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**AIR FORCE MISSILE DEVELOPMENT CENTER
TECHNICAL REPORT**

RAT SCAT CROSS SECTION MEASUREMENTS OF
017-2, ROCKET EXHAUST PLUMES

HAROLD C. MARLOW
MAJOR, USAF MDRT



December 1966

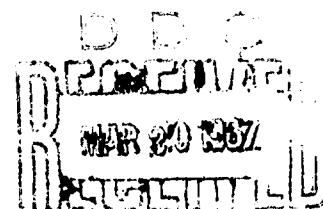
RAT SCAT
RADAR TARGET SCATTER DIVISION
HOLLOMAN AIR FORCE BASE, NEW MEXICO

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RAT SCAT CROSS SECTION MEASUREMENTS OF
017-2, ROCKET EXHAUST PLUMES (U)

December 1966

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HAROLD C. MARLOW, Major, USAF
Chief, Radar Target Scatter Division

RAT SCAT
Radar Target Scatter Division
Missile Development Center
Air Force Systