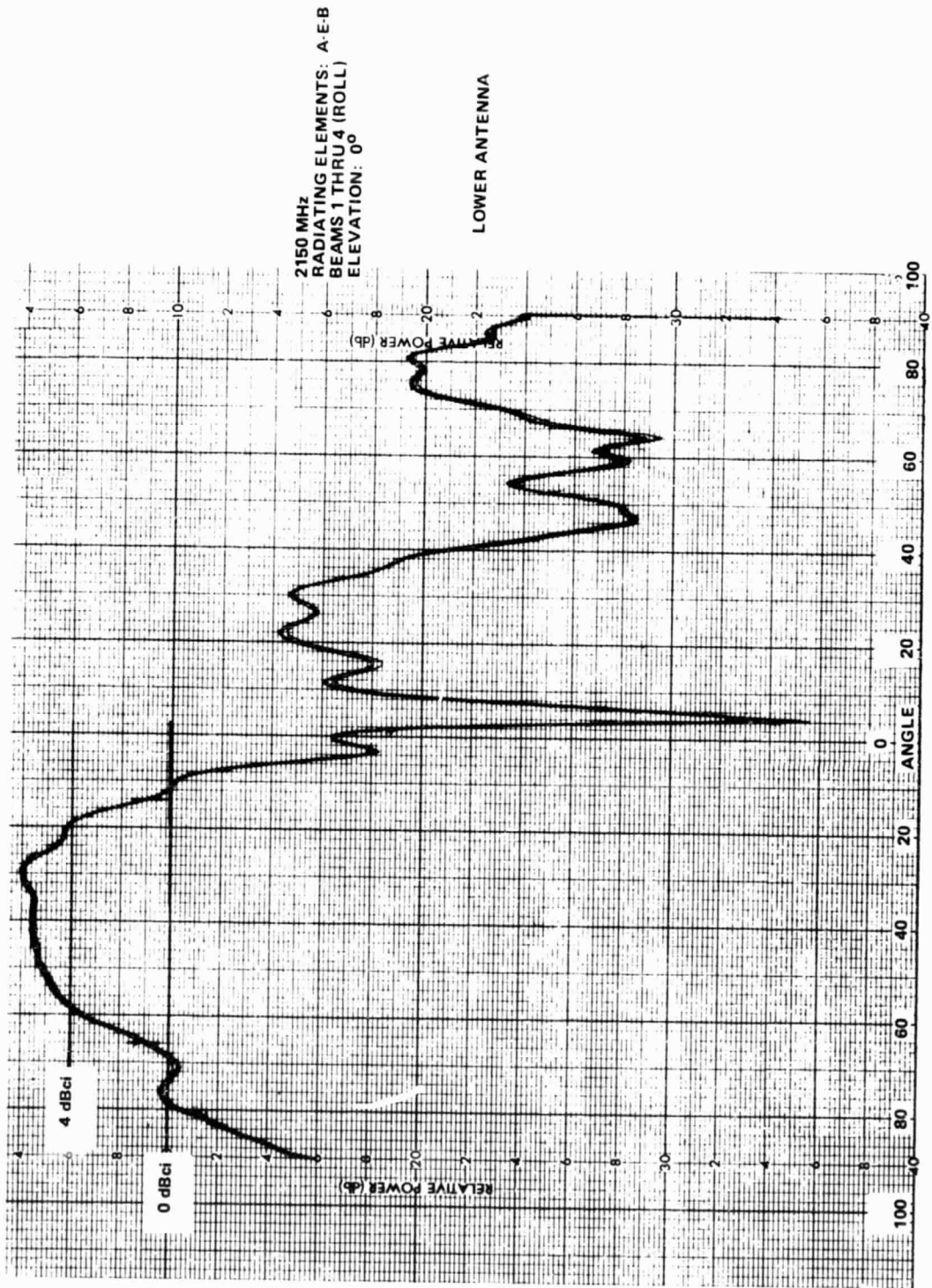
2106.4 MHz  
BEAMS 3 AND 7 (ROLL)  
ELEVATION: 12.5° UP  
MEASURED USING  
SCAN ANGLES  
FROM 2150 MHz  
LOWER ANTENNA

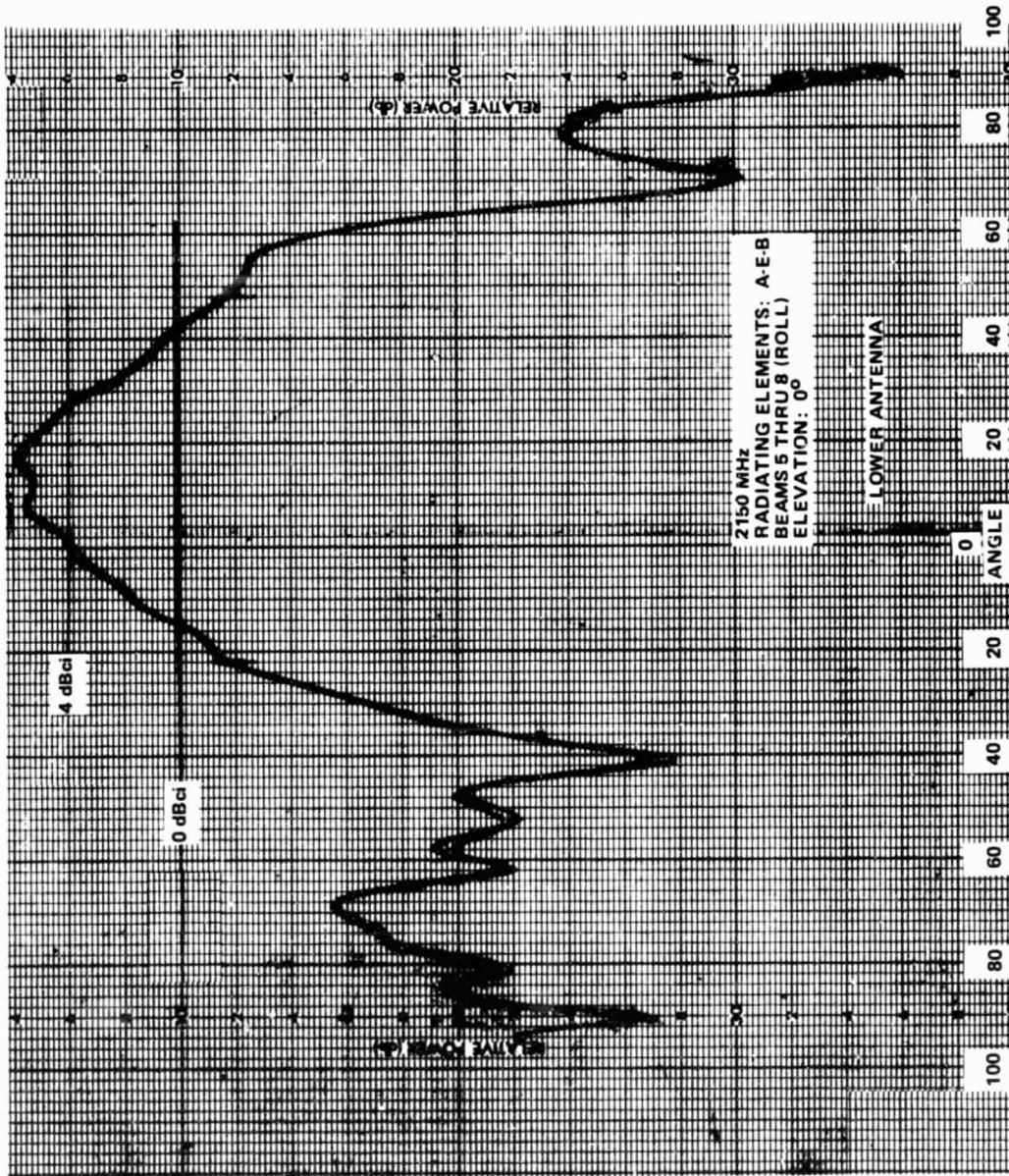


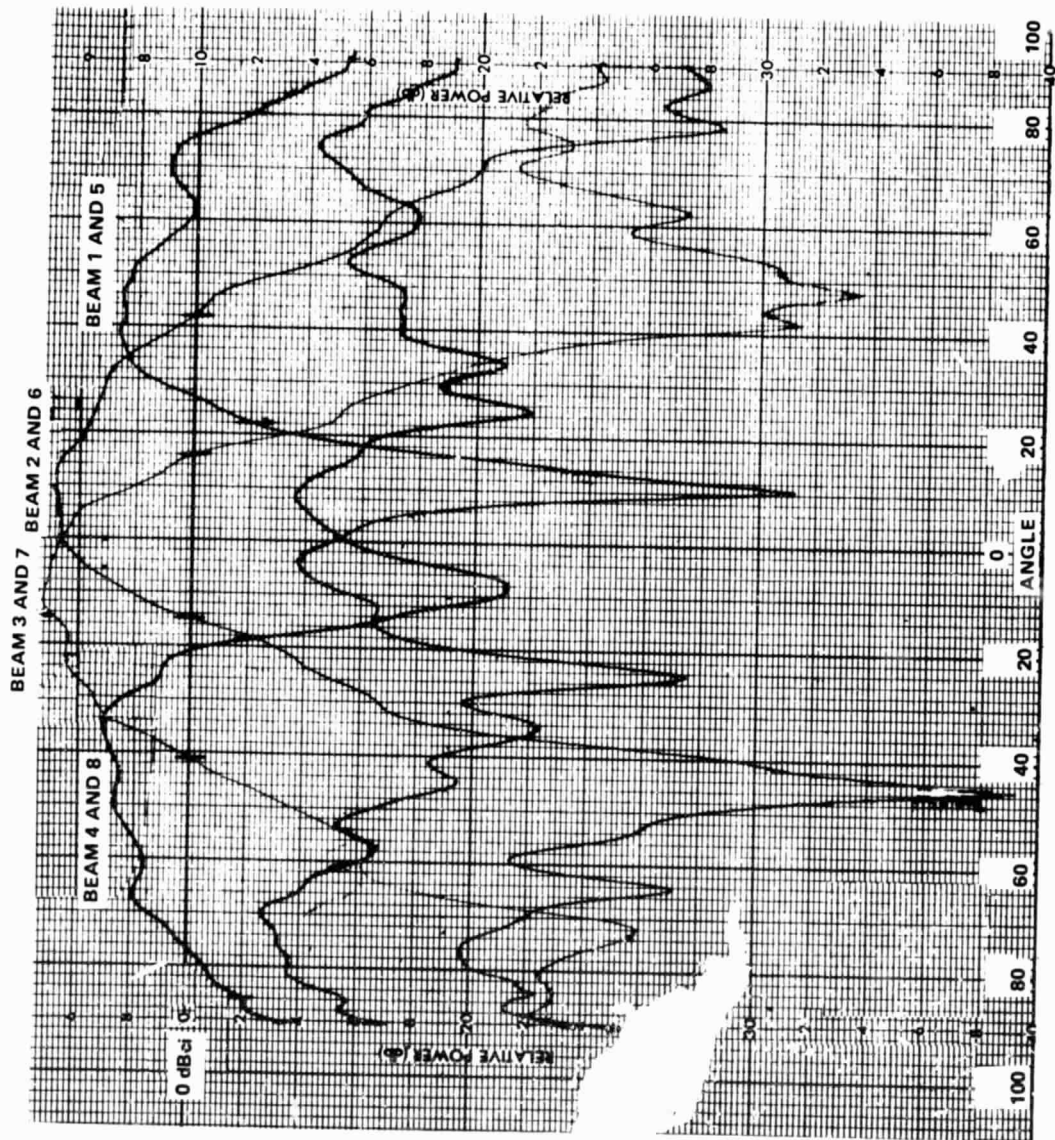
2106.4 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 52.0° UP  
MEASURED USING  
SCAN ANGLES  
FROM 2150 MHz  
LOWER ANTENNA





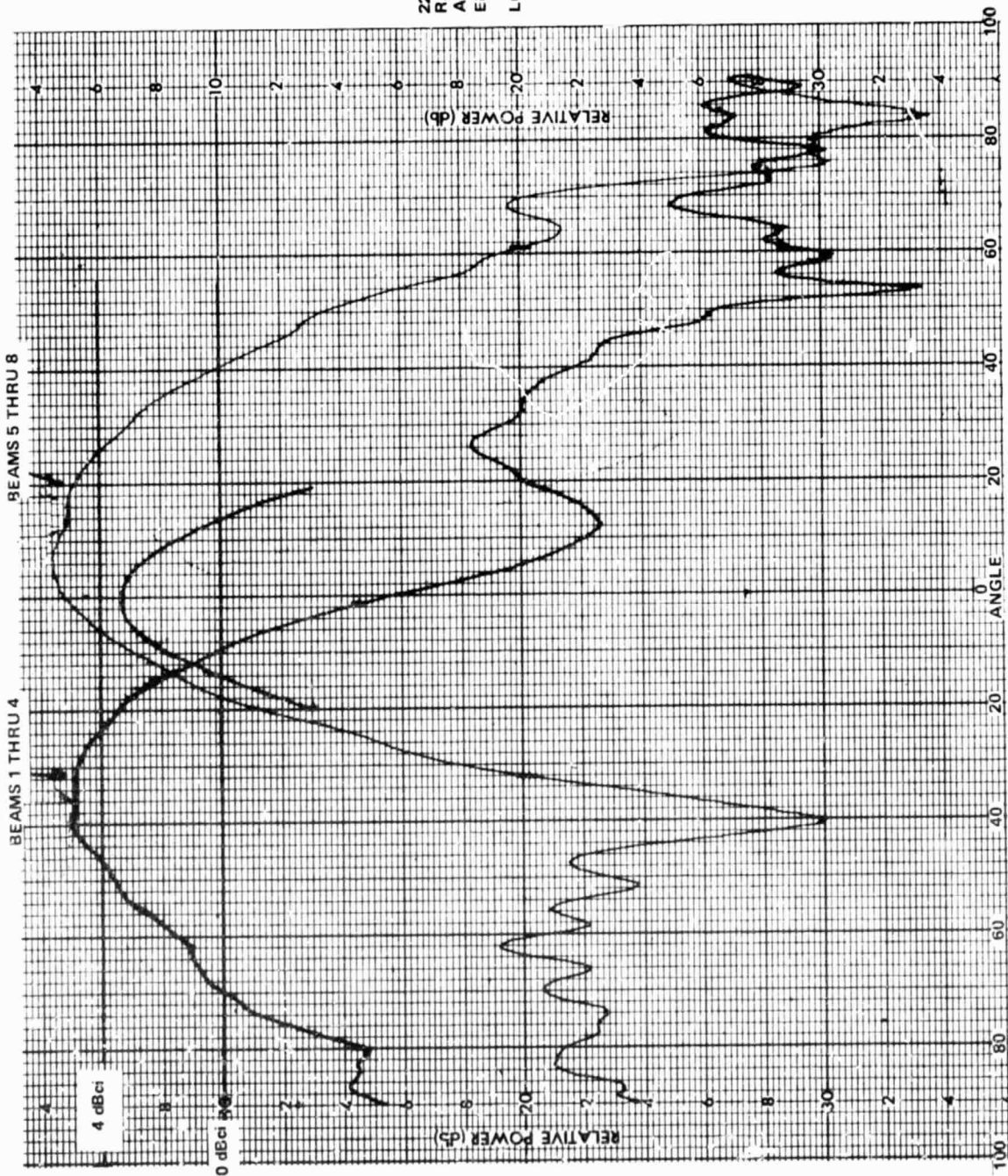






2150 MHz  
 RADIATING ELEMENTS: C-E-D  
 BEAMS 1 THRU 4, 5 THRU 8  
 ELEVATION: 0°

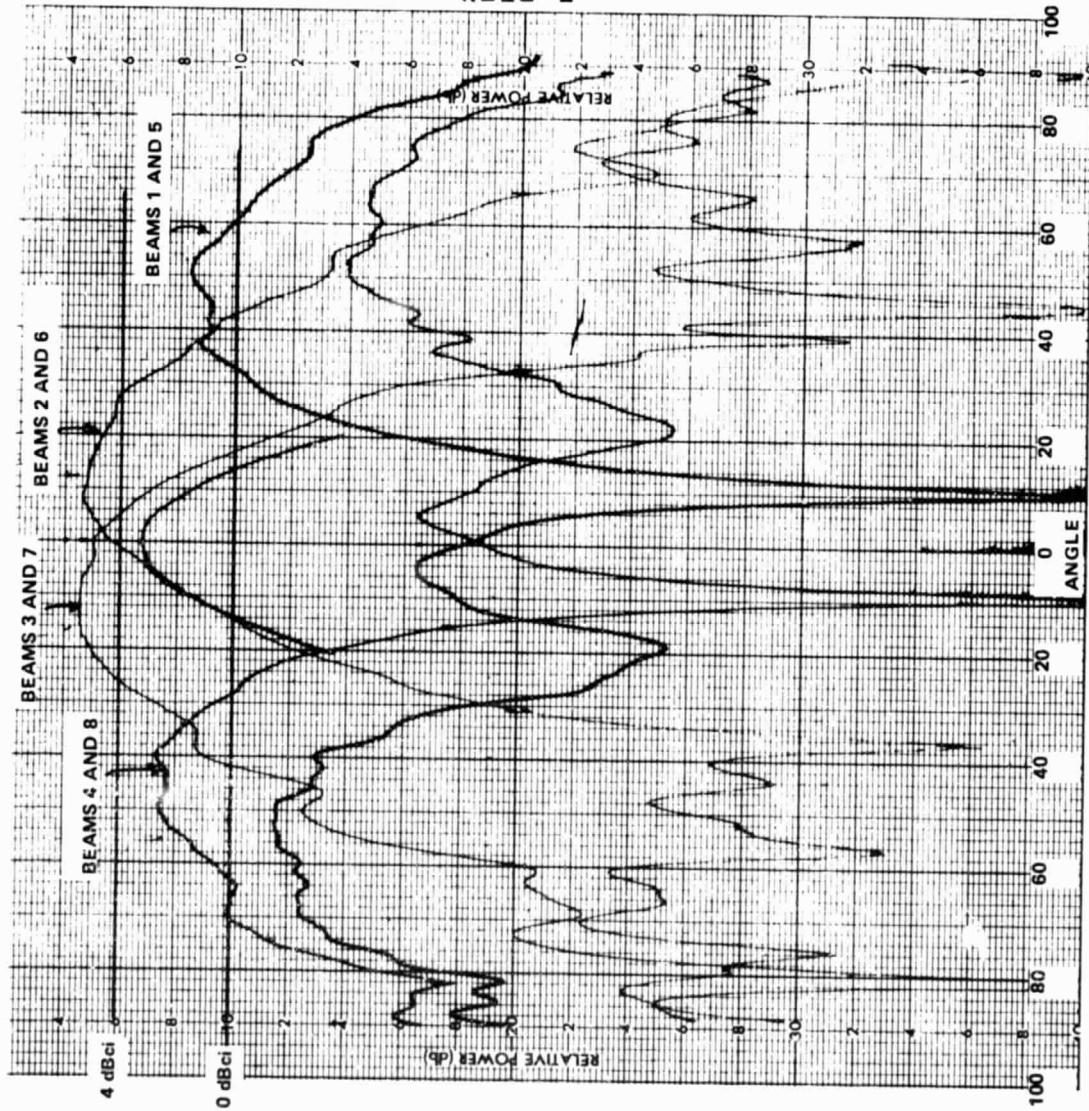
LOWER ANTENNA

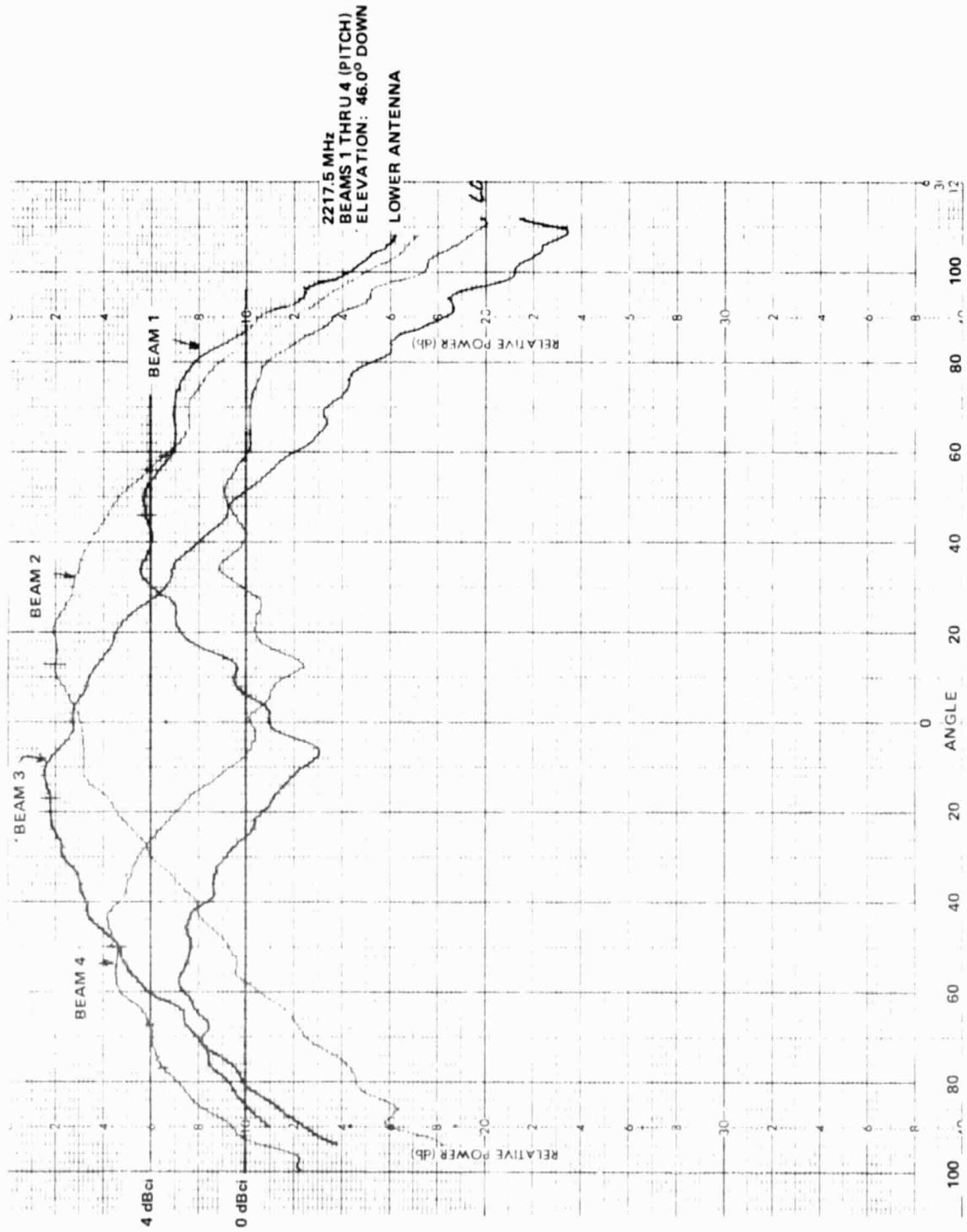


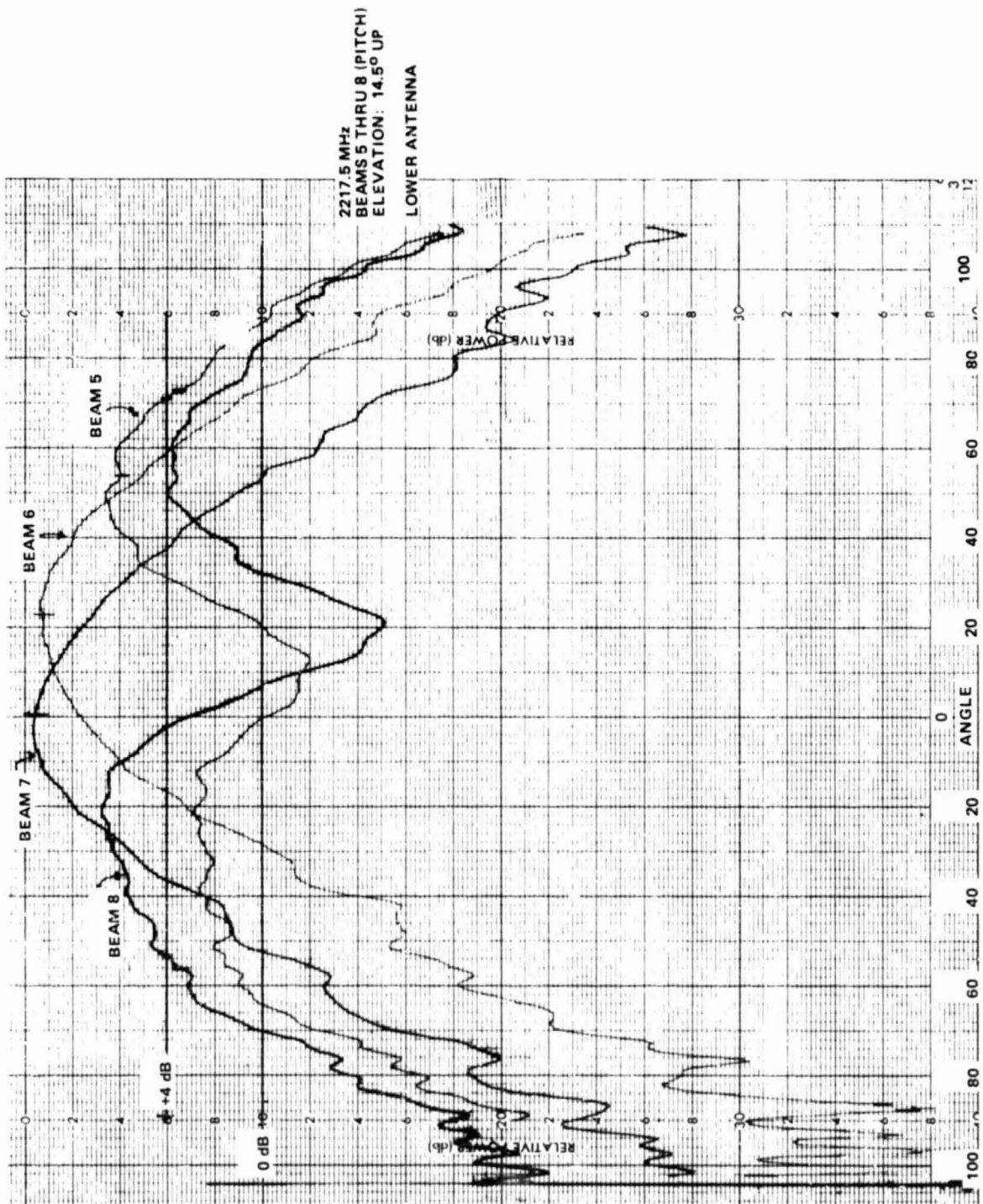
2217.5 MHz  
 RADIATING ELEMENTS:  
 A-E B ROLL PLANE  
 ELEVATION: 0°  
 LOWER ANTENNA

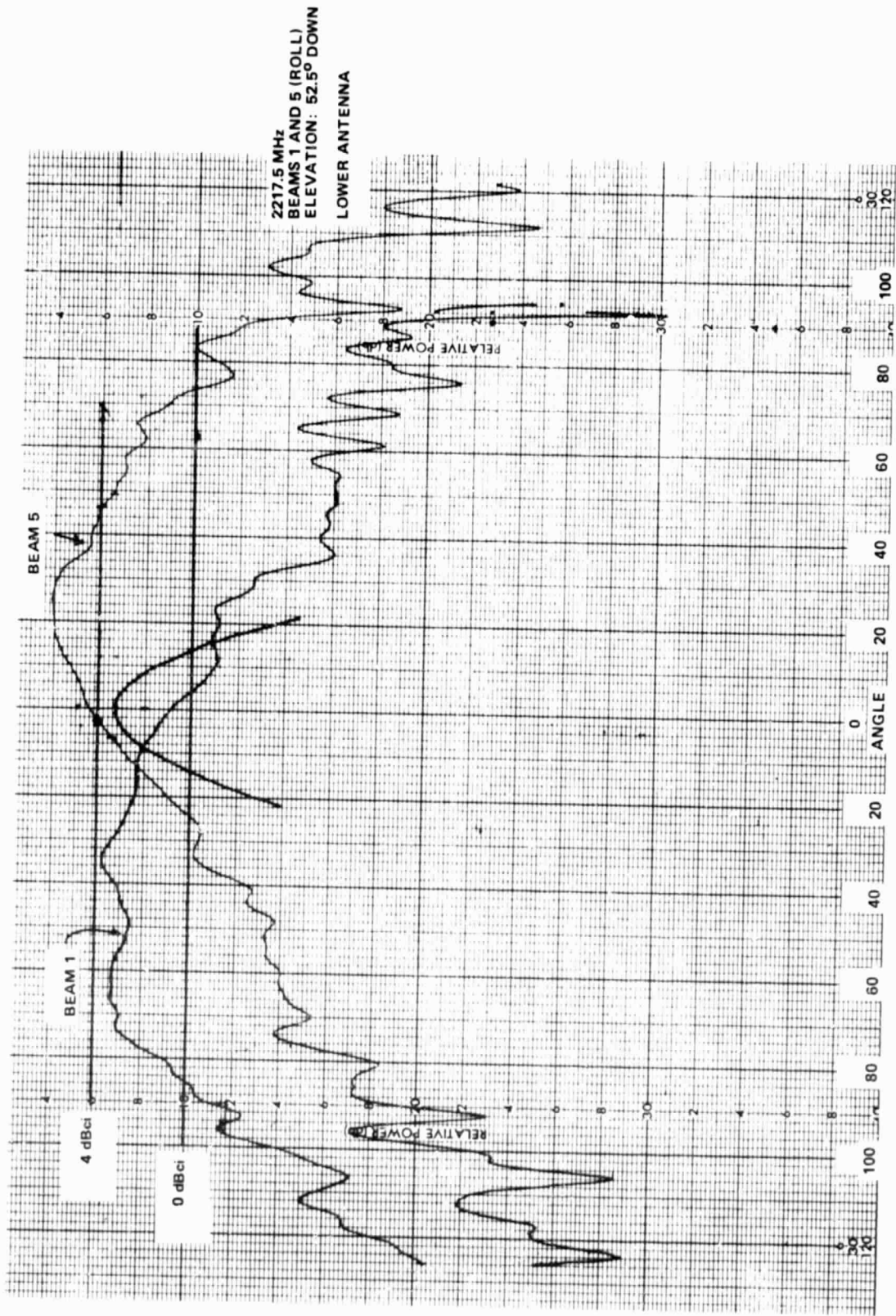


2217.5 MHz  
RADIATING ELEMENTS: C-E-D  
PITCH PLANE  
ELEVATION: 0°  
LOWER ANTENNA

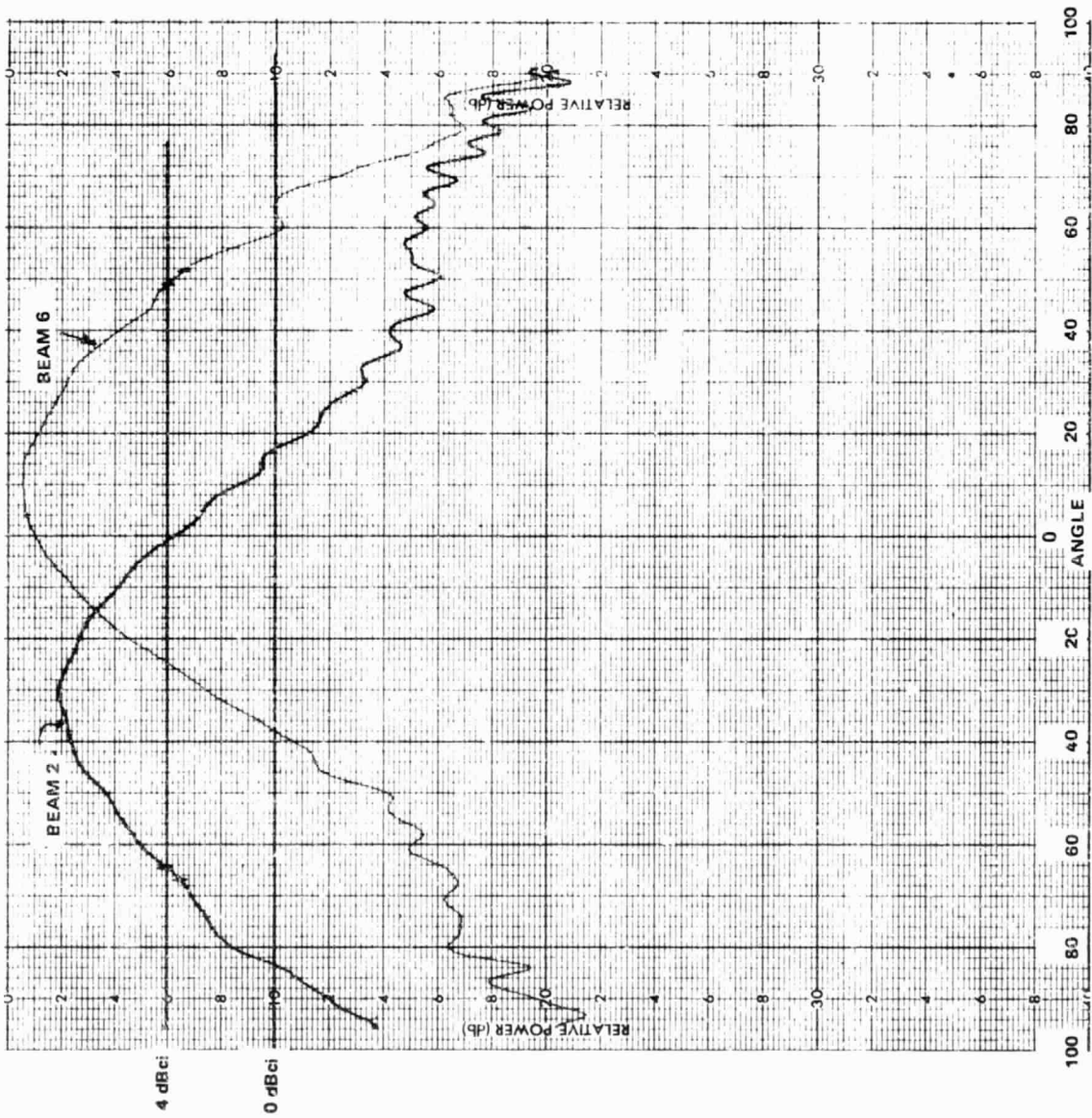


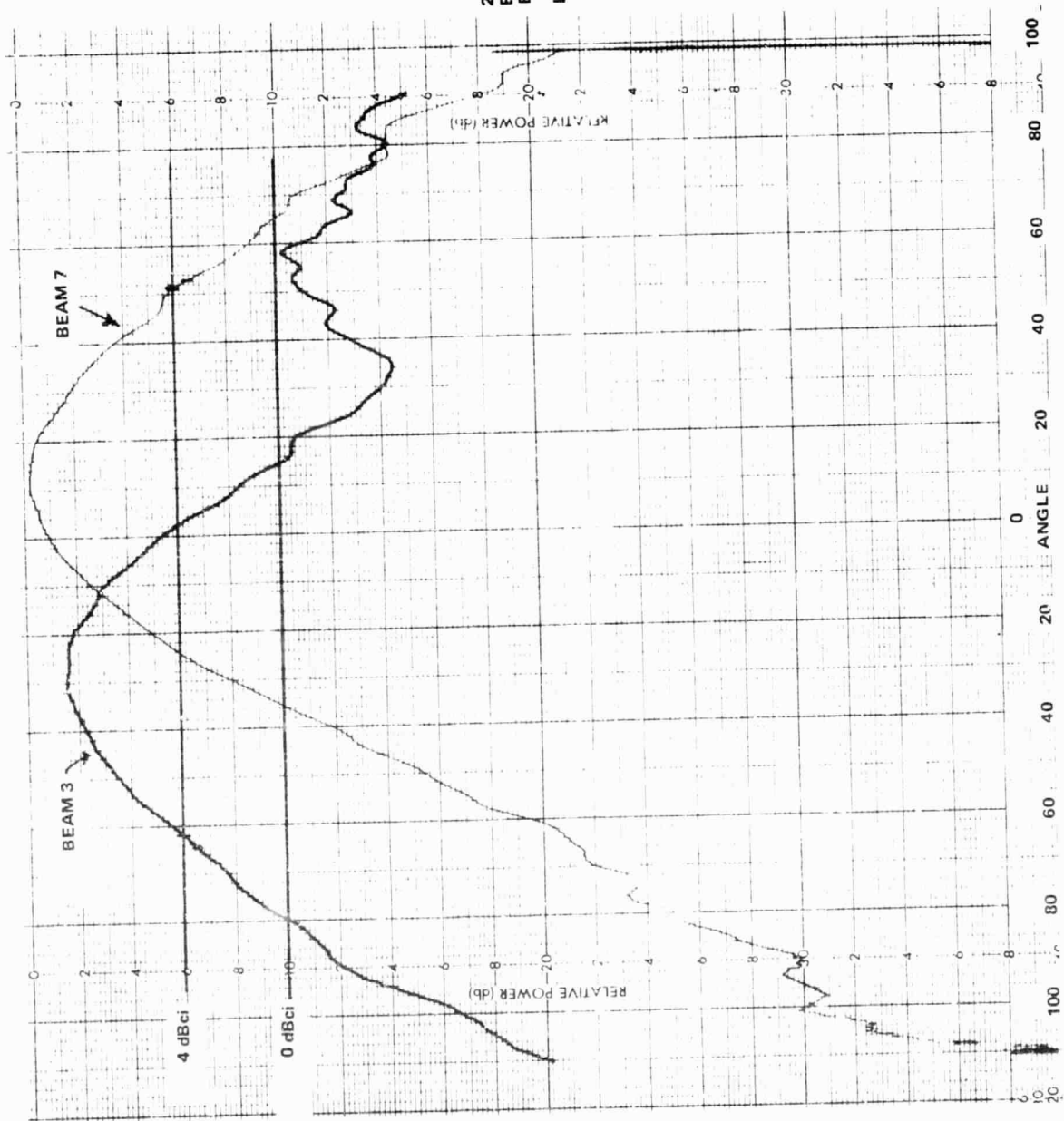






2217.5 MHz  
BEAMS 2 AND 6 (ROLL)  
ELEVATION: 17.5° DOWN  
LOWER ANTENNA

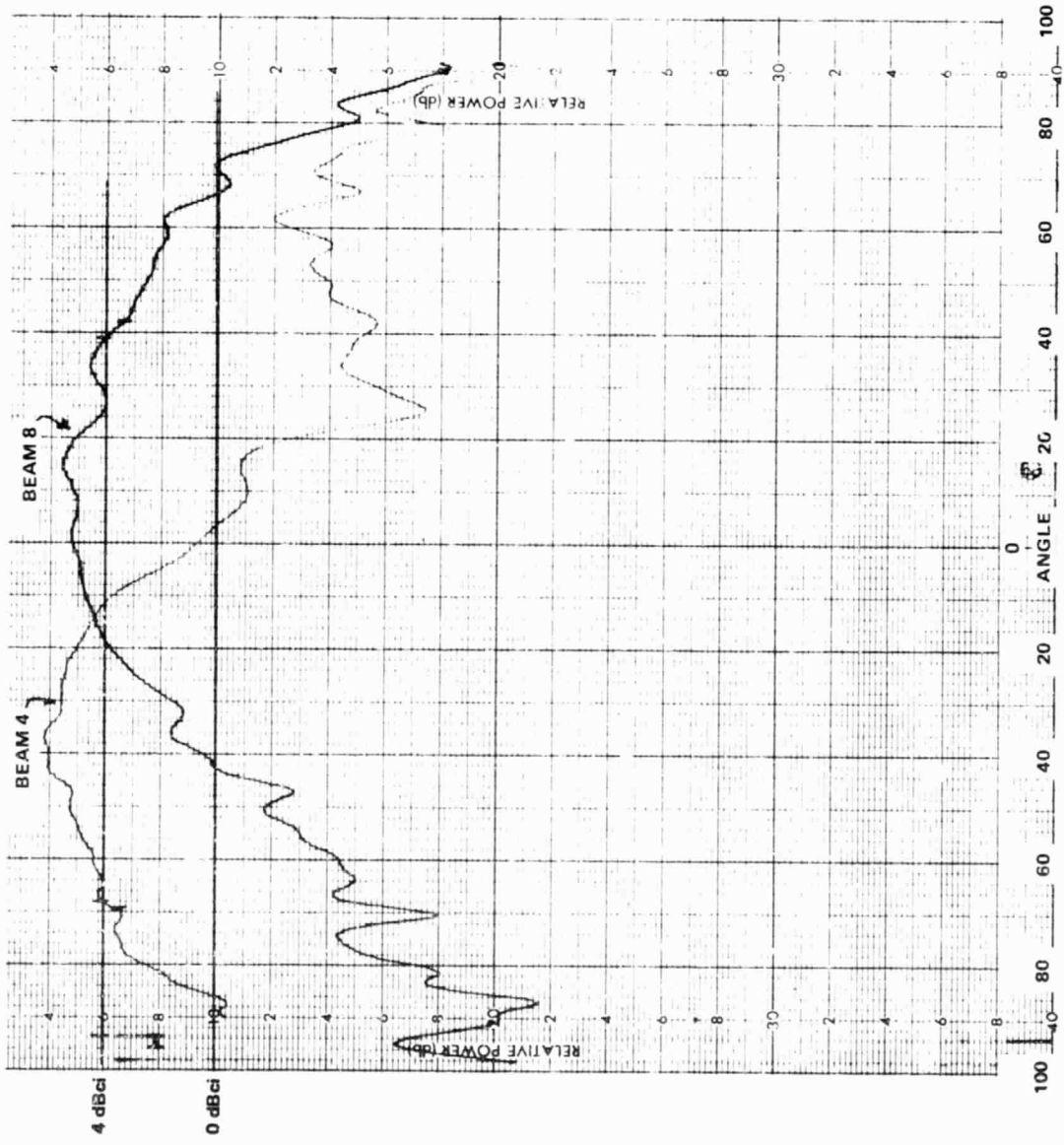




2217.5 MHz  
 BEAMS 3 AND 7 (ROLL)  
 ELEVATION: 13.5° UP  
 LOWER ANTENNA

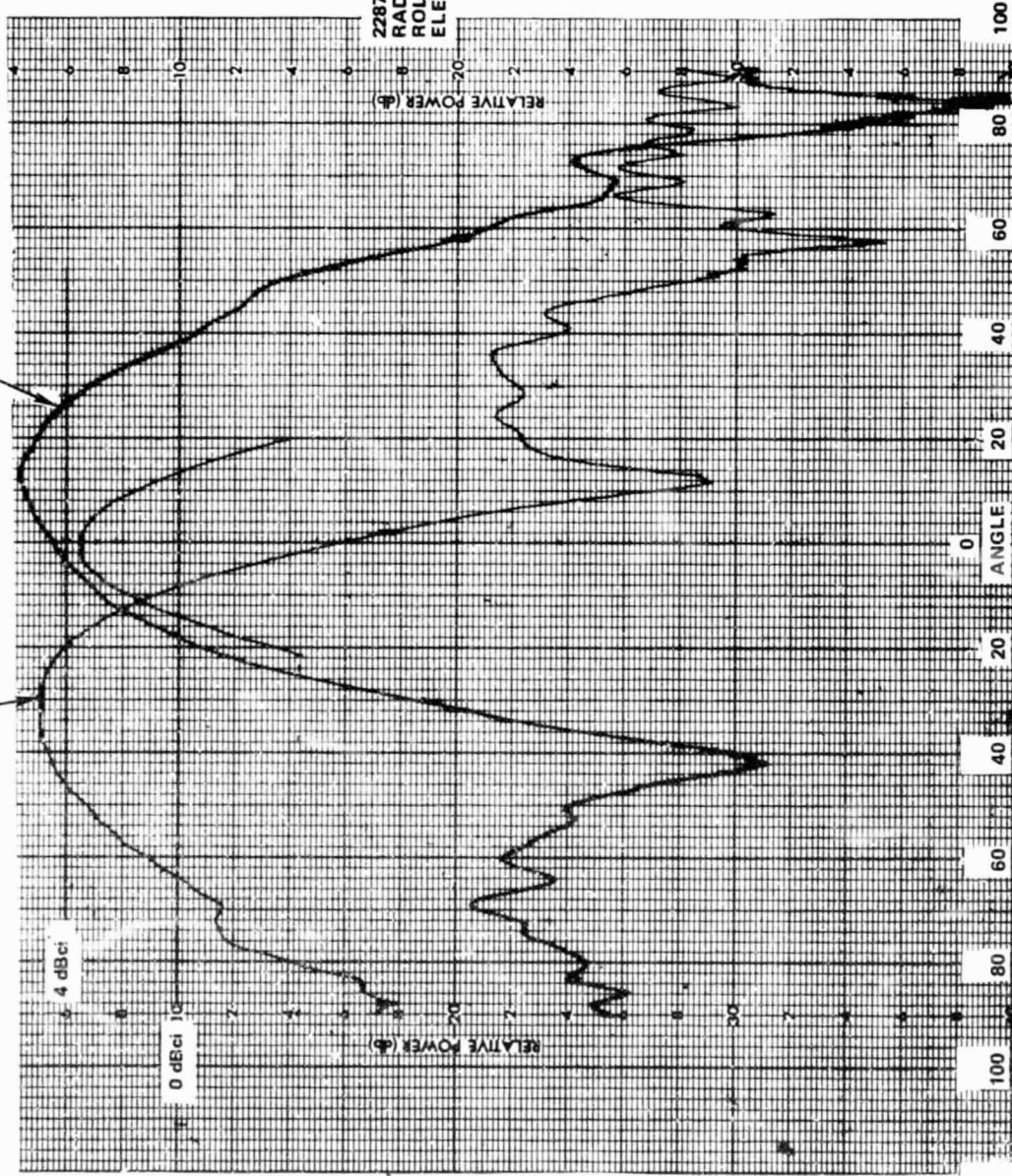


2217.5 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 48.5° UP  
LOWER ANTENNA



BEAMS 5 THRU 8

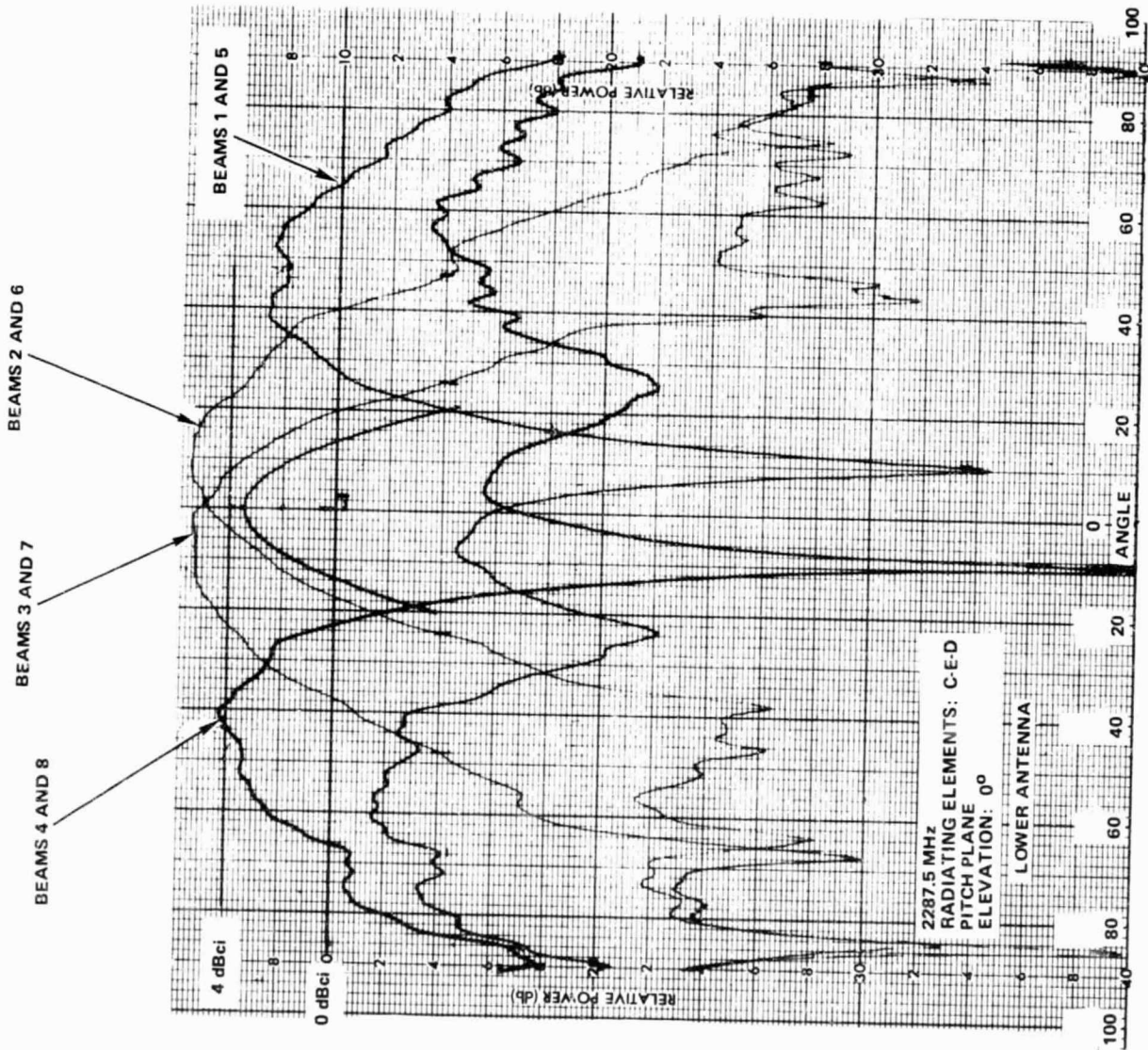
BEAMS 1 THRU 4

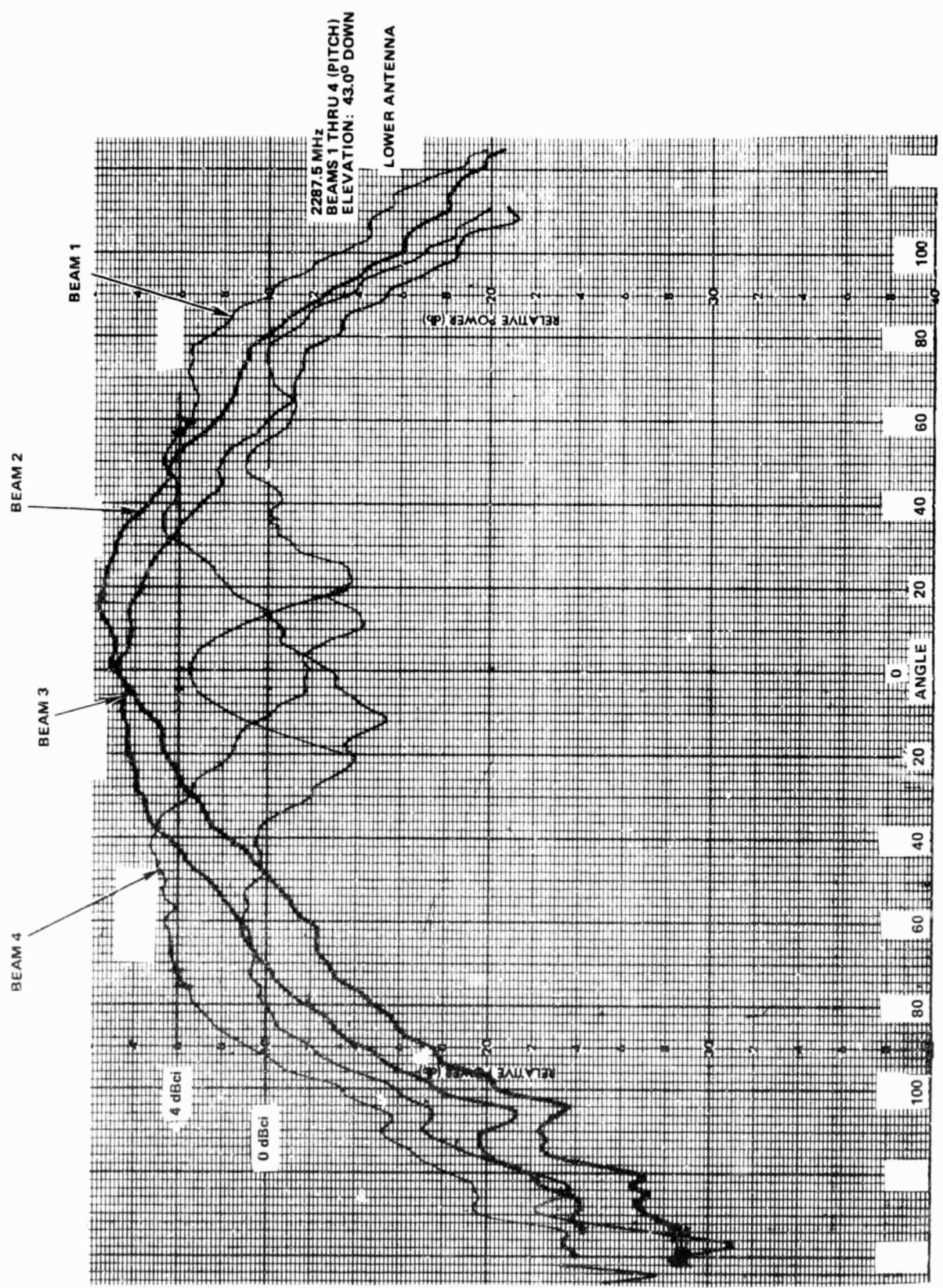


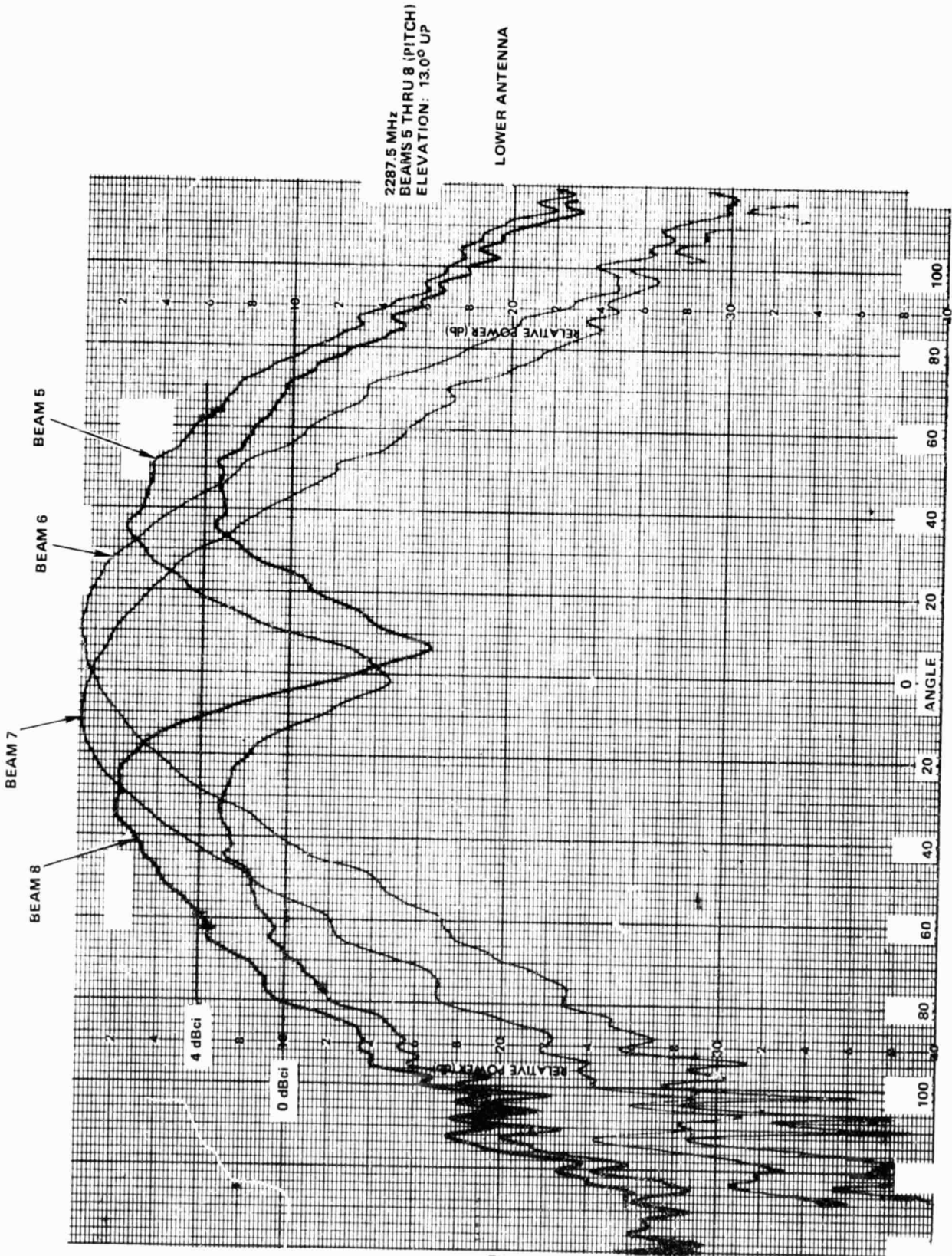
2287.5 MHz  
RADIATING ELEMENTS: A-E-B  
ROLL PLANE  
ELEVATION: 0°

LOWER ANTENNA



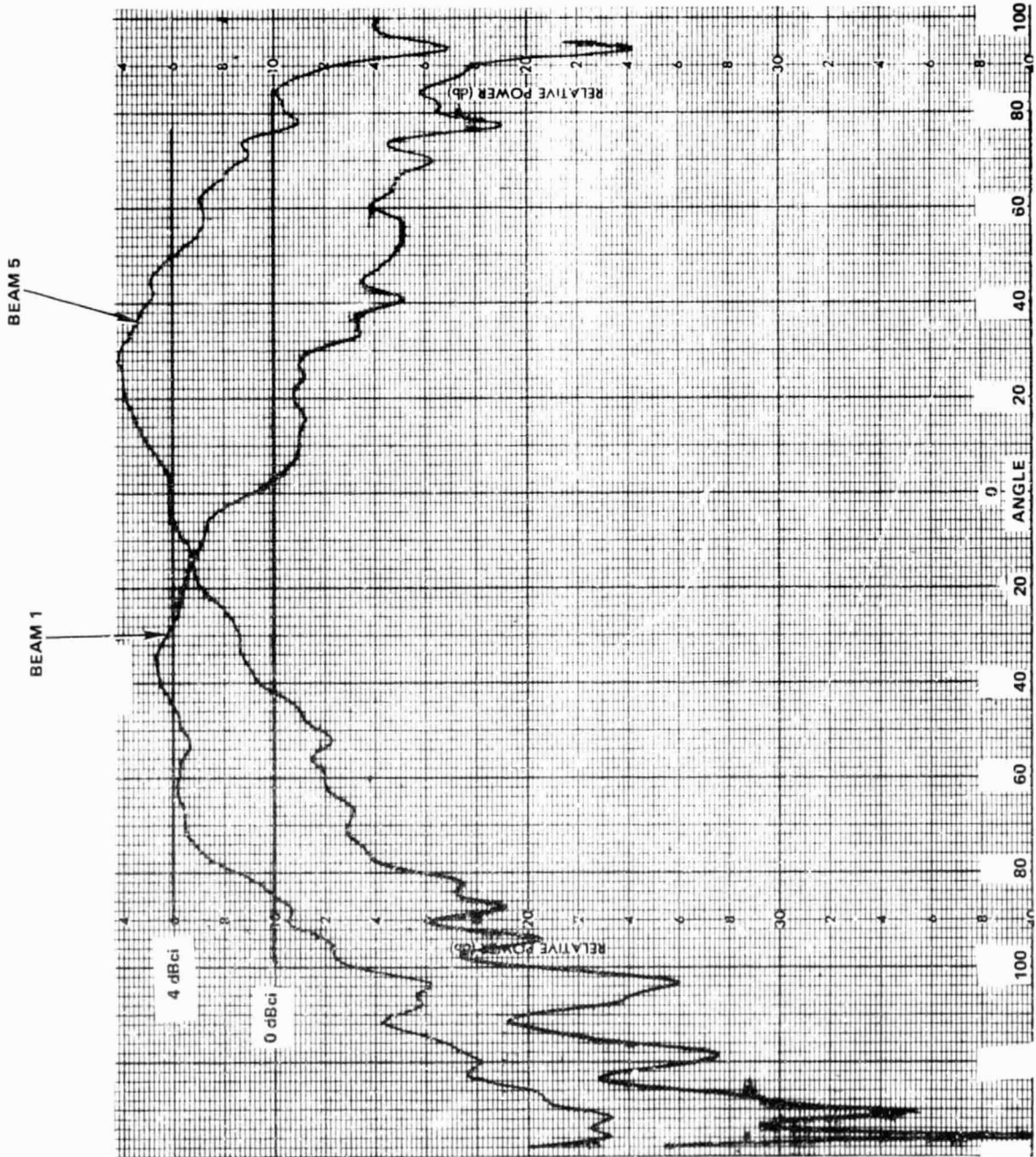




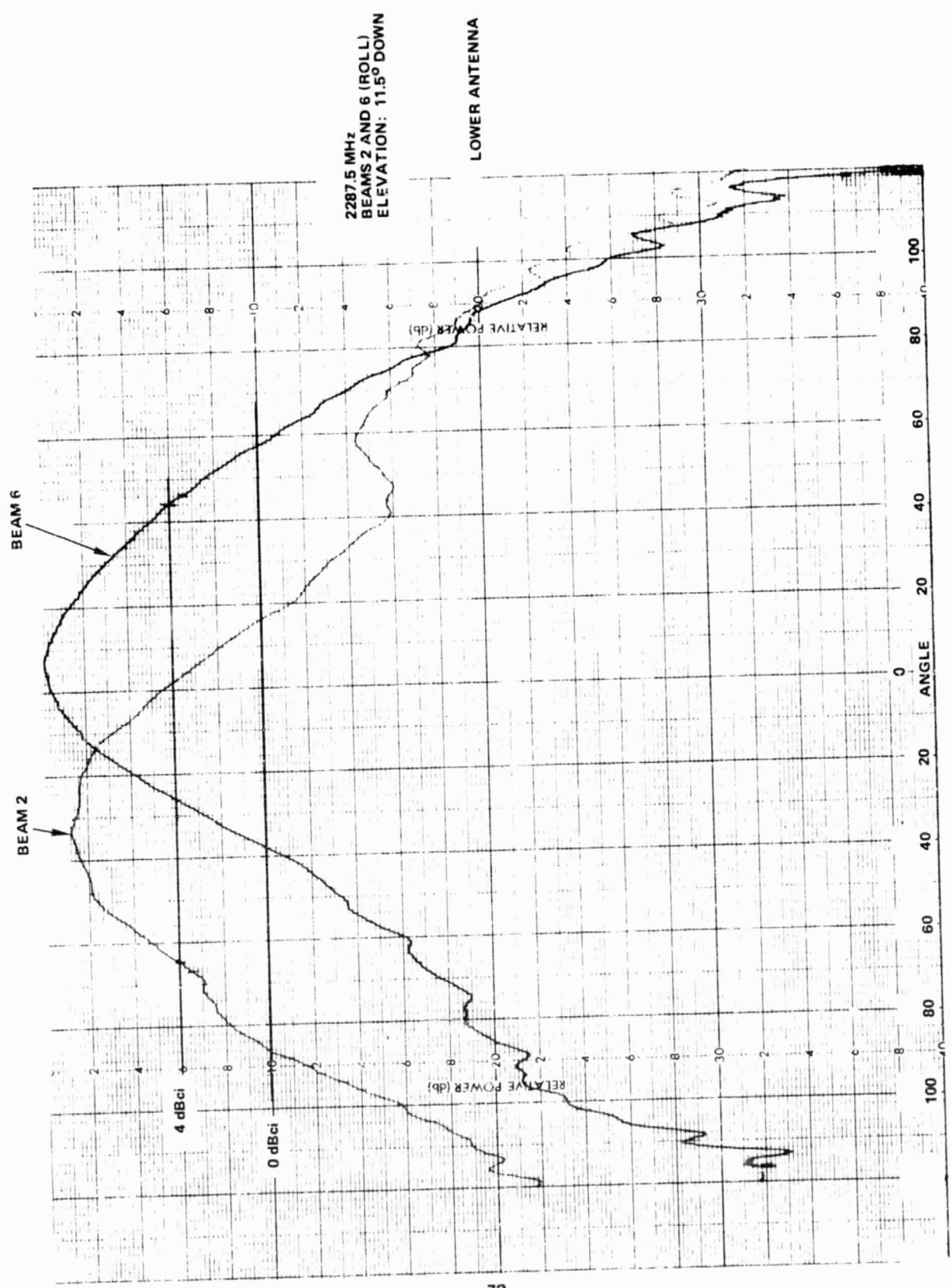


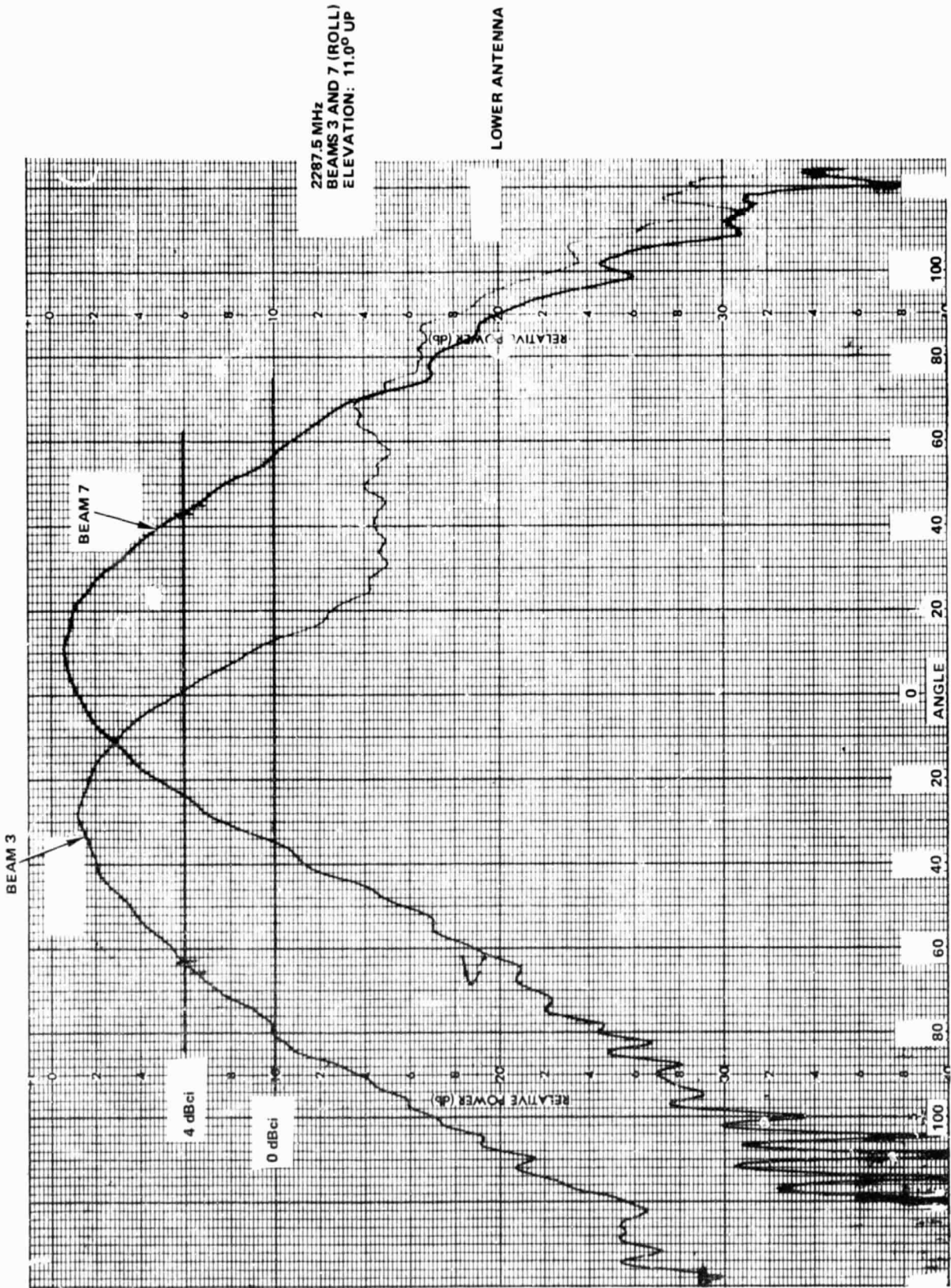
2287.5 MHz  
BEAMS 1 AND 5 (ROLL)  
ELEVATION: 53.5° DOWN

LOWER ANTENNA







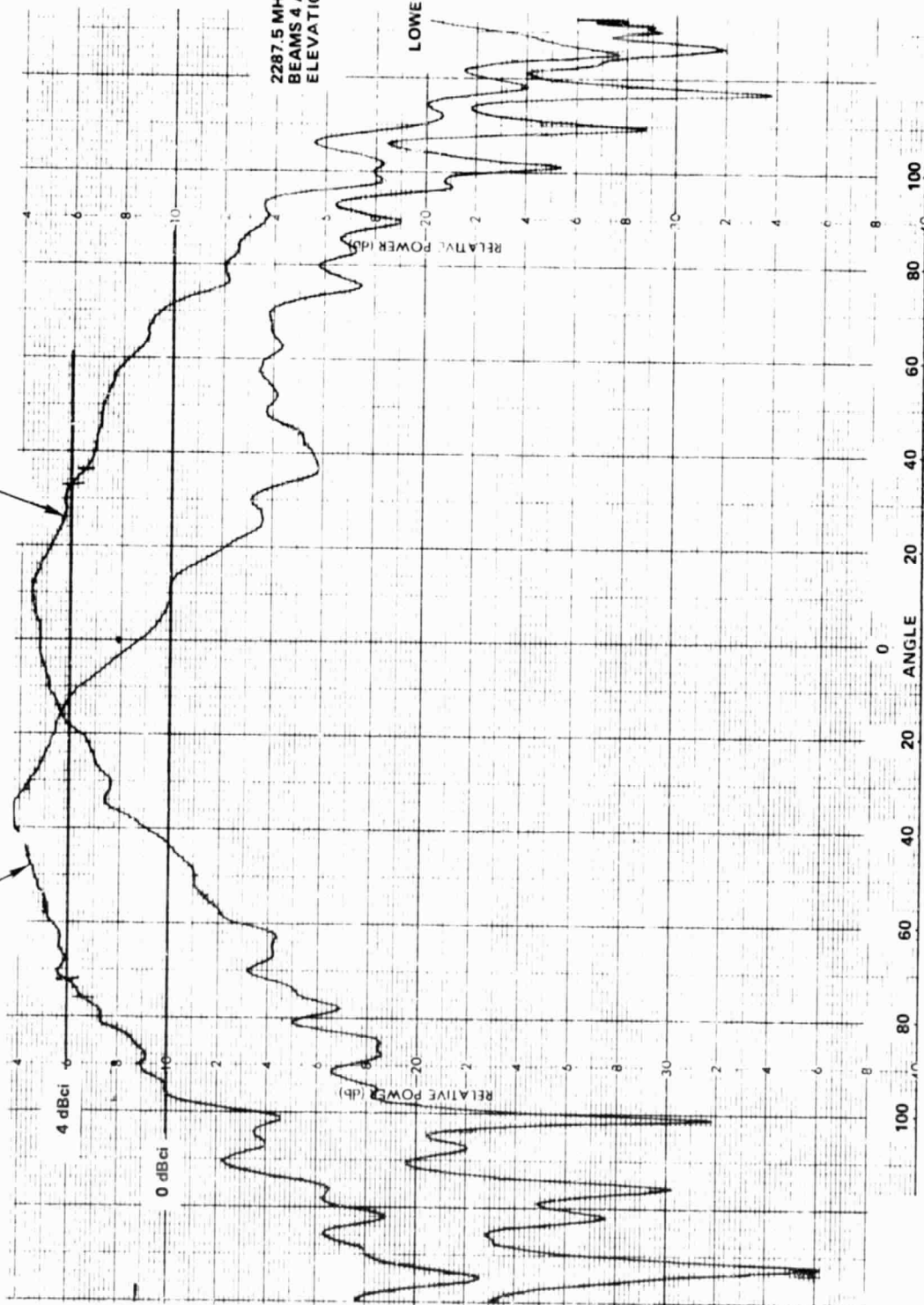


BEAM 8

BEAM 4

2287.5 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 52.5° UP

LOWER ANTENNA



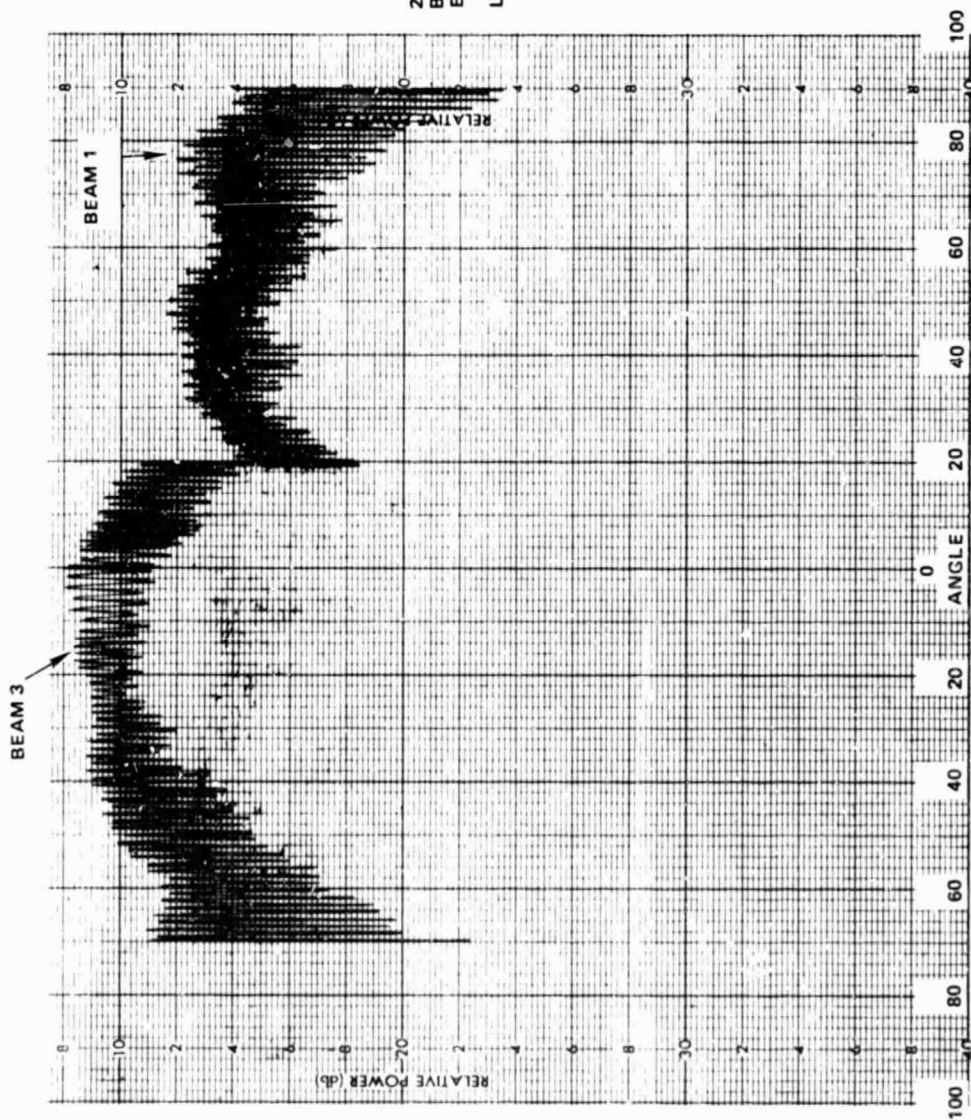
## 9. AXIAL RATIO PATTERNS

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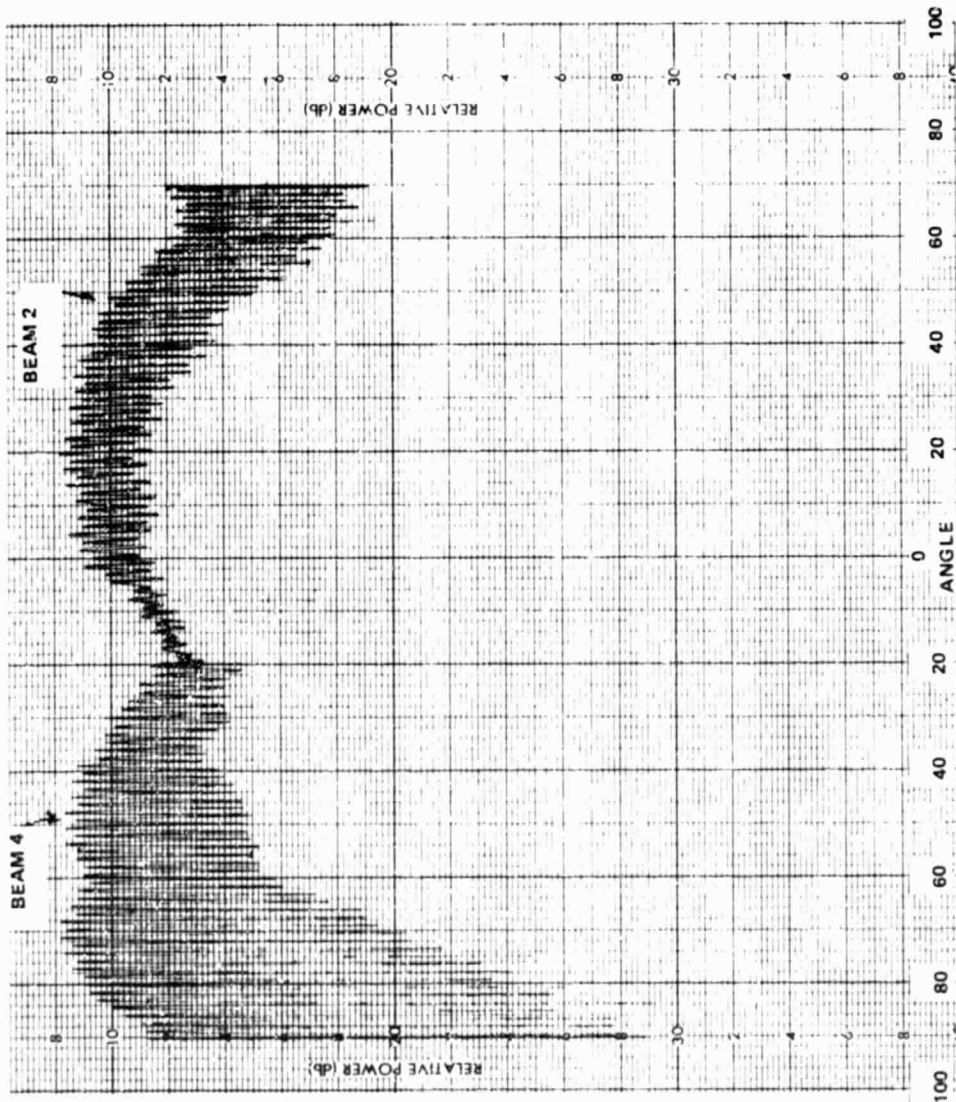
~~76~~



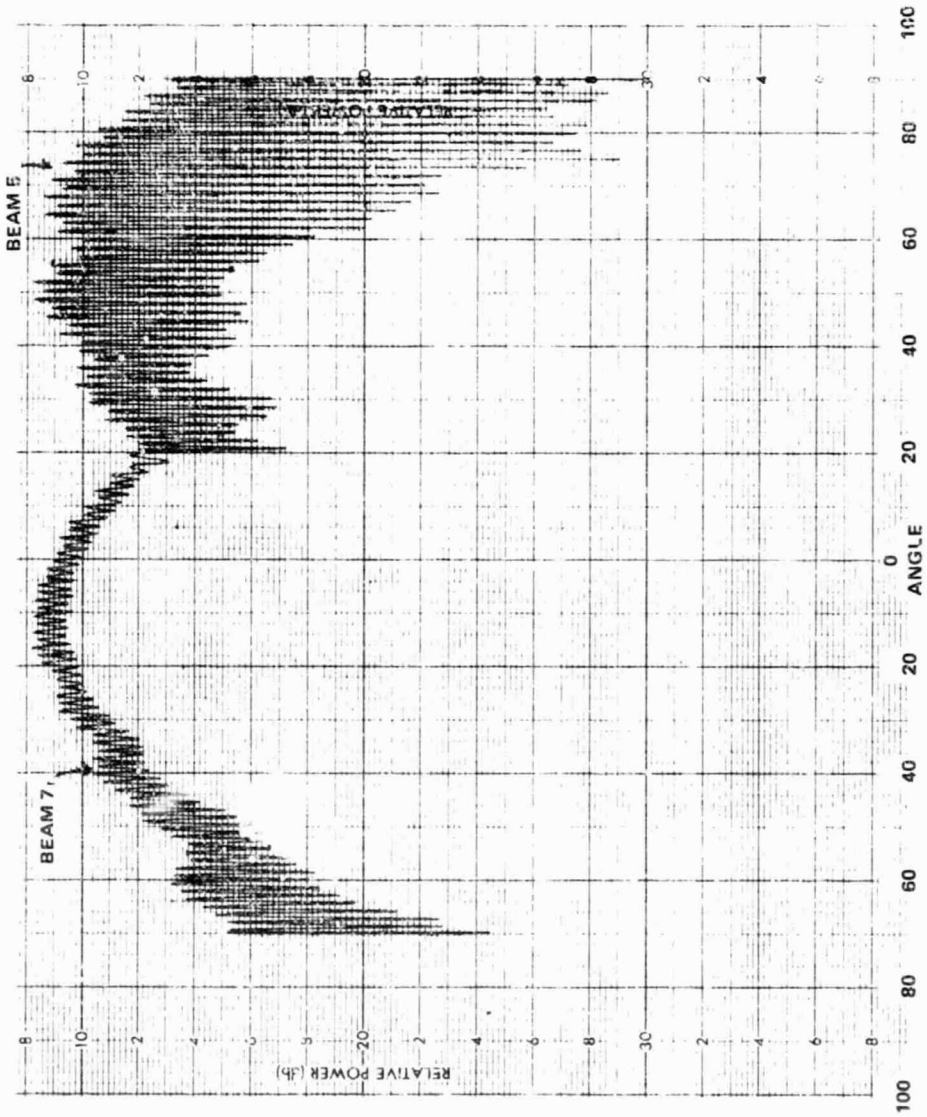
2041.9 MHz  
BEAMS 1 AND 3 (PITCH)  
ELEVATION: 38.5° DOWN  
LOWER ANTENNA



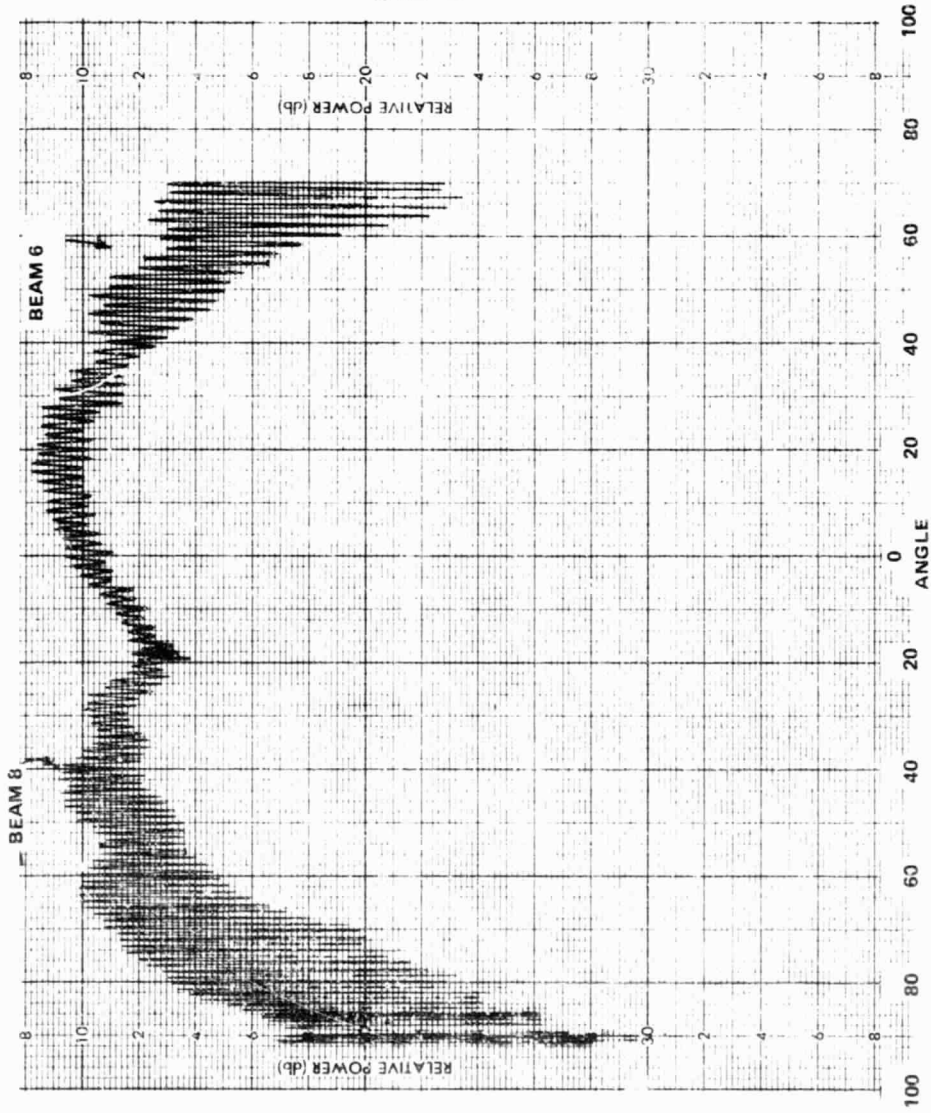
2041.9 MHz  
BEAMS 2 AND 4 (PITCH)  
ELEVATION: 38.5° DOWN  
LOWER ANTENNA



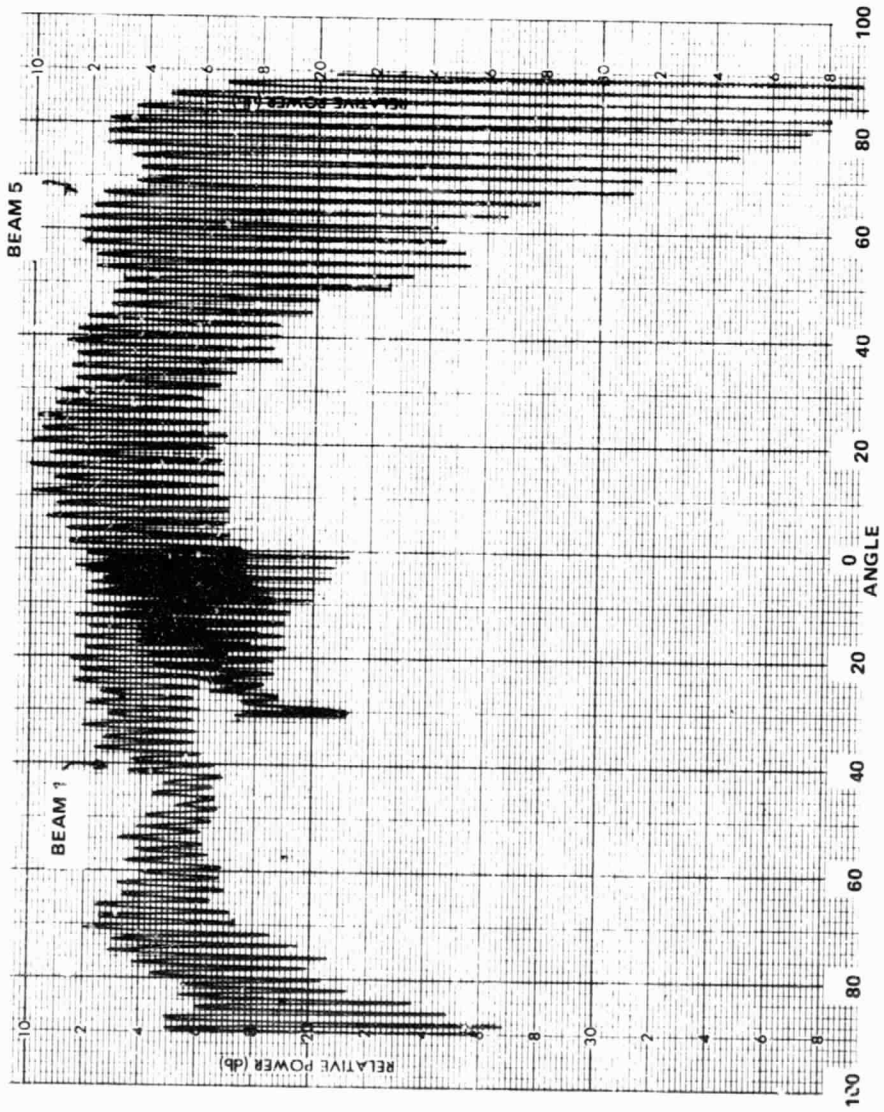
2041.9 MHz  
BEAMS 5 AND 7 (PITCH)  
ELEVATION: 19.5° UP  
LOWER ANTENNA



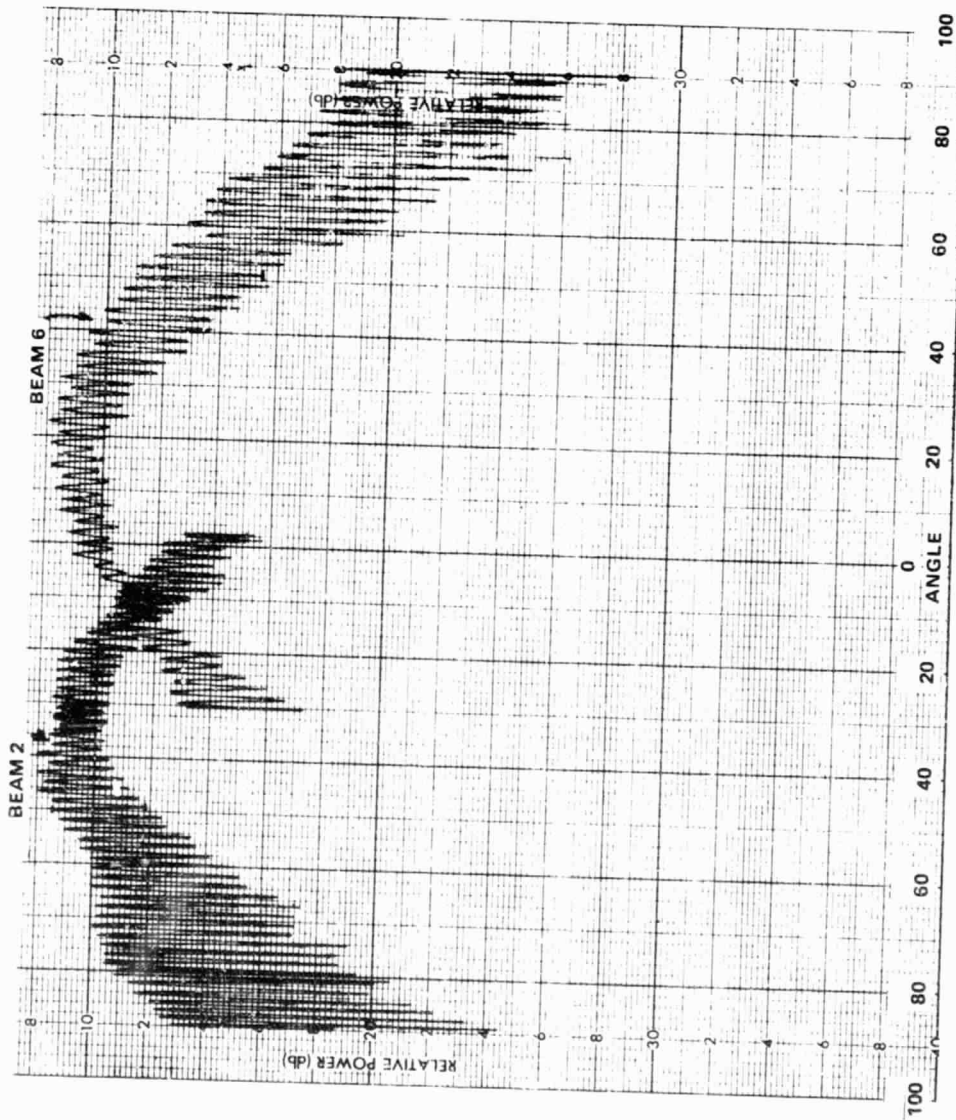
2041.9 MHz  
BEAMS 6 AND 8 (PITCH)  
ELEVATION: 19.5° UP  
LOWER ANTENNA



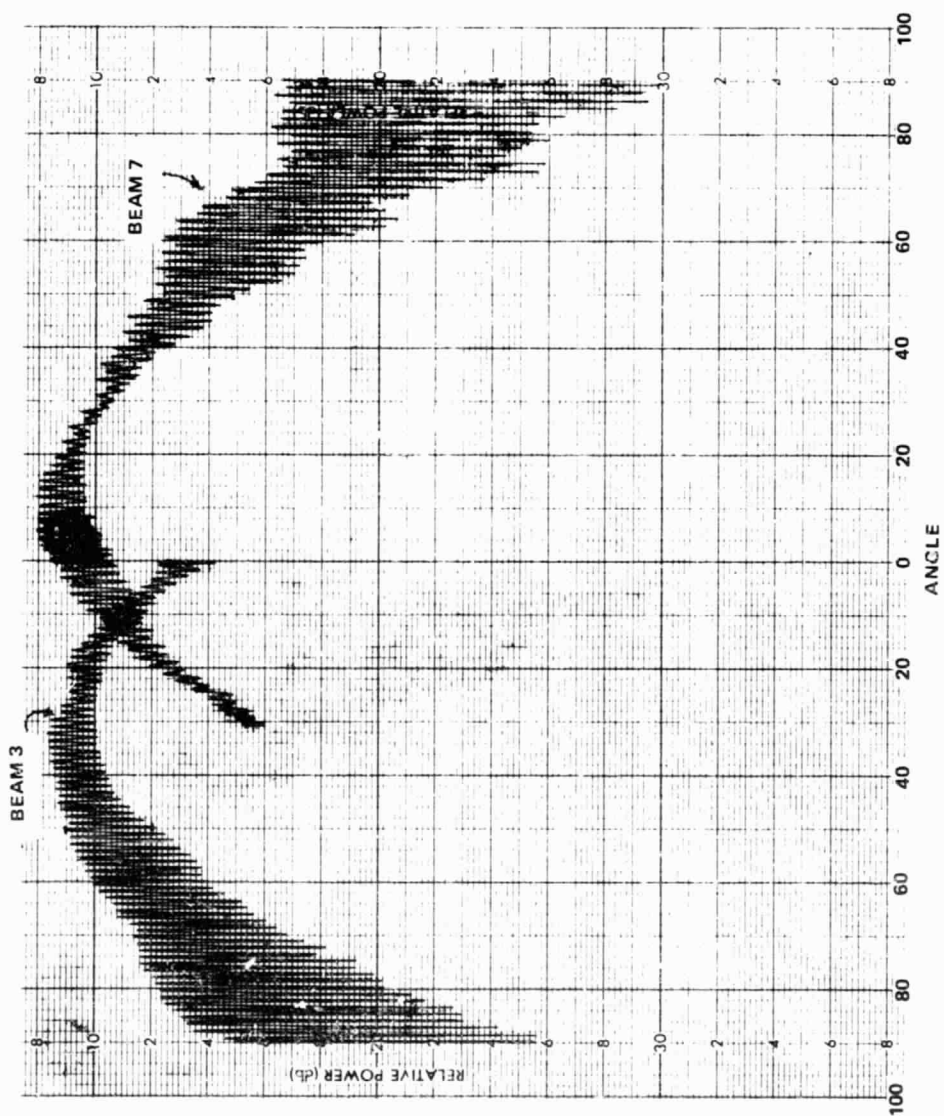
2041.9 MHz  
BEAMS 1 AND 5 (ROLL)  
ELEVATION: 53.0° DOWN  
LOWER ANTENNA



2041.9 MHz  
BEAMS 2 AND 6 (ROLL)  
ELEVATION: 21.5° DOWN  
LOWER ANTENNA

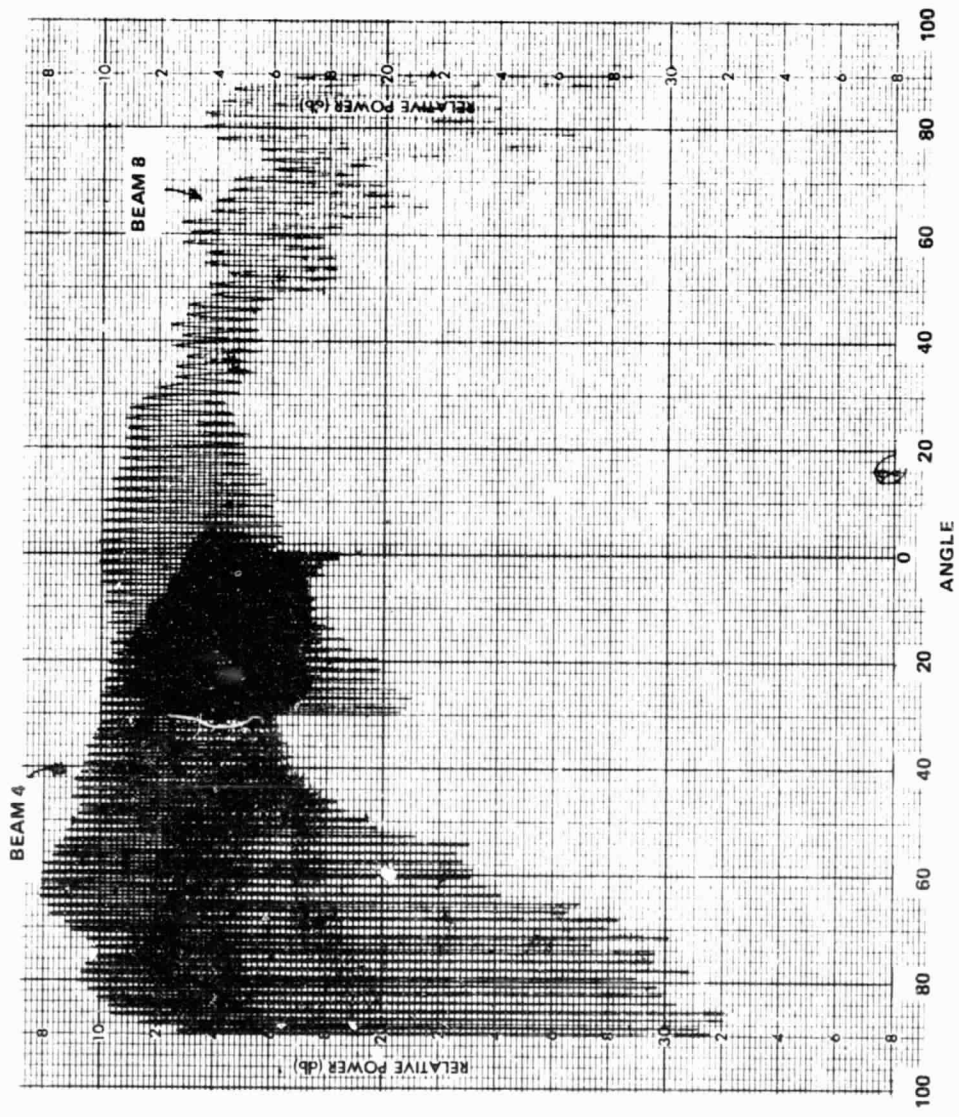


2041.9 MHz  
BEAMS 3 AND 7 (ROLL)  
ELEVATION: 17.5° UP  
LOWER ANTENNA



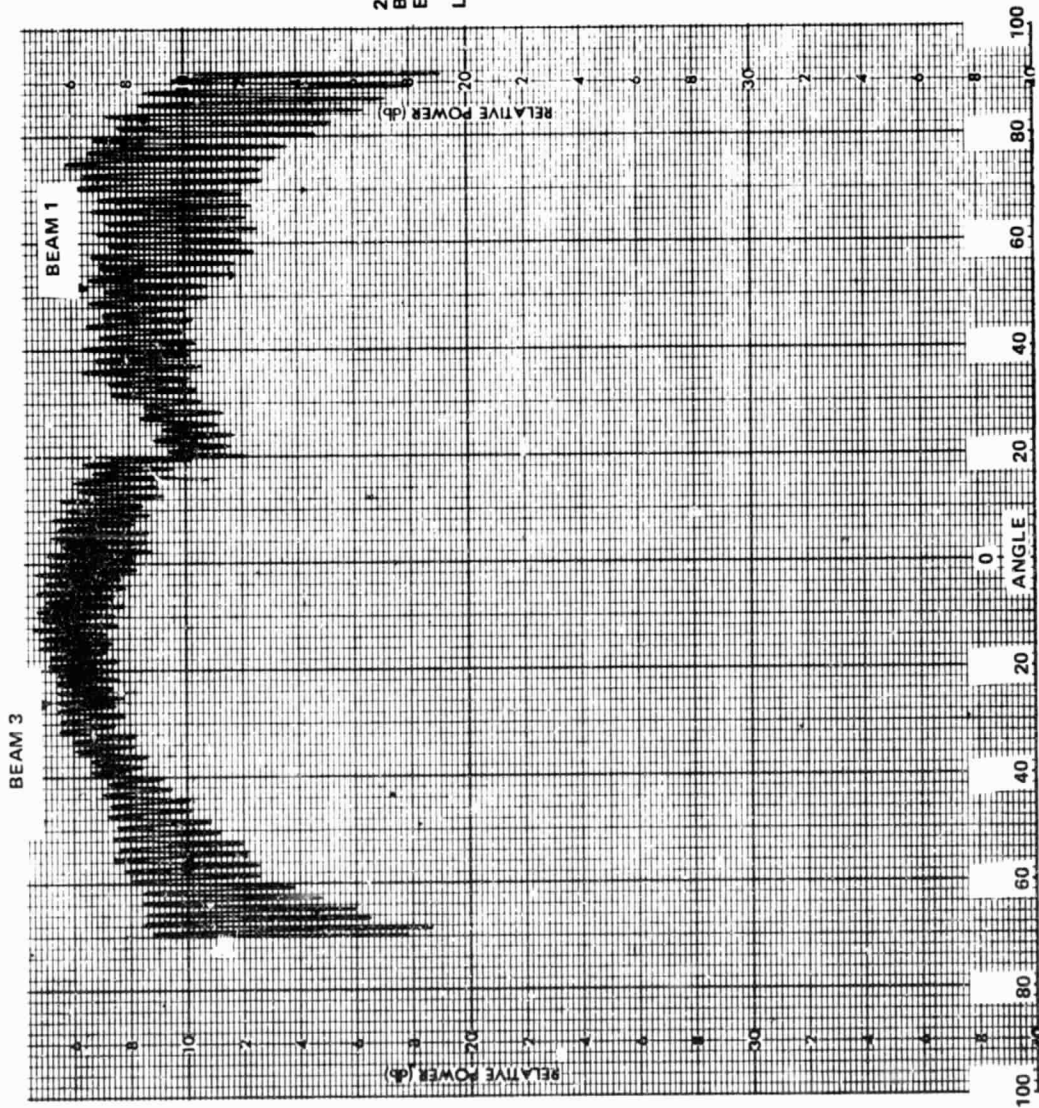


2041.9 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 53.0° UP  
LOWER ANTENNA

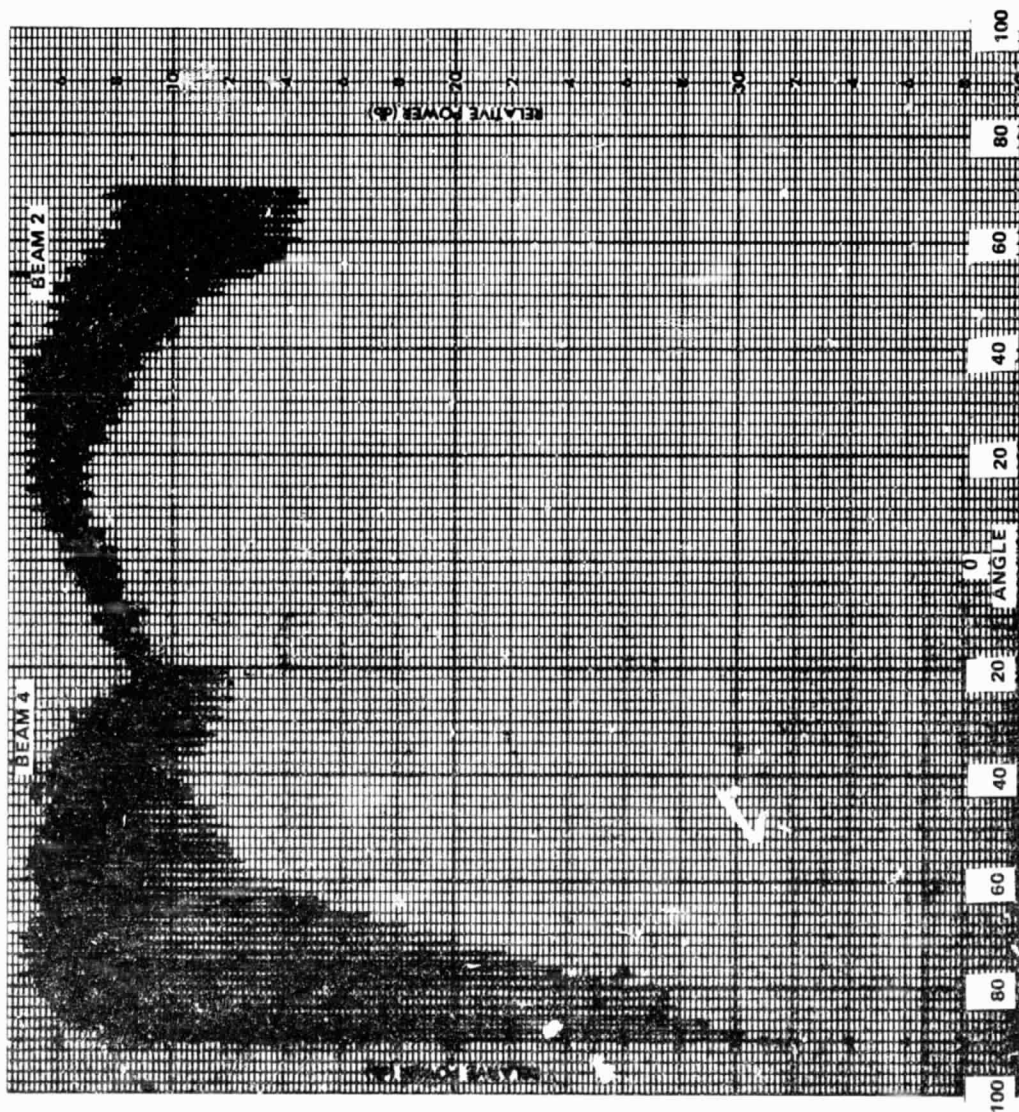




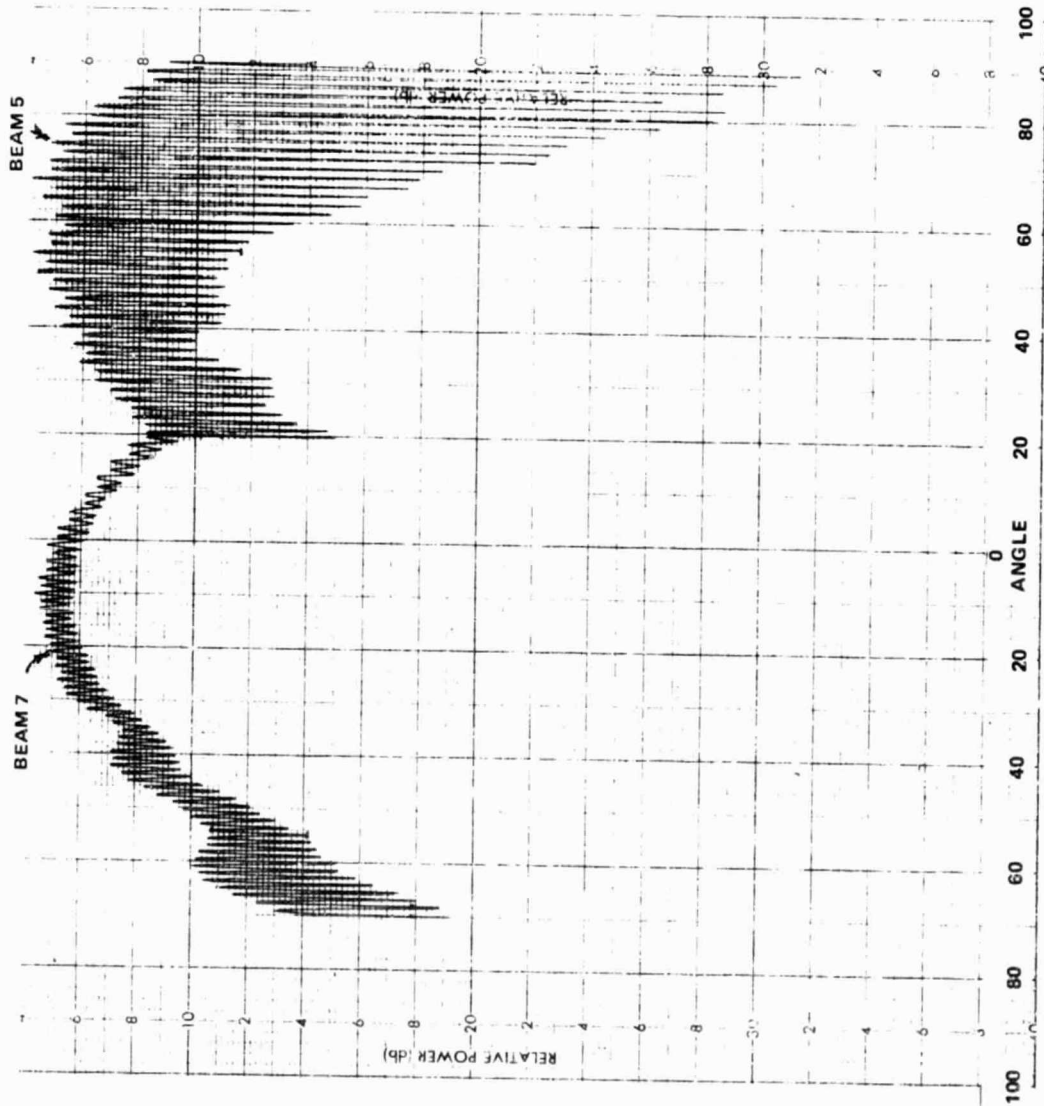
2106.4 MHz  
BEAMS 1 AND 3 (PITCH)  
ELEVATION: 40.0° DOWN  
LOWER ANTENNA



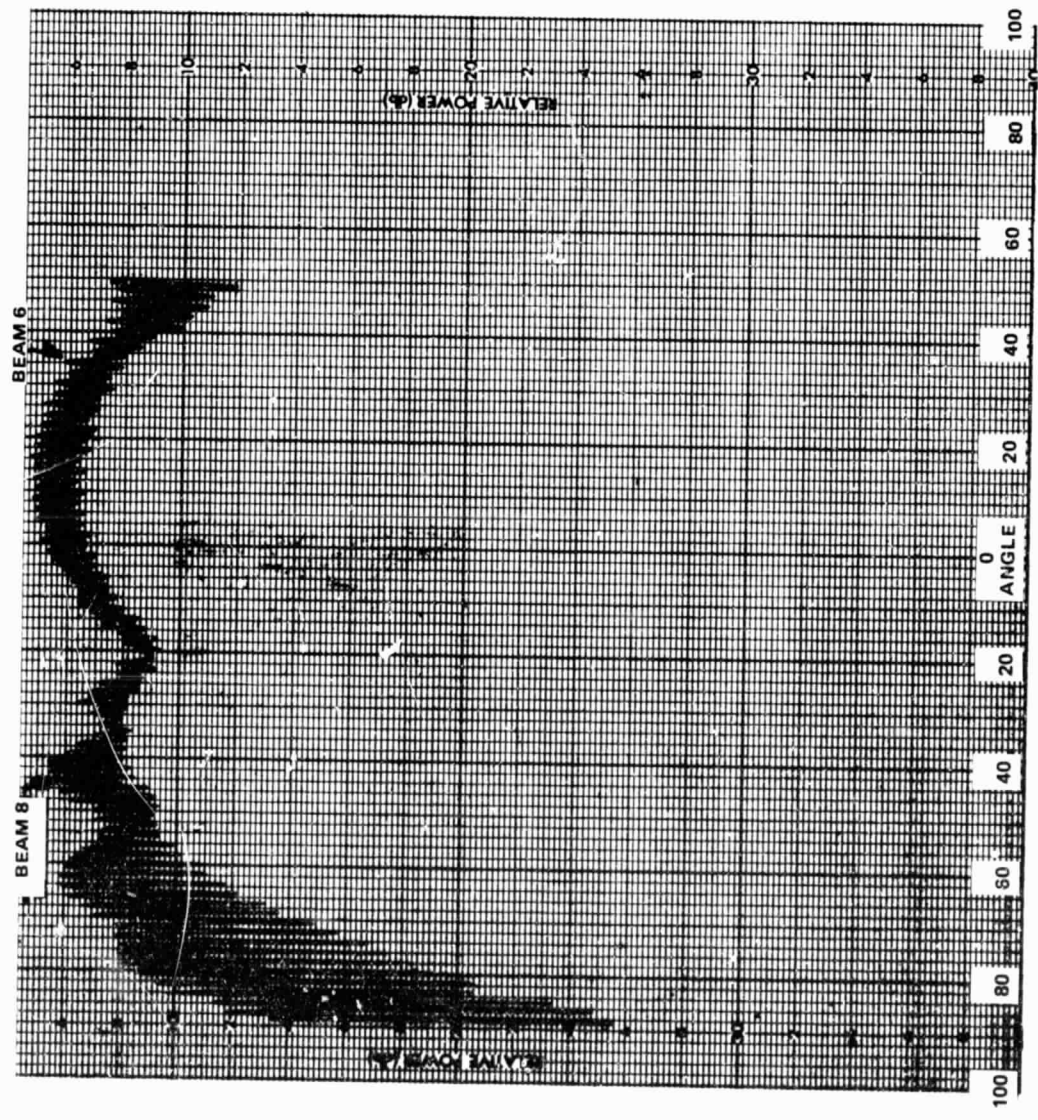
2106.4 MHz  
BEAMS 2 AND 4 (PITCH)  
ELEVATION: 40.0° DOWN  
LOWER ANTENNA

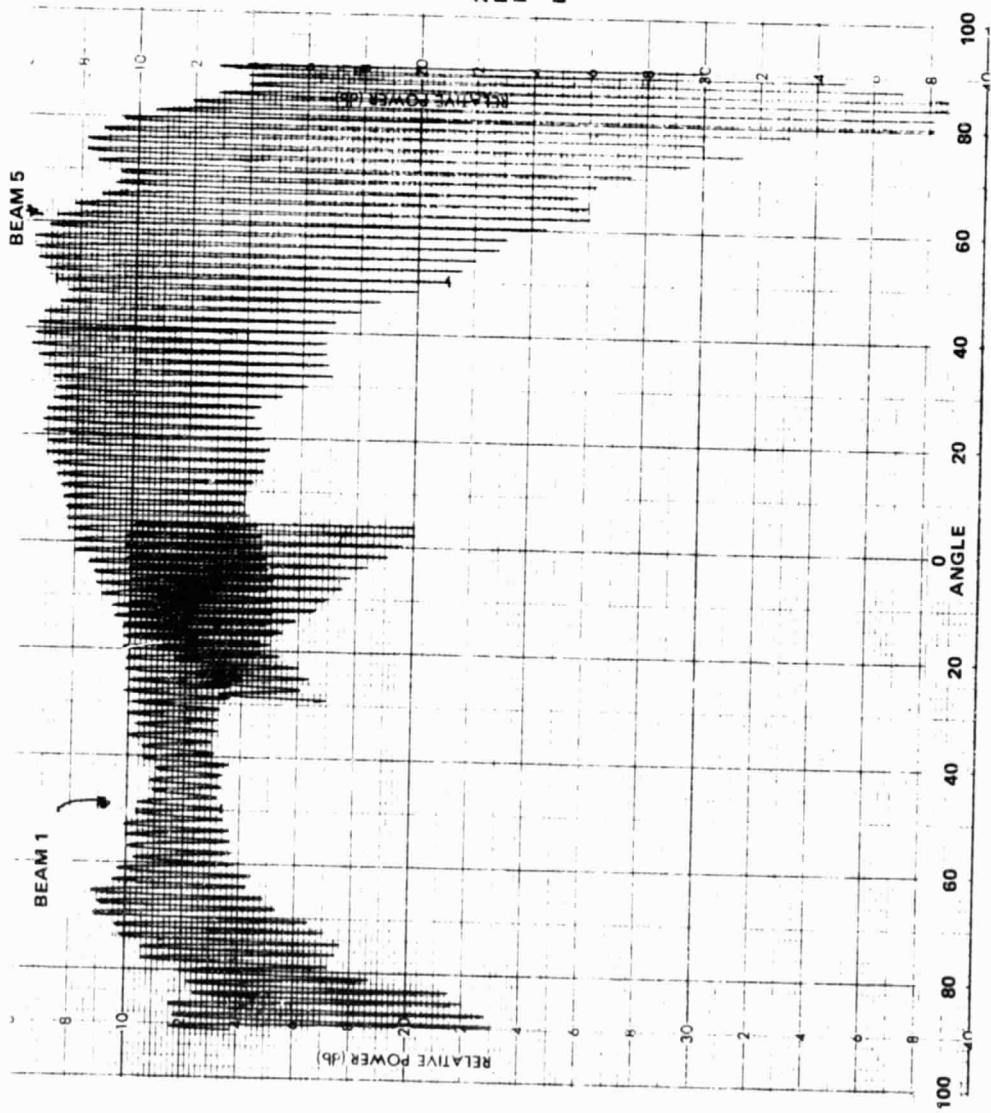


2106.4 MHz  
BEAMS 5 AND 7 (PITCH)  
ELEVATION: 20.5° UP  
LOWER ANTENNA

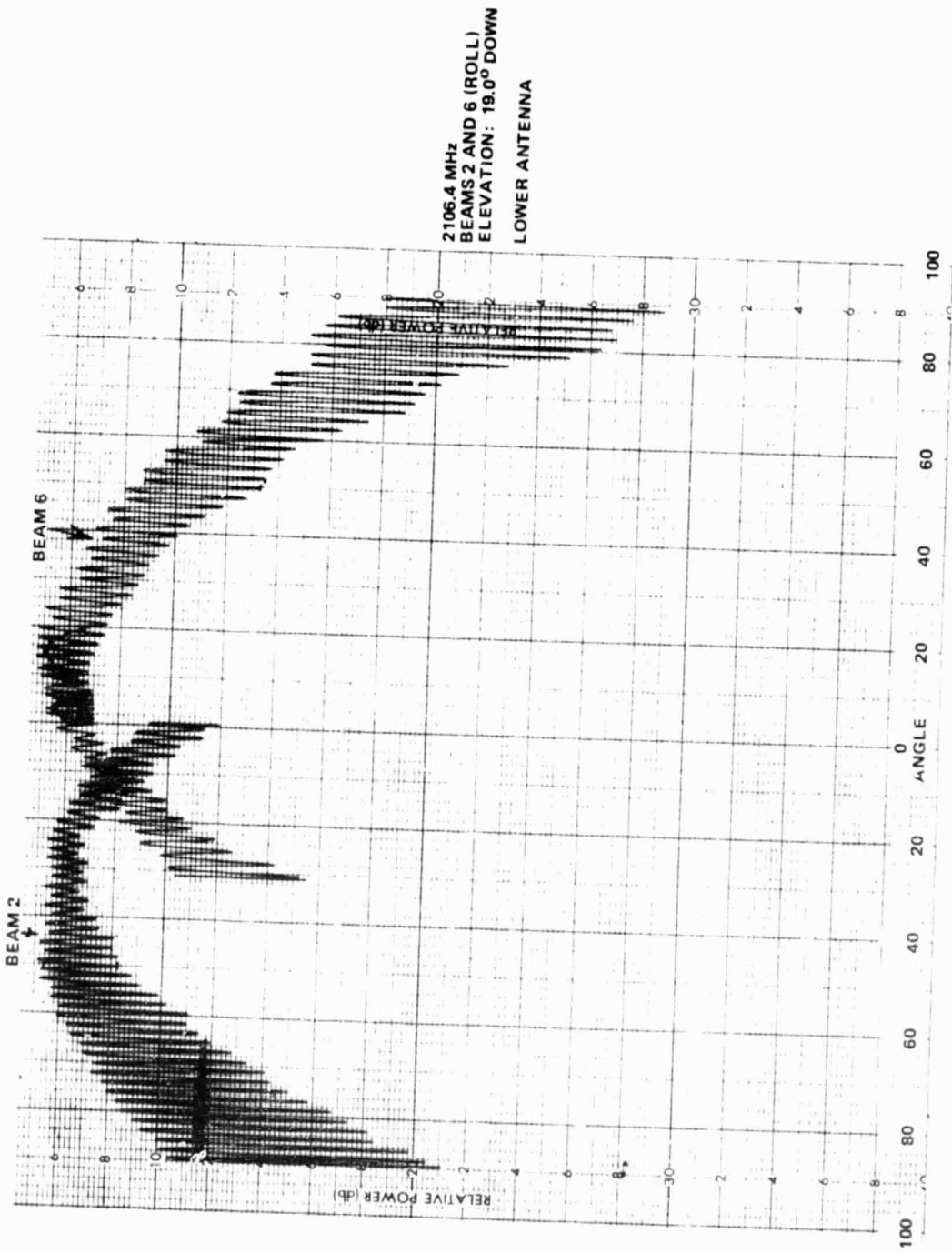


2106.4 MHz  
BEAMS 6 AND 8 (PITCH)  
ELEVATION: 20.5° UP  
LOWER ANTENNA



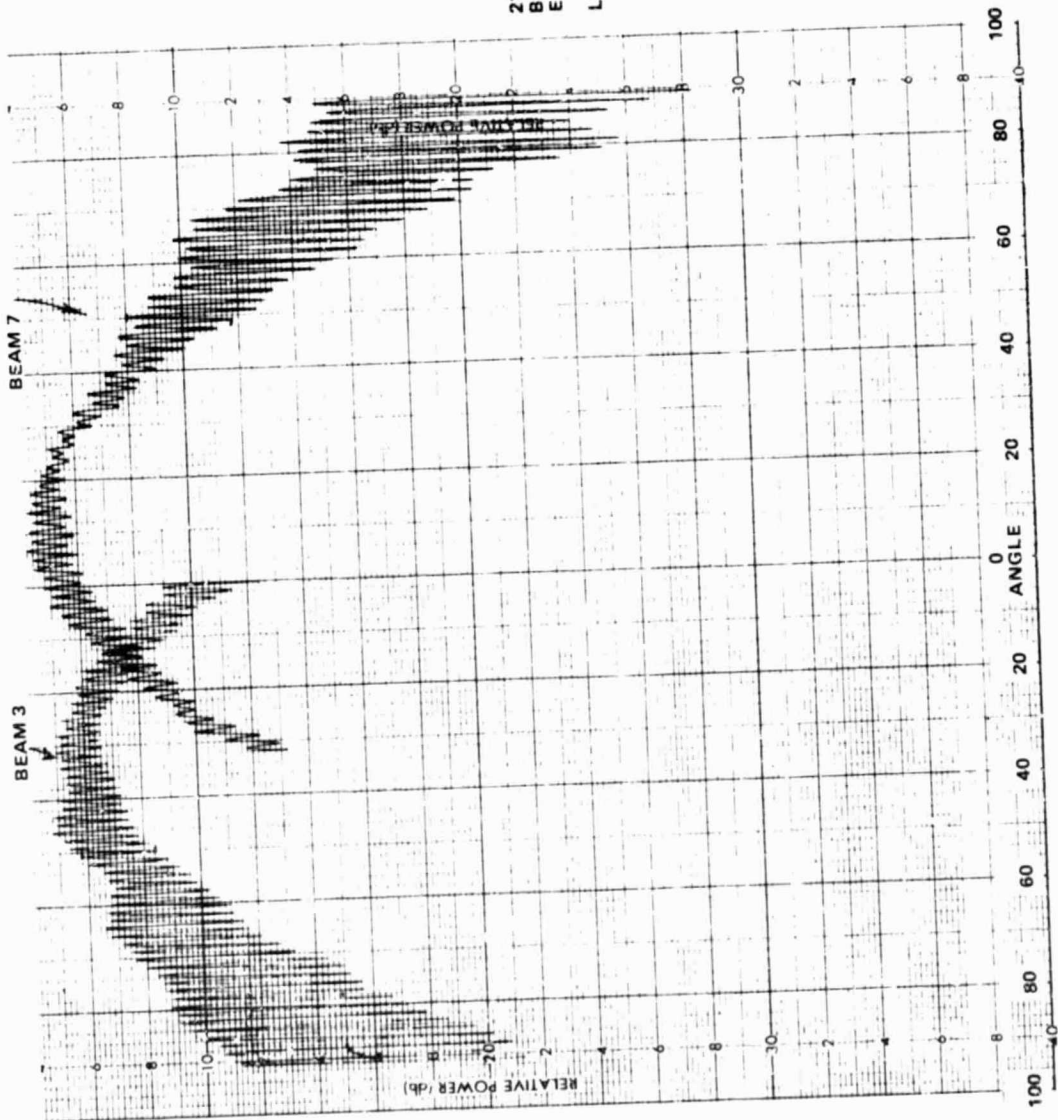


2106.4 MHz  
 BEAMS 1 AND 5 (ROLL)  
 ELEVATION: 57.0° DOWN  
 LOWER ANTENNA

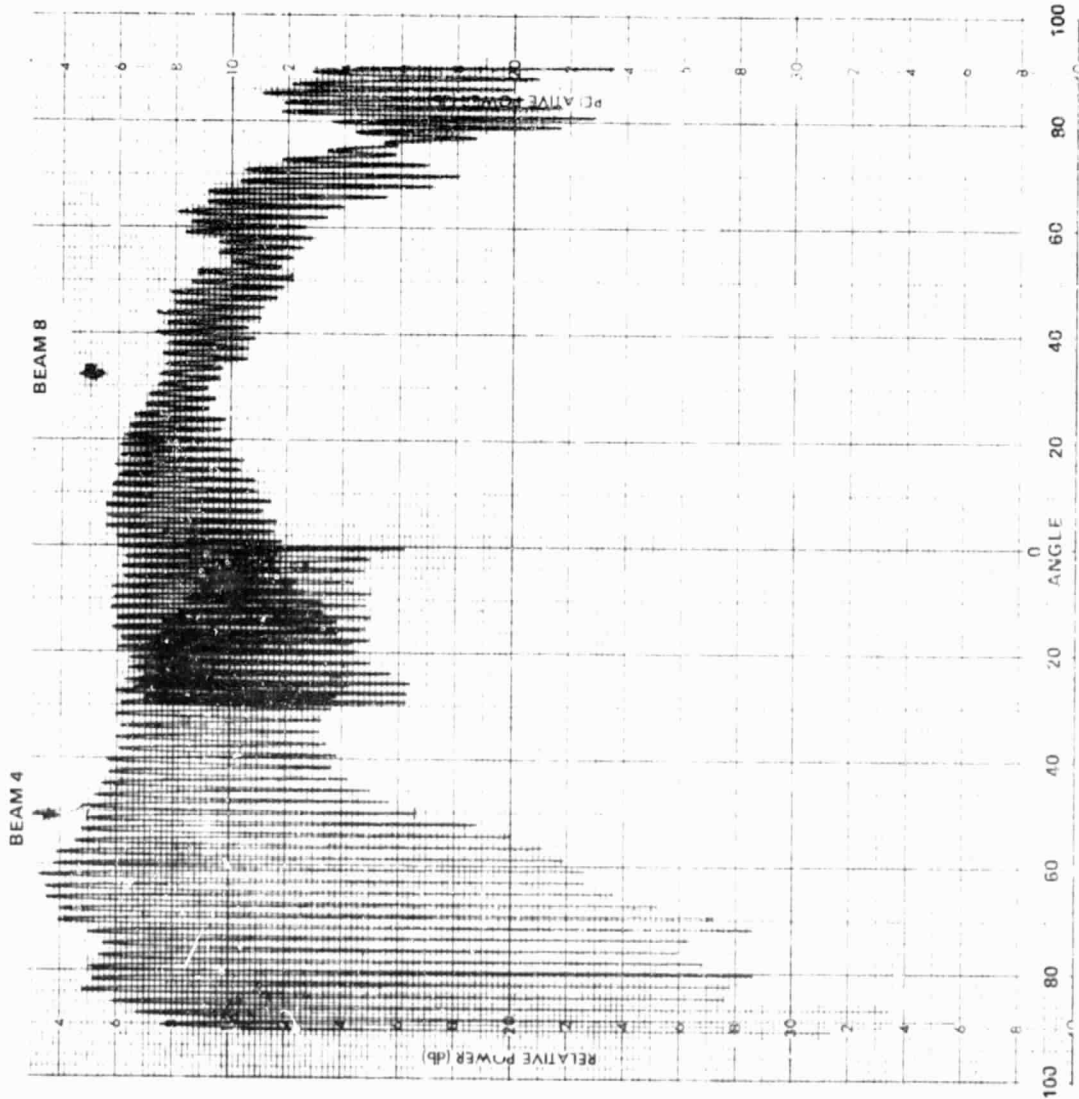




2106.4 MHz  
BEAMS 3 AND 7 (ROLL)  
ELEVATION: 18.0° UP  
LOWER ANTENNA

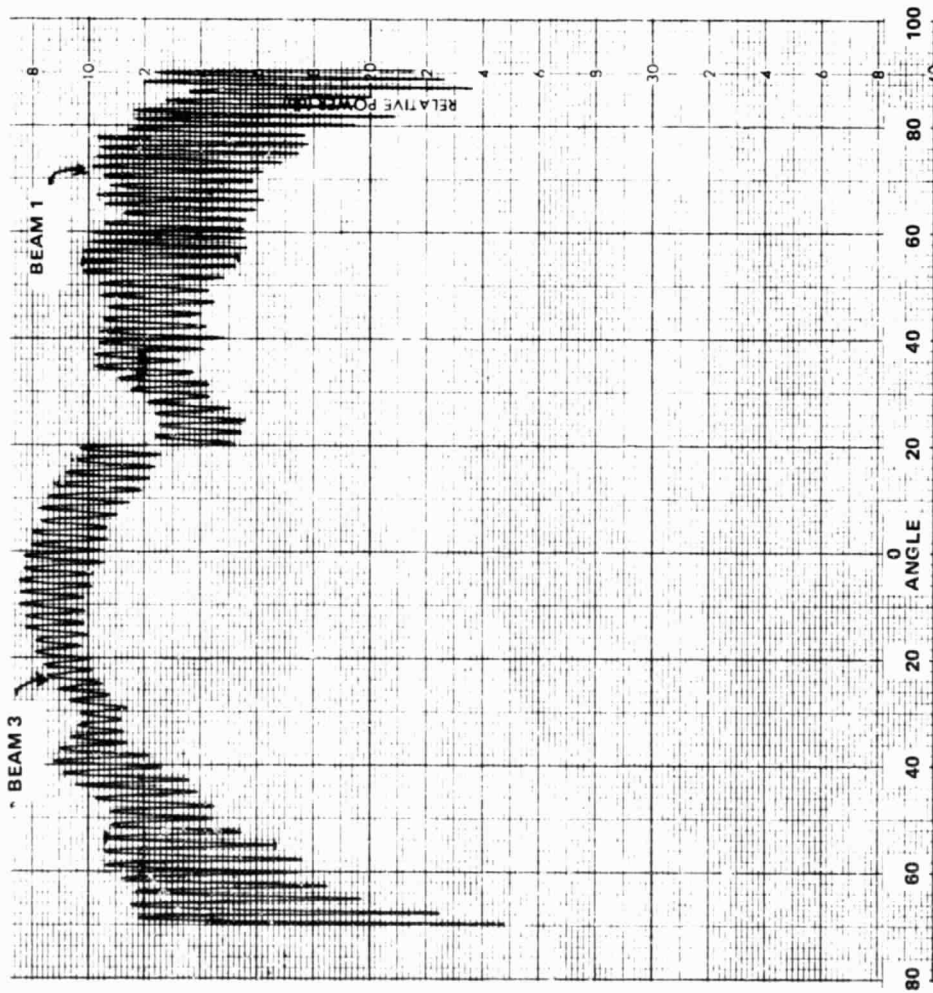


2106.4 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 54.0° UP  
LOWER ANTENNA



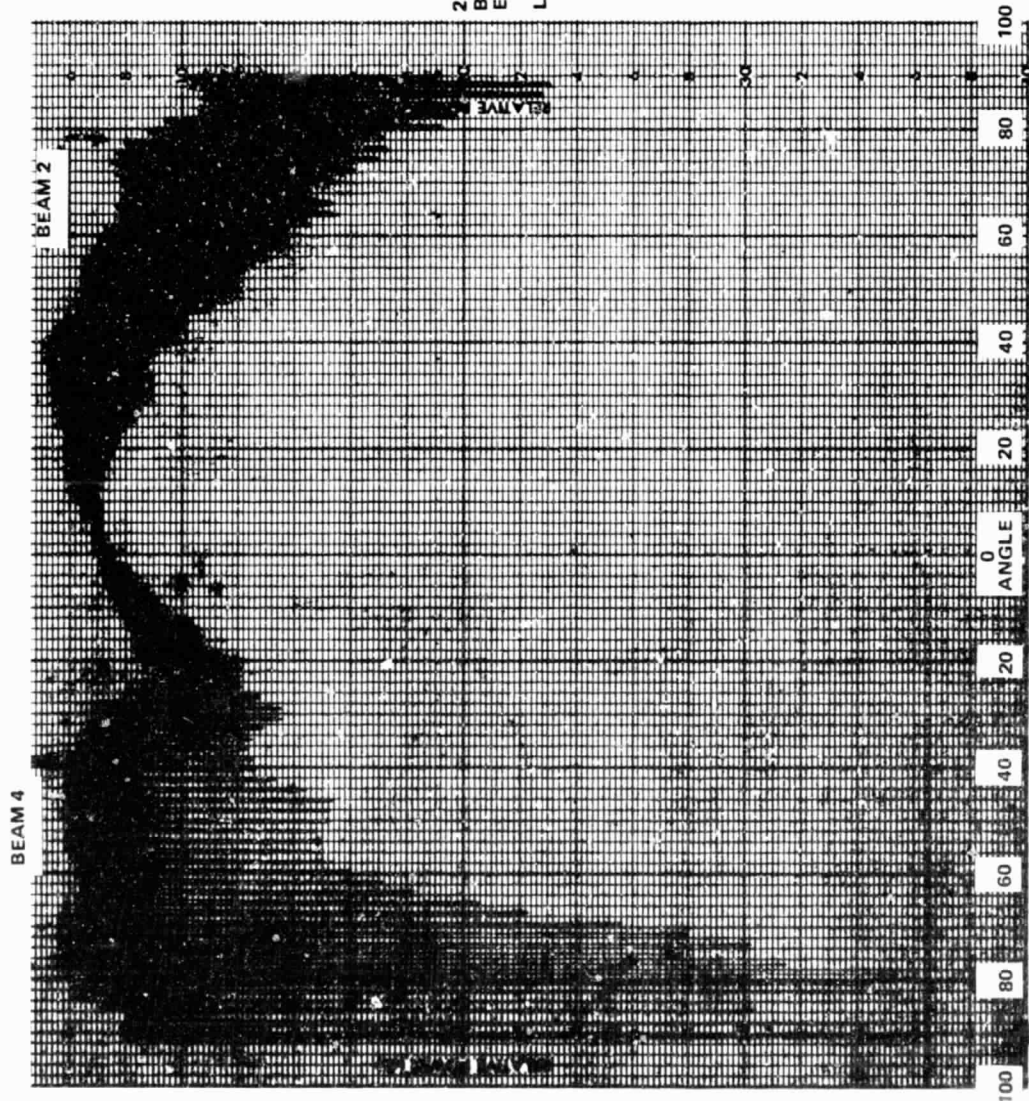


2217.5 MHz  
BEAMS 1 AND 3 (PITCH)  
ELEVATION: 46.0° DOWN  
LOWER ANTENNA

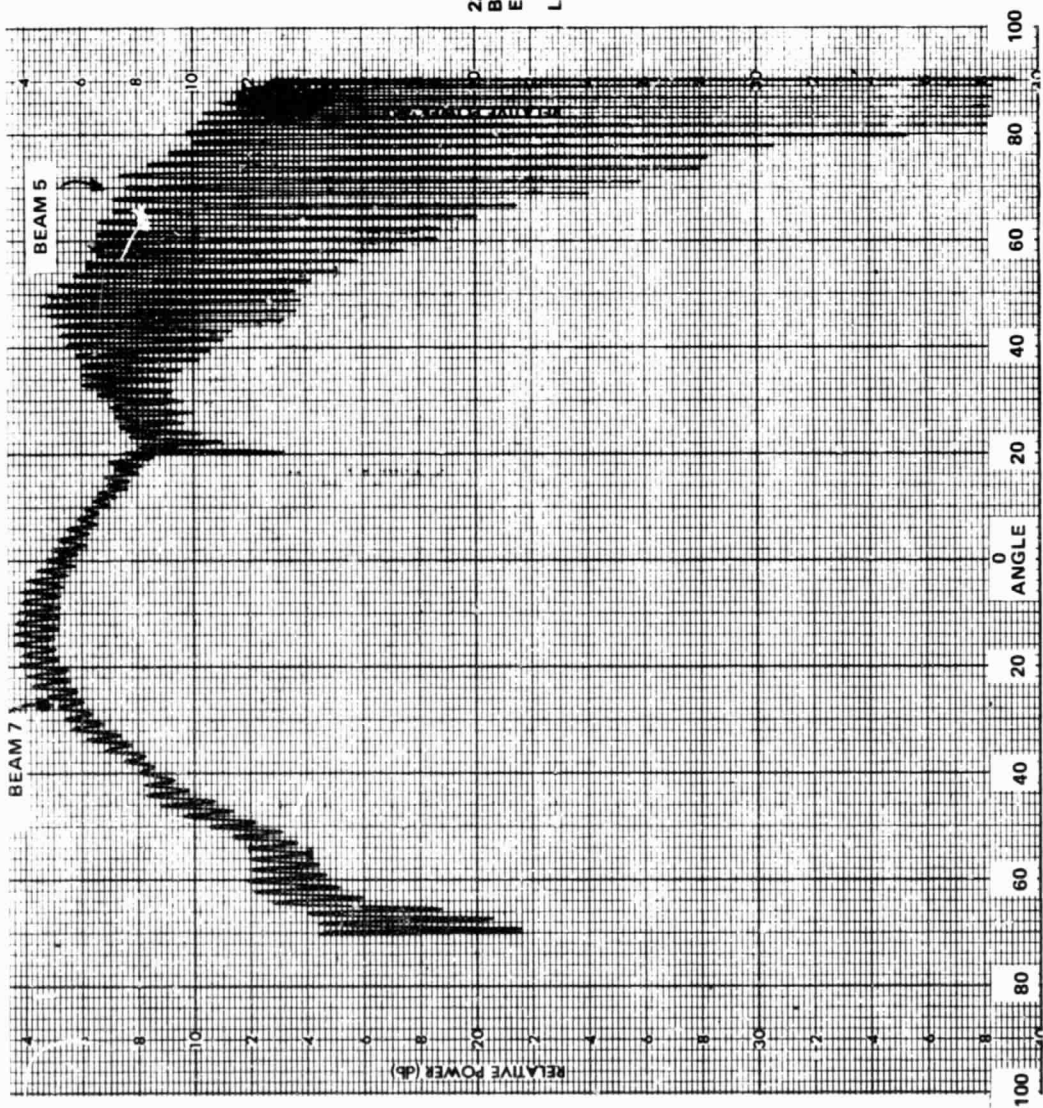


C-2

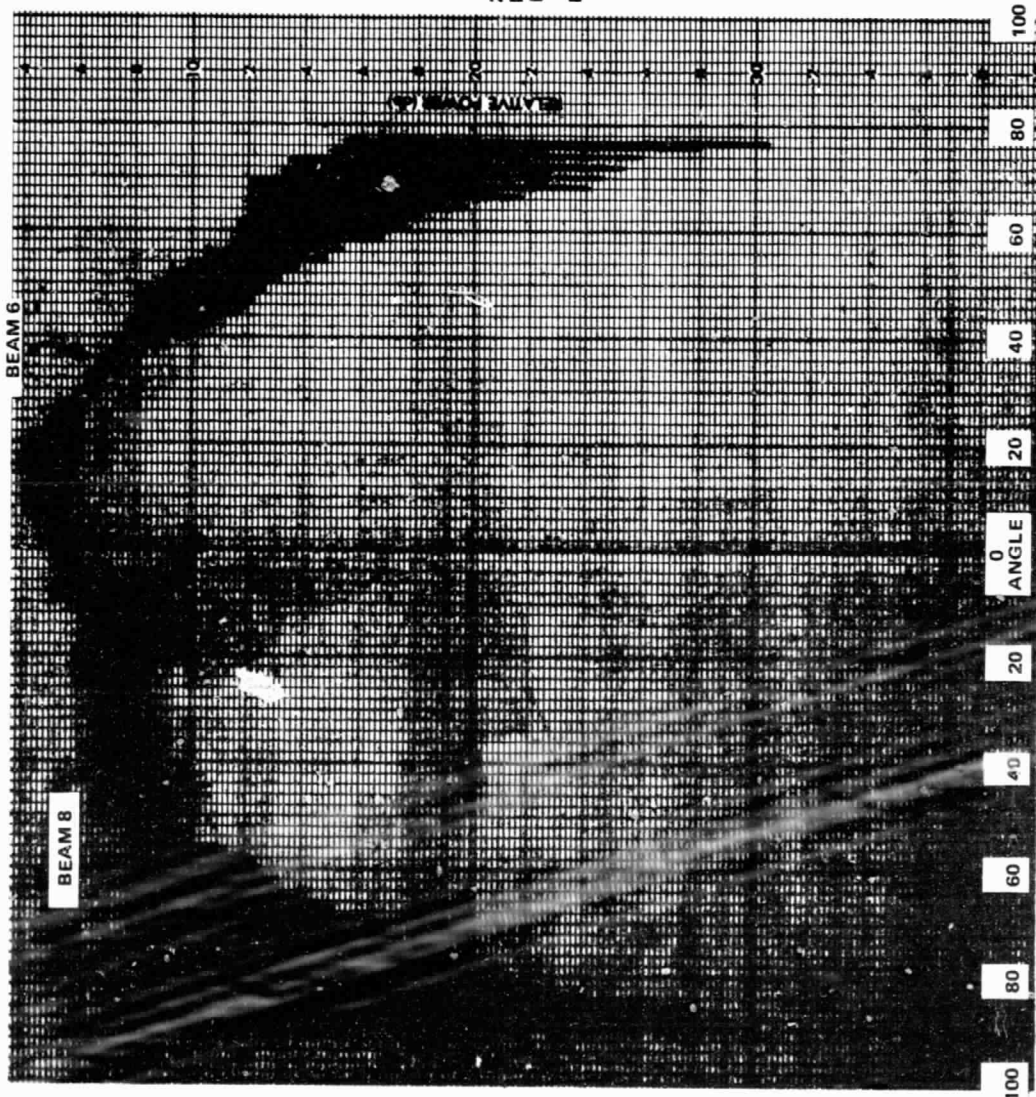
2217.5 MHz  
BEAMS 2 AND 4 (PITCH)  
ELEVATION: 46.0° DOWN  
LOWER ANTENNA



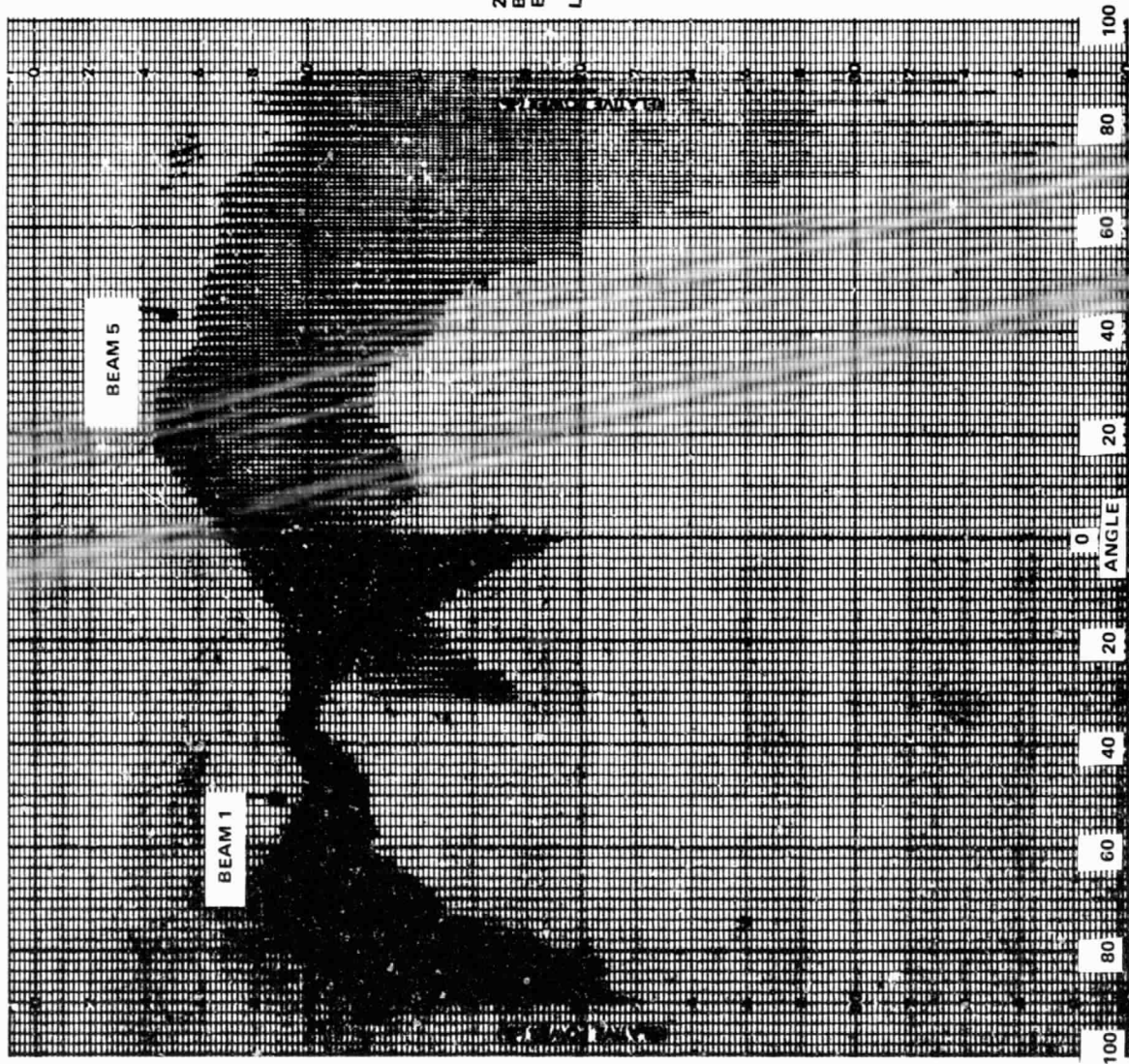
2217.5 MHz  
BEAMS 5 AND 7 (PITCH)  
ELEVATION: 14.5° UP  
LOWER ANTENNA



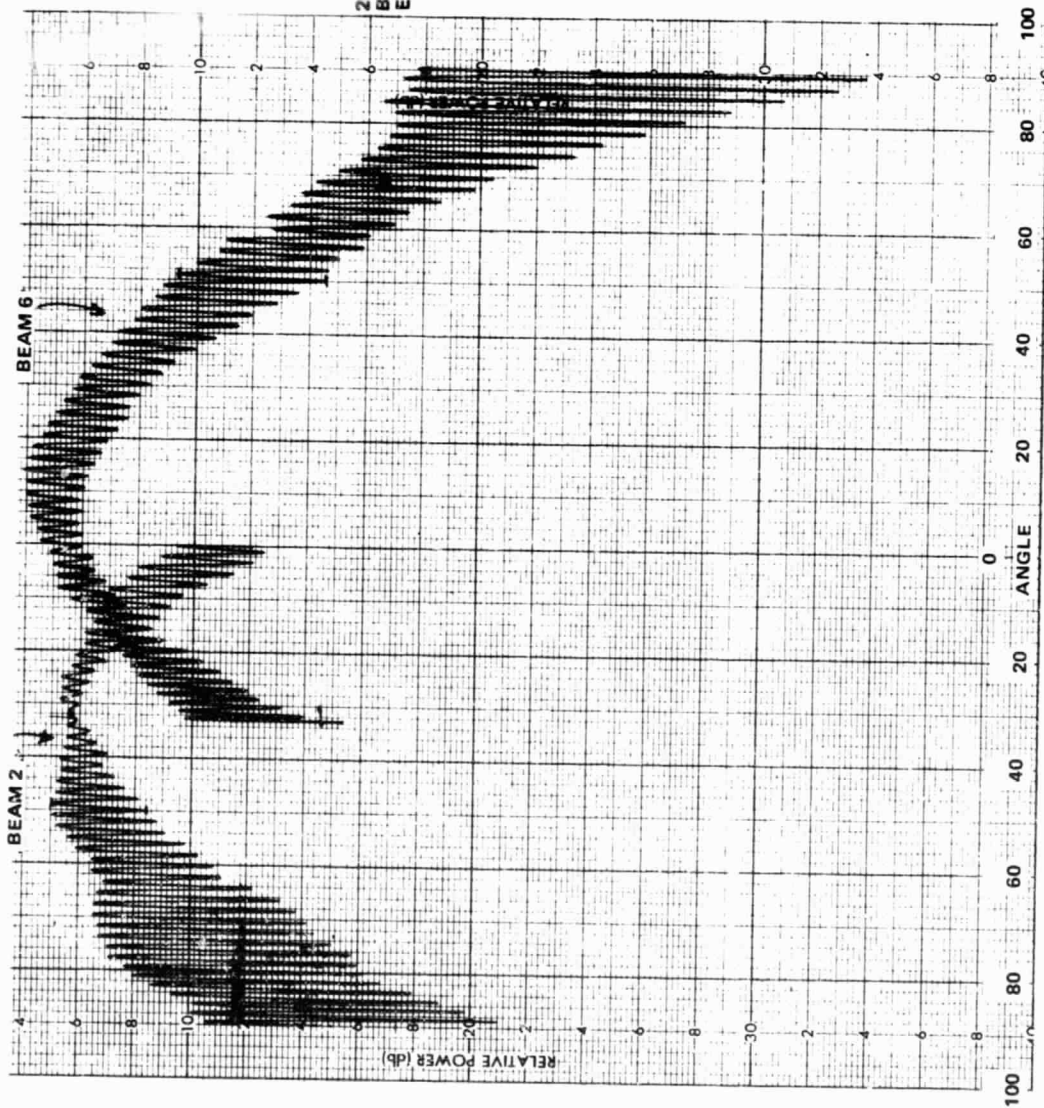
2217.5 MHz  
BEAMS 6 AND 8 (PITCH)  
ELEVATION: 14.5° UP  
LOWER ANTENNA



2217.5 MHz  
BEAMS 1 AND 5 (ROLL)  
ELEVATION: 52.5° DOWN  
LOWER ANTENNA



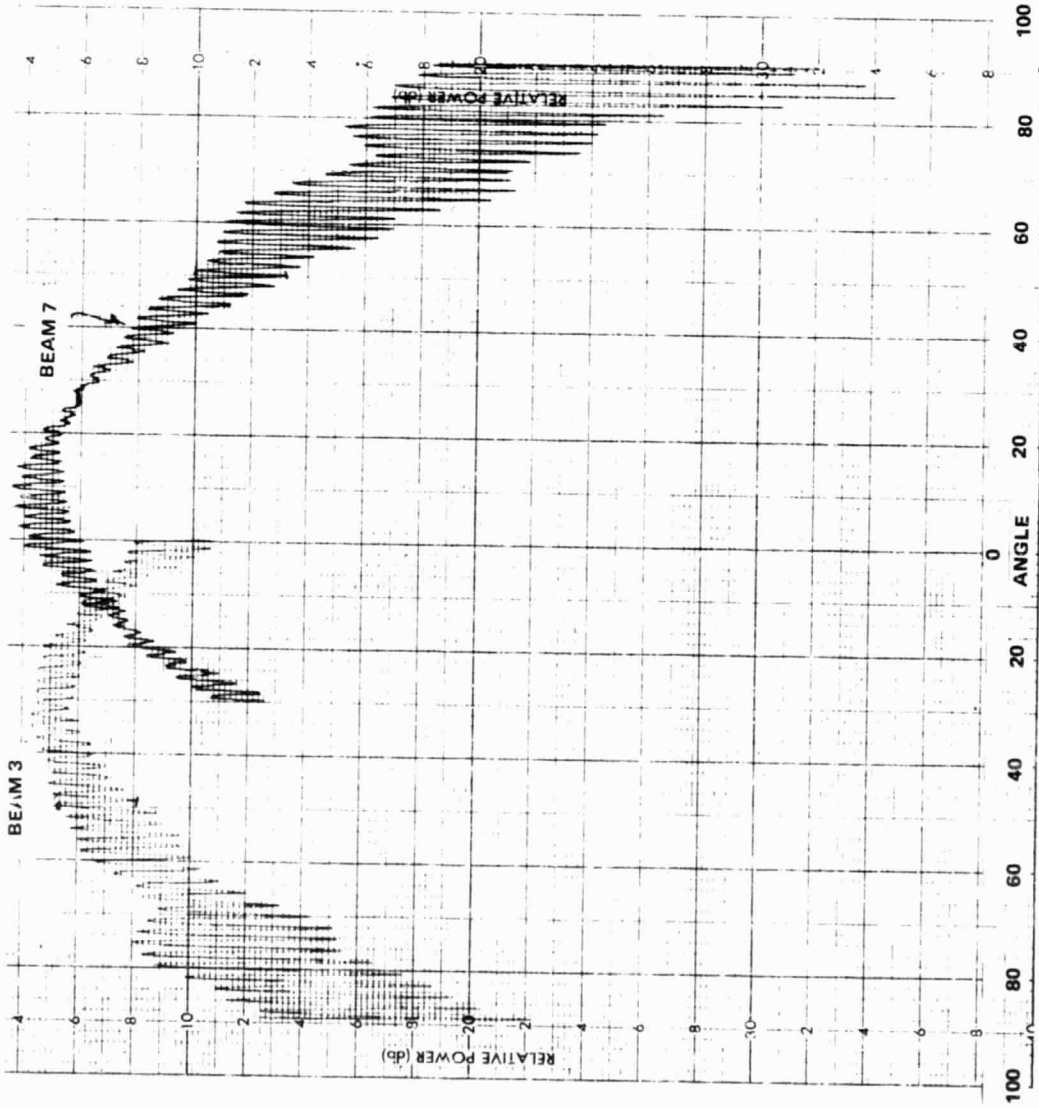




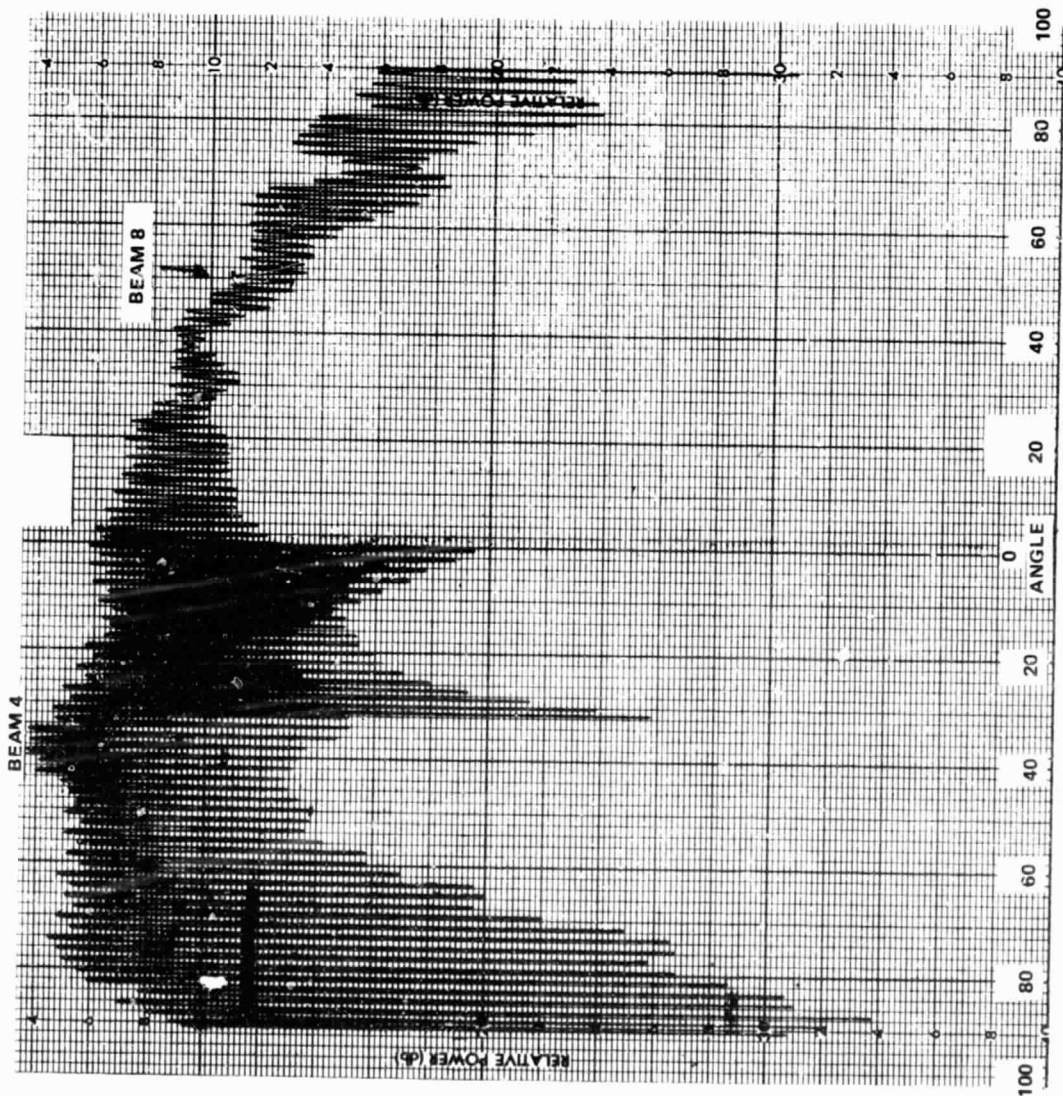
2287.5 MHz  
 BEAMS 2 AND 6 (FOLL)  
 ELEVATION: 17.5° DOWN

LOWER ANTENNA

2217.5 MHz  
BEAMS 3 AND 7 (ROLL)  
ELEVATION: 13.5° UP  
LOWER ANTENNA

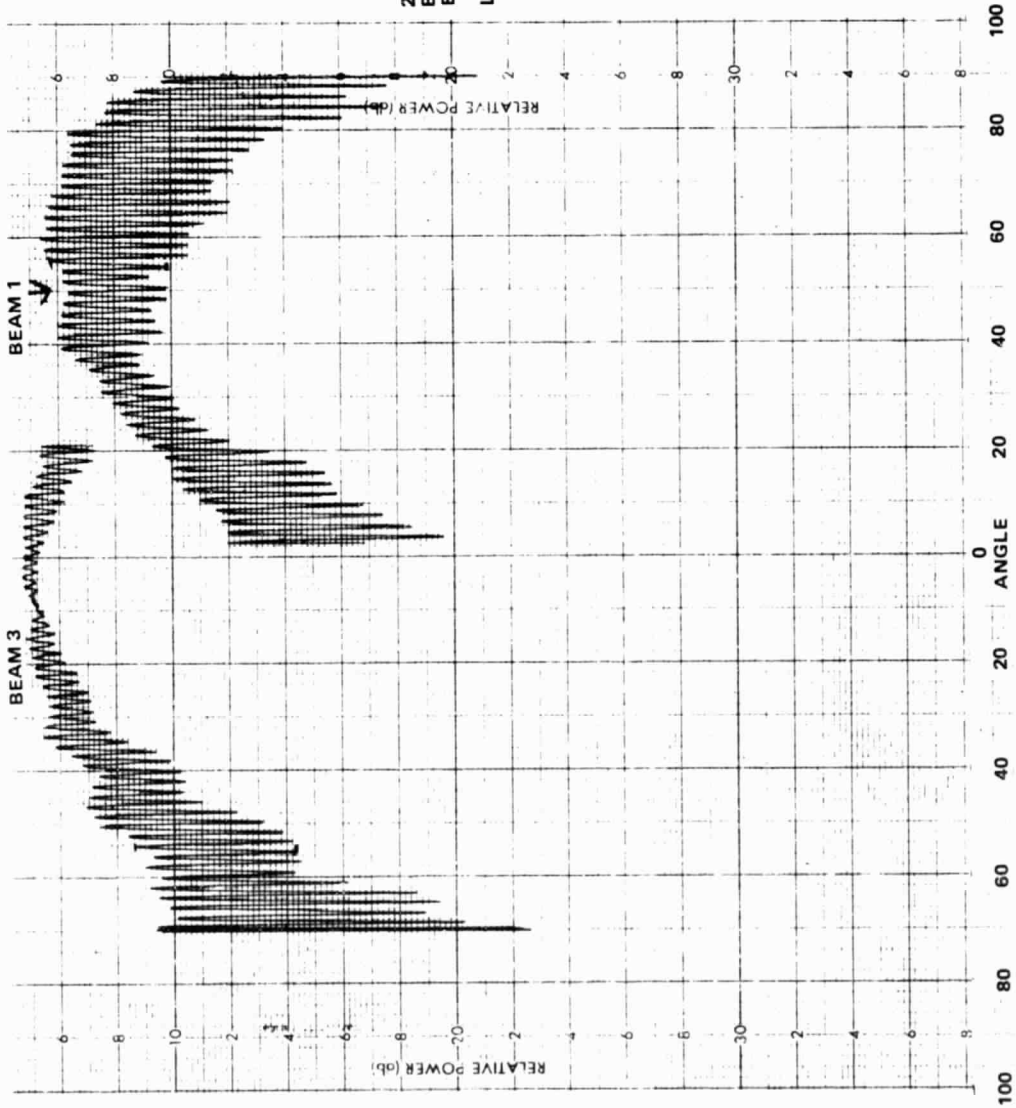


2217.5 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 48.5° UP  
LOWER ANTENNA

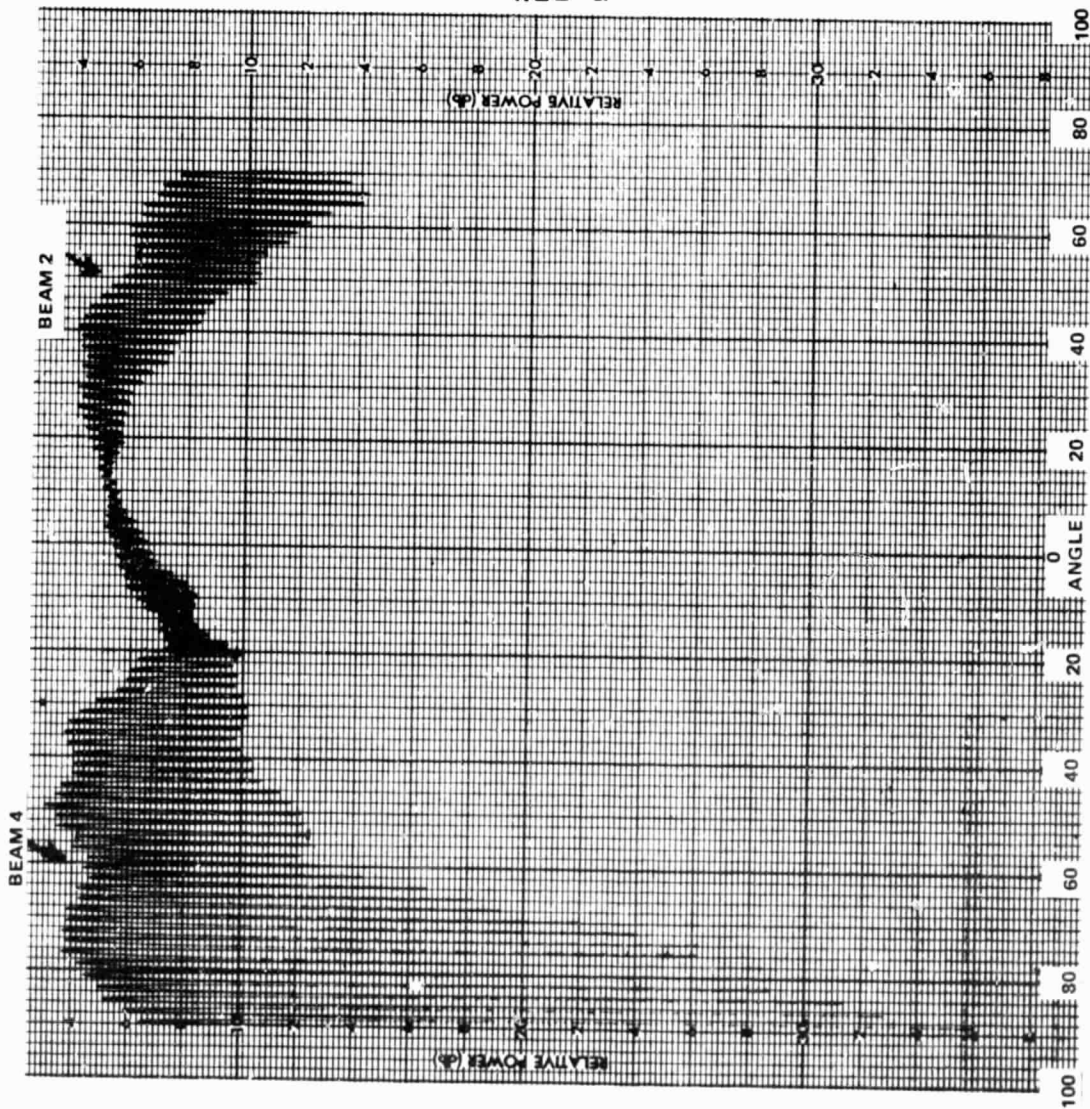




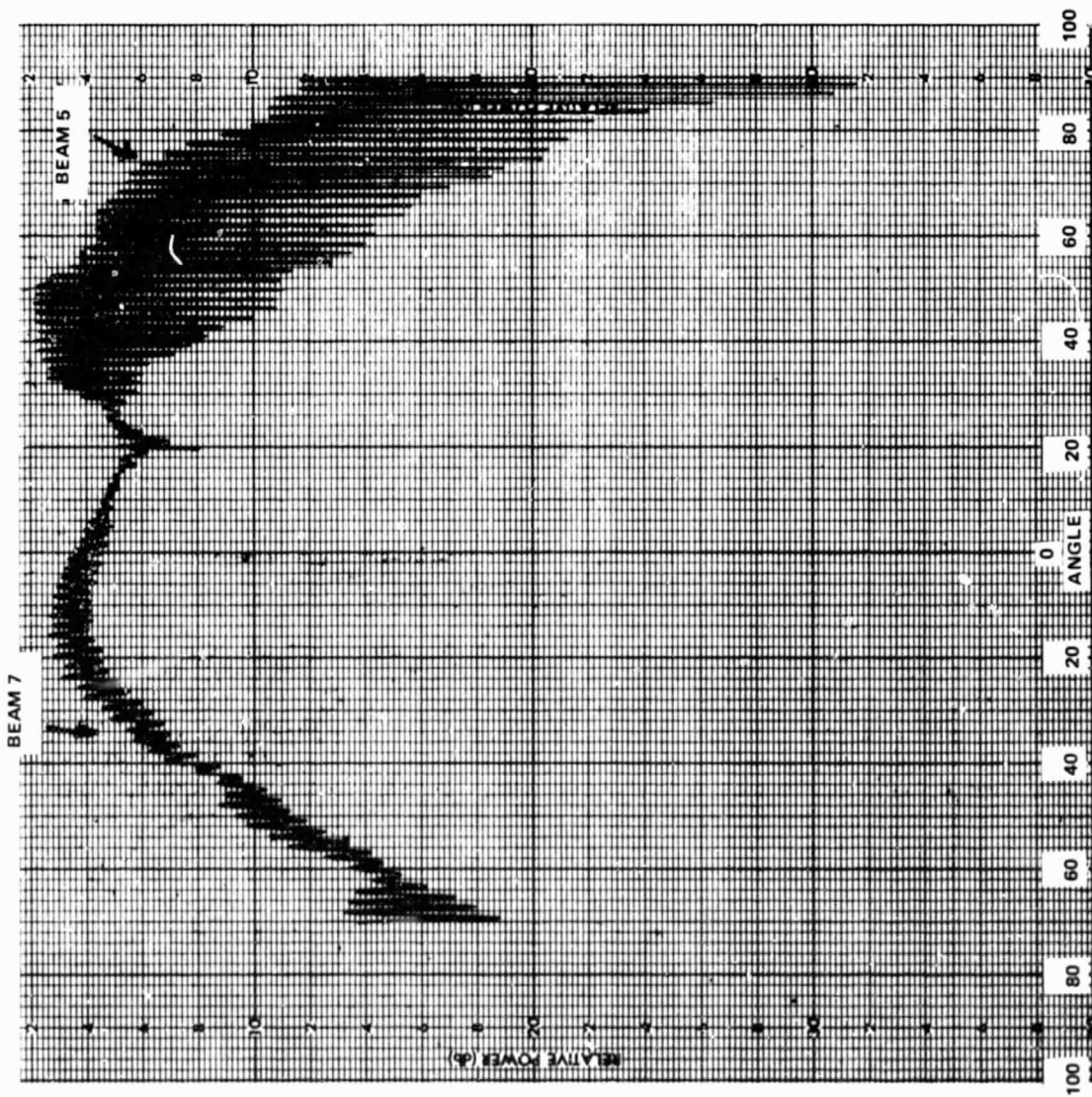
2287.5 MHz  
BEAMS 1 AND 3 (PITCH)  
ELEVATION: 43.0° DOWN  
LOWER ANTENNA



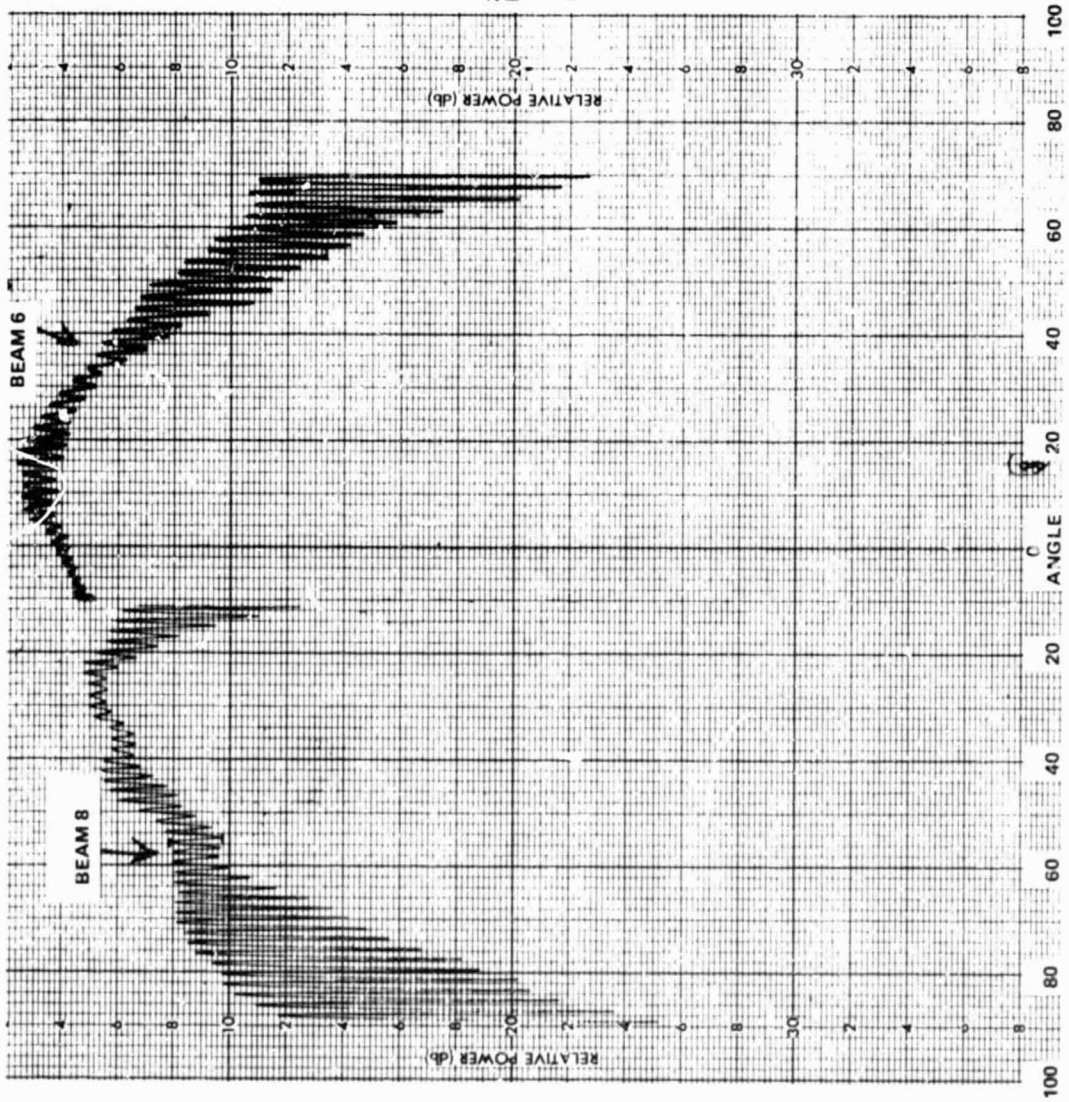
2287.5 MHz  
BEAMS 2 AND 4 (PITCH)  
ELEVATION: 43.0° DOWN  
LOWER ANTENNA



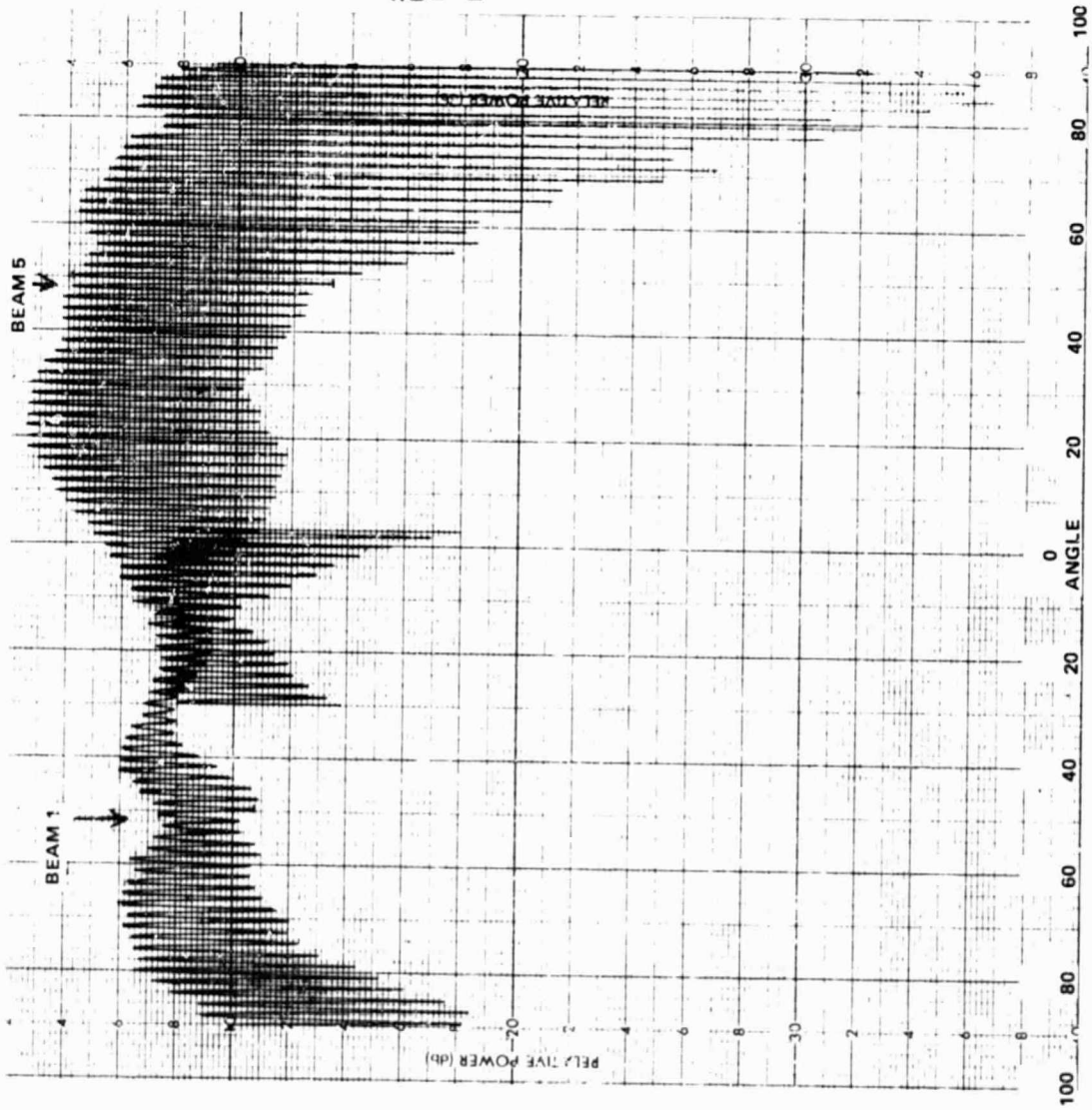
2287.5 MHz  
BEAMS 5 AND 7 (PITCH)  
ELEVATION: 13.0° UP  
LOWER ANTENNA

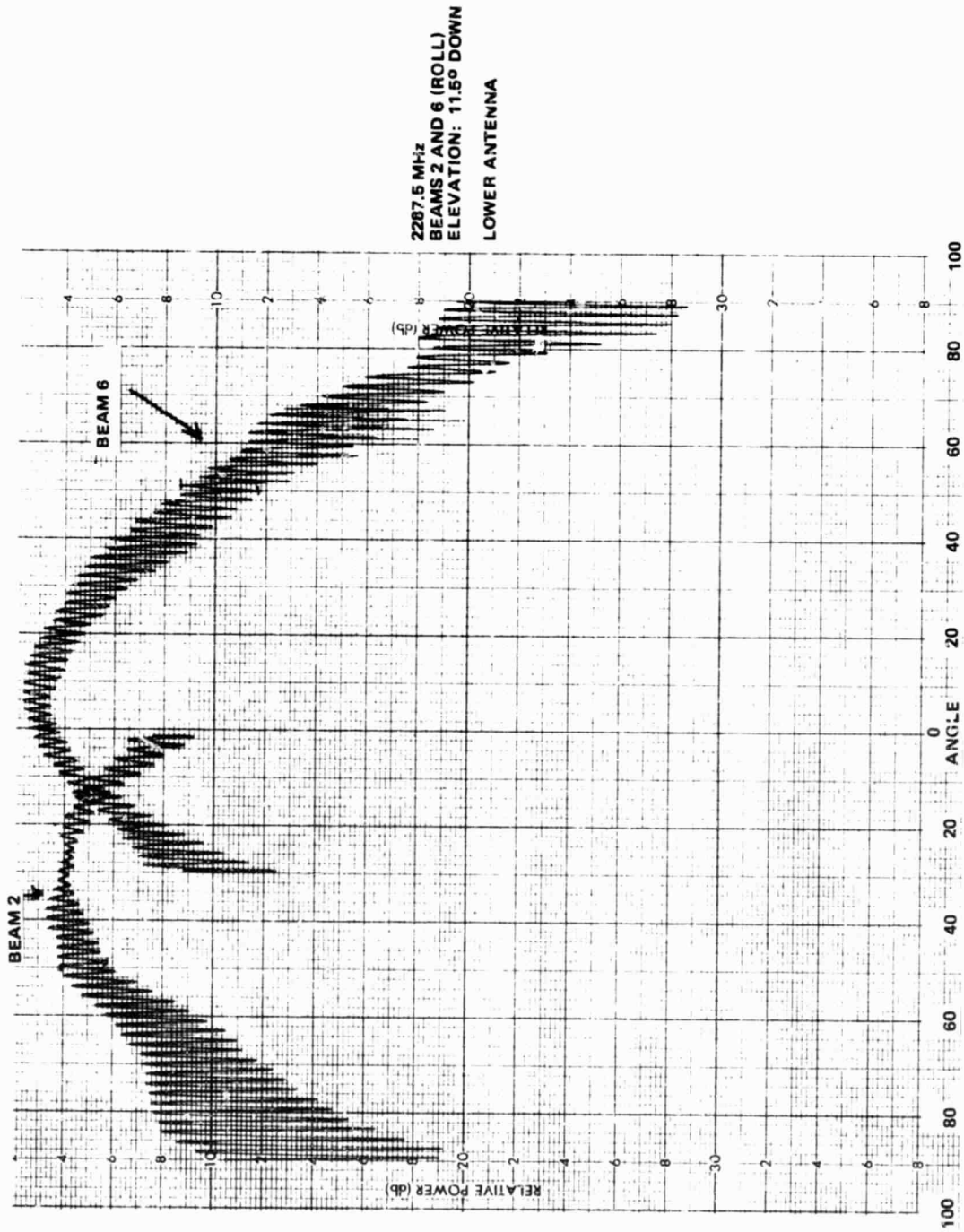


2287.5 MHz  
BEAMS 6 AND 8 (PITCH)  
ELEVATION: 13.0° UP  
LOWER ANTENNA



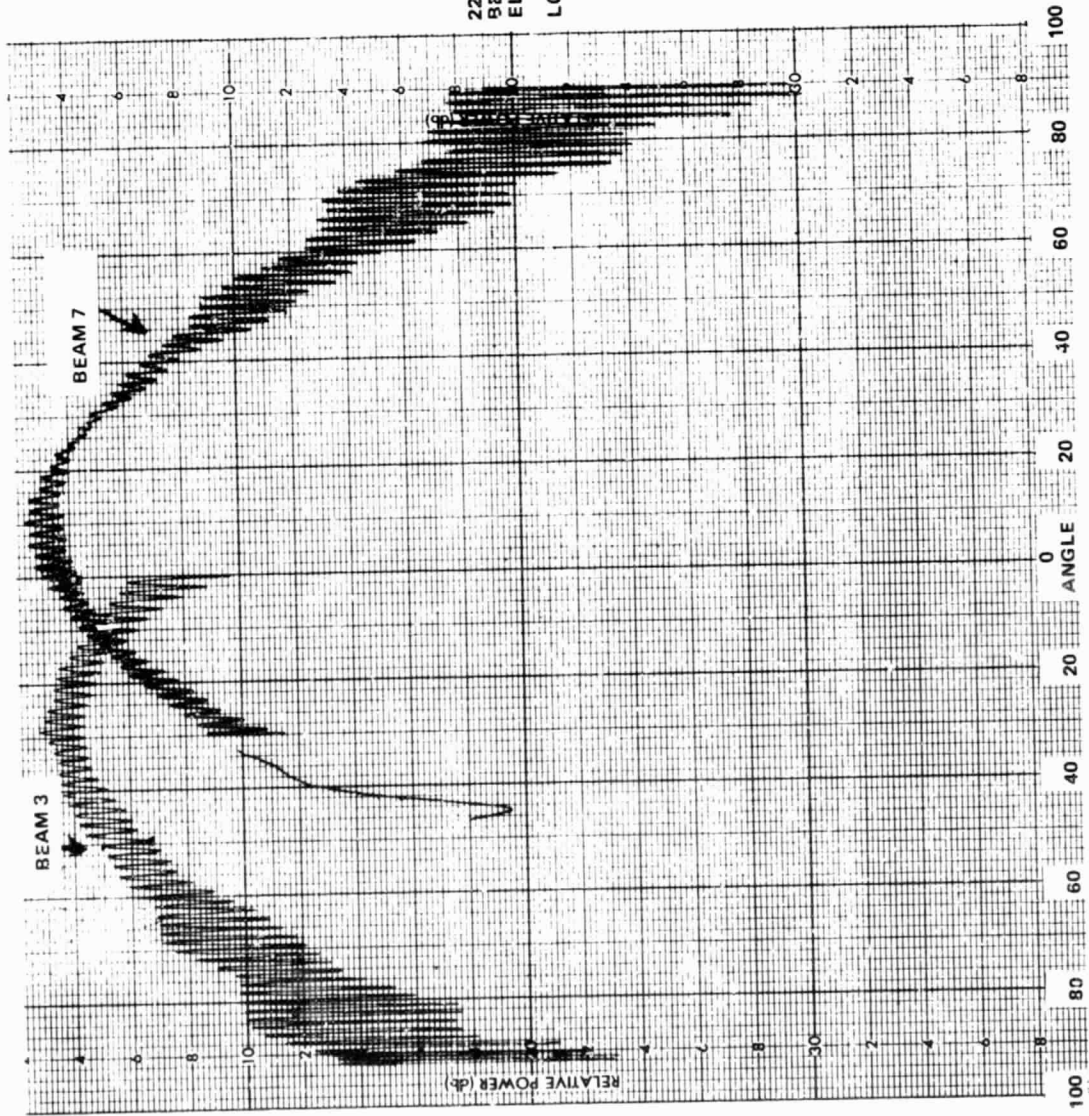
2287.5 MHz  
BEAMS 1 AND 5 (ROLL)  
ELEVATION: 53.5° DOWN  
LOWER ANTENNA





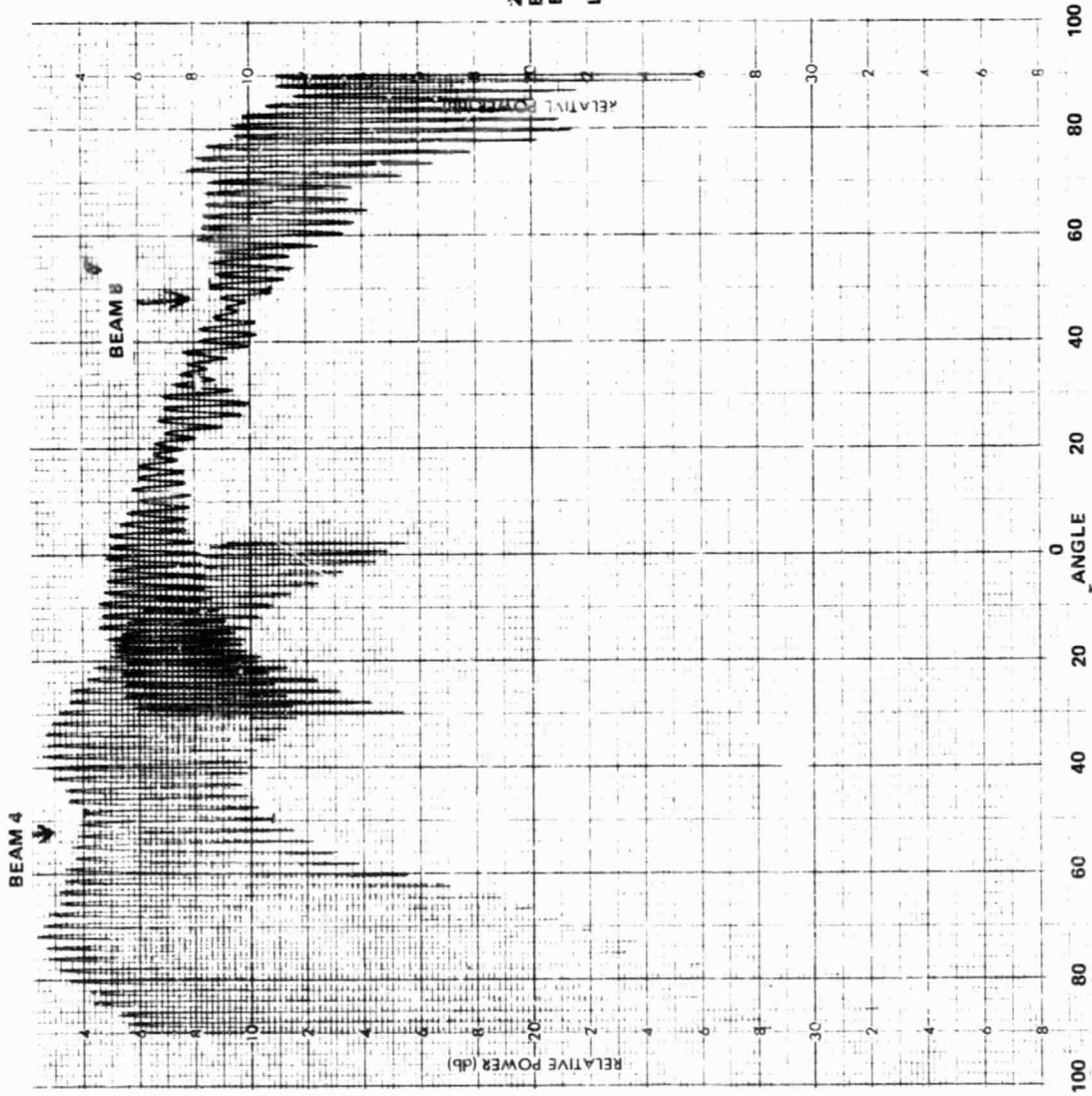


2297.5 MHz  
BEAMS 3 AND 7 (ROLL)  
ELEVATION: 11.0° UP  
LOWER ANTENNA

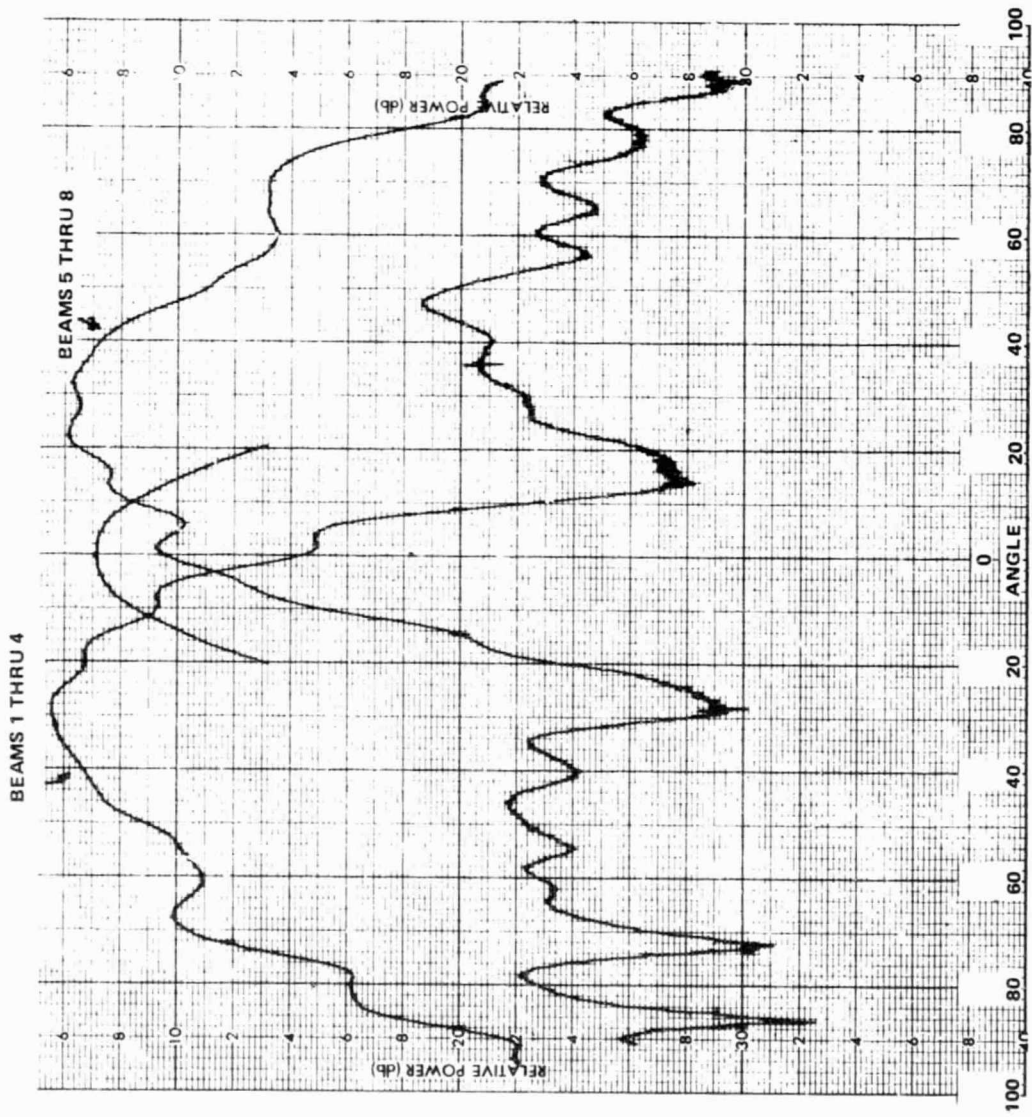




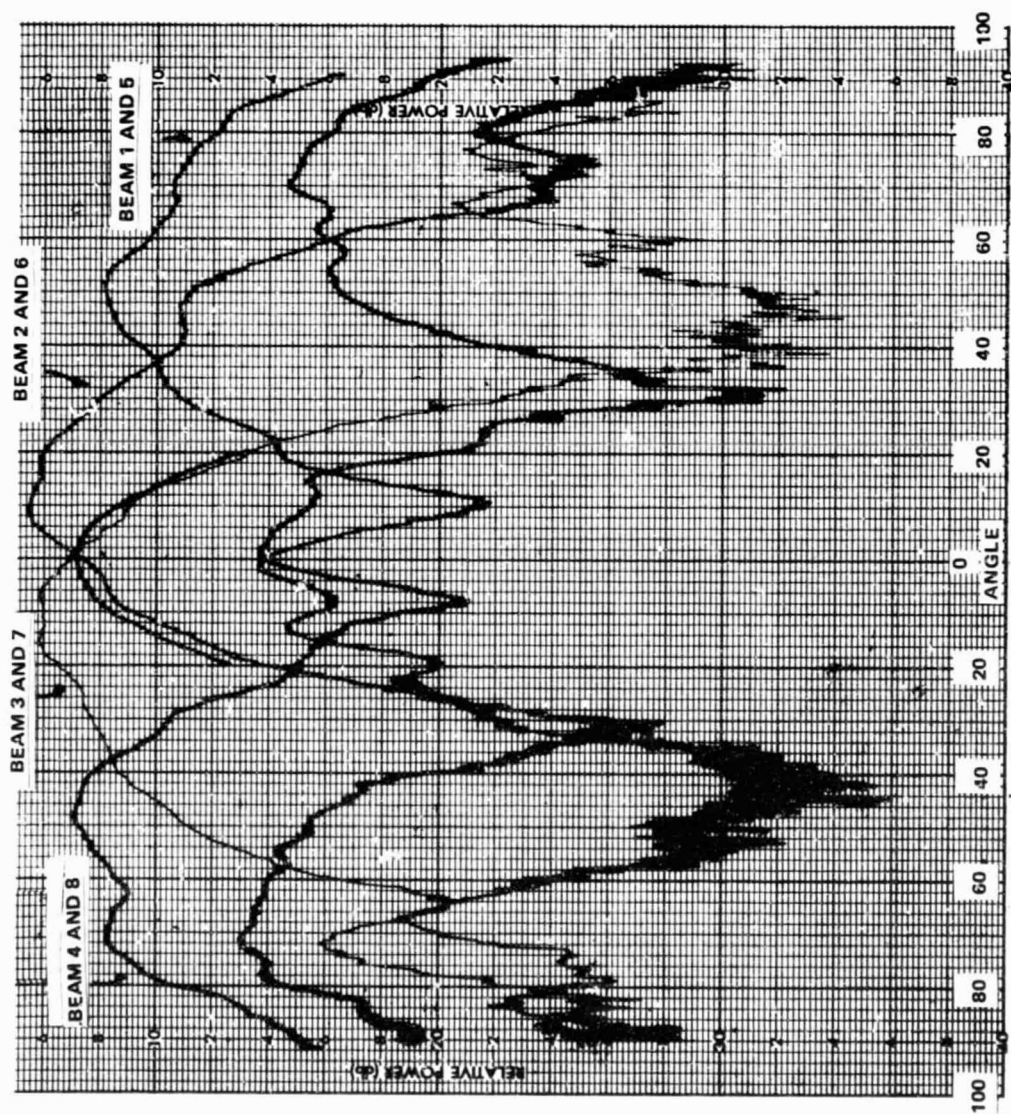
2287.5 MHz  
BEAMS 4 AND 8 (ROLL)  
ELEVATION: 52.5° UP  
LC WER ANTENNA



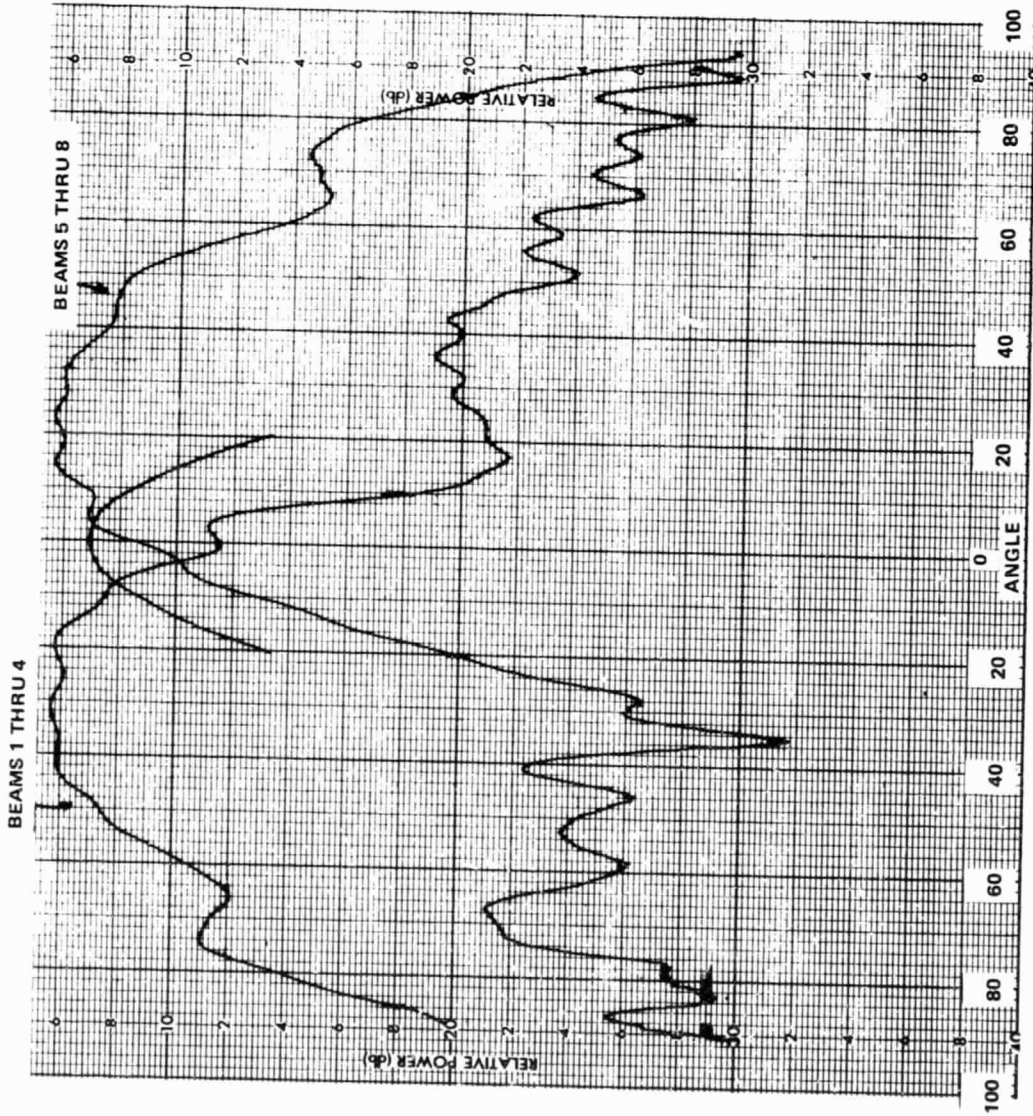
2041.9 MHz  
RADIATING ELEMENTS: A-E-B  
ROLL PLANE  
ELEVATION: 0°  
UPPER ANTENNA

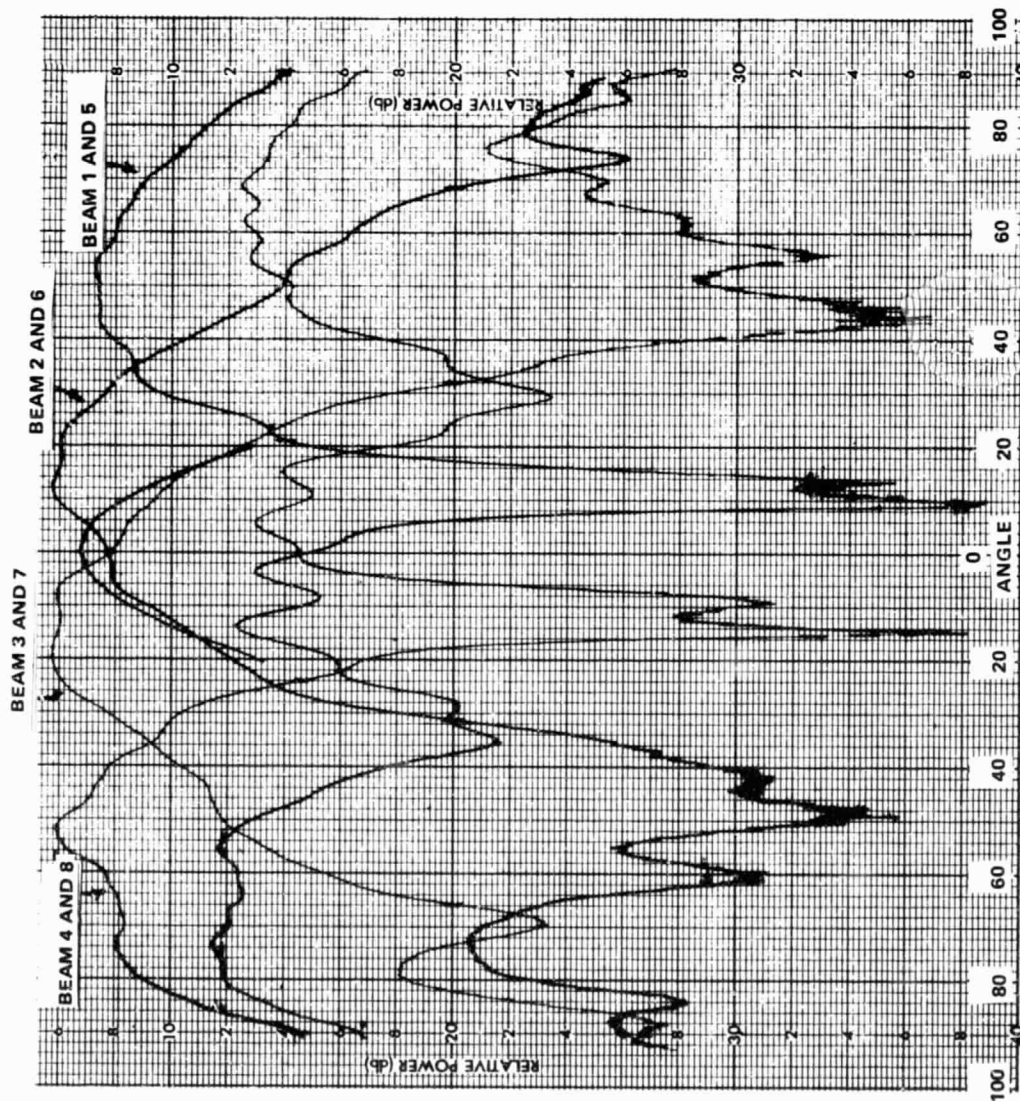


2041.9 MHz  
RADIATING ELEMENTS: C-E-D  
PITCH PLANE  
ELEVATION: 0°  
UPPER ANTENNA



2106.4 MHz  
RADIATING ELEMENTS: A-E-B  
ROLL PLANE  
ELEVATION: 0°  
UPPER ANTENNA

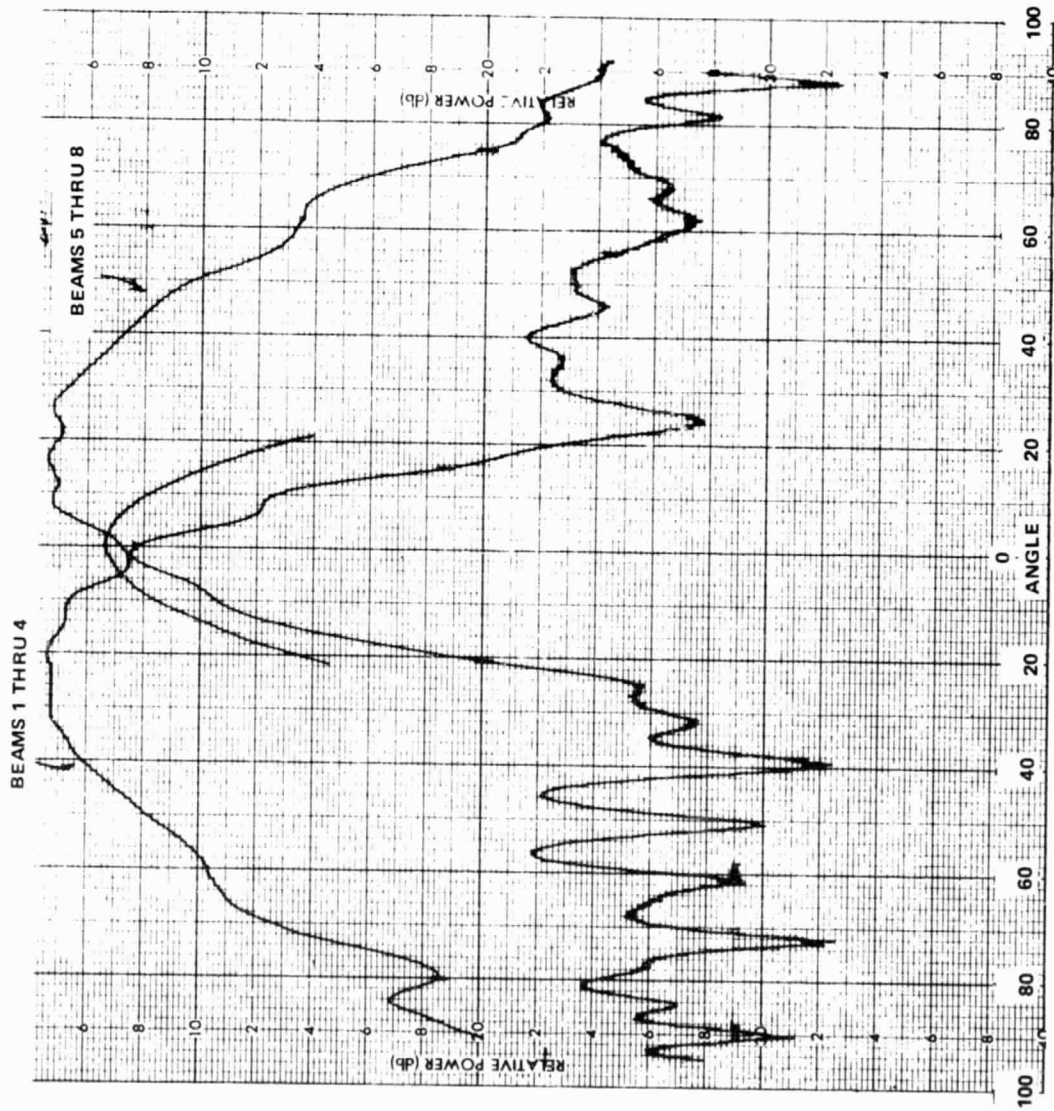




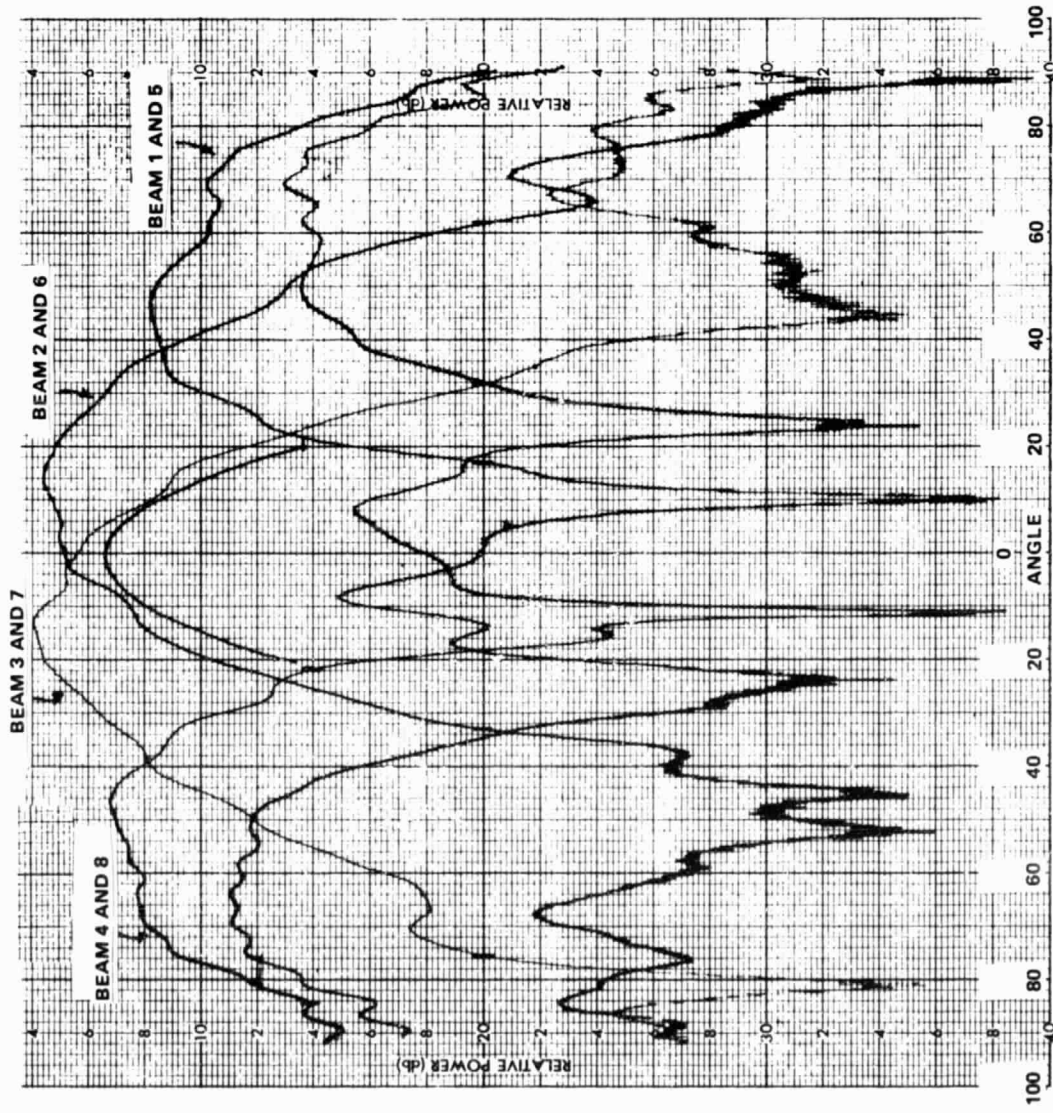
2106.4 MHz  
 RADIATING ELEMENTS: C-E-D  
 PITCH PLANE  
 ELEVATION: 0°  
 UPPER ANTENNA



2217.5 MHz  
RADIATING ELEMENTS: ^ E-B  
ROLL PLANE  
ELEVATION: 0°  
UPPER ANTENNA

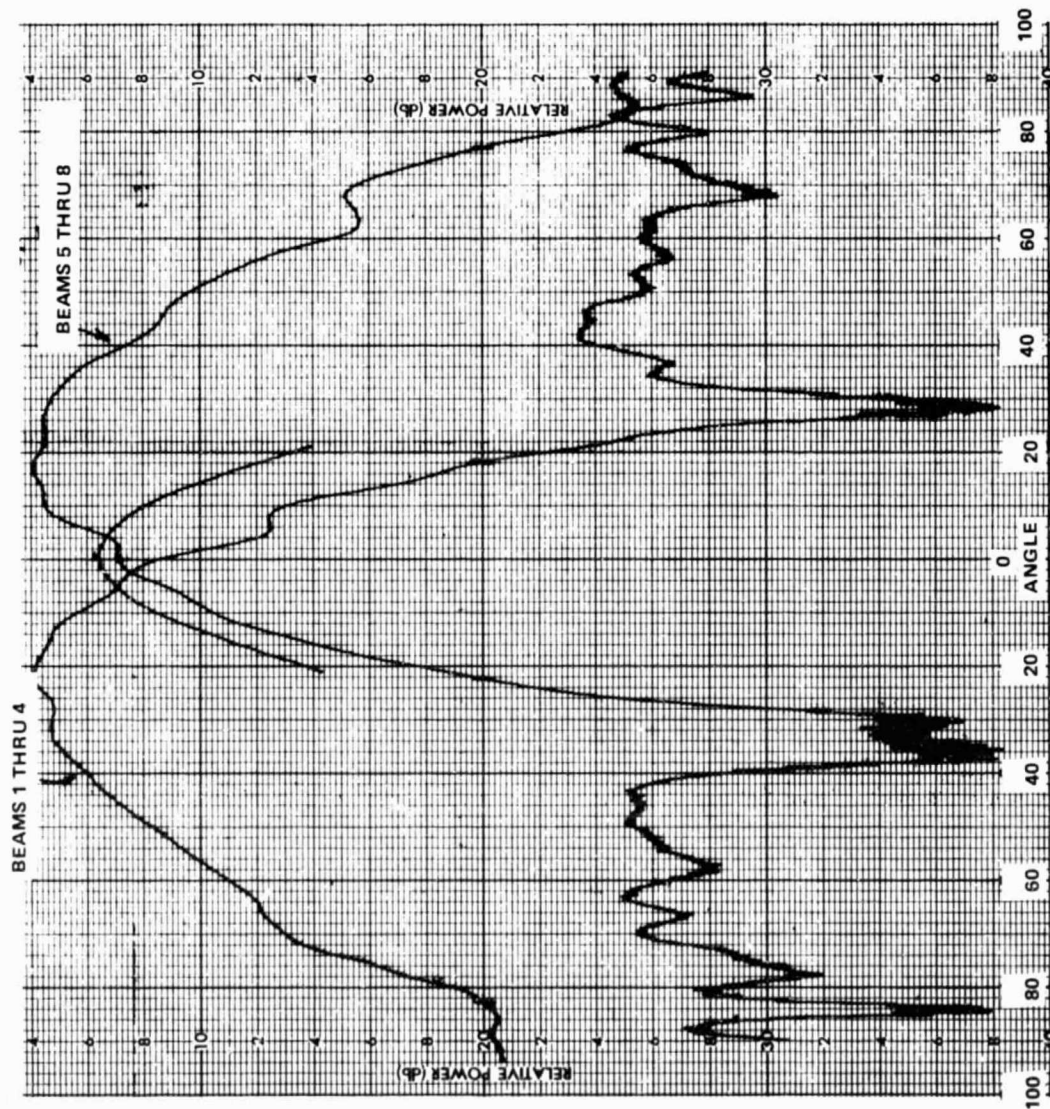


2217.5 MHz  
RADIATING ELEMENTS: C-E-D  
PITCH PLANE  
ELEVATION: 0°  
UPPER ANTENNA





2287.5 MHz  
RADIATING ELEMENTS: A-E-B  
ROLL PLANE  
ELEVATION: 0°  
UPPER ANTENNA



2287.5 MHz  
RADIATING ELEMENTS: C-E-D  
PITCH PLANE  
ELEVATION: 0°  
UPPER ANTENNA

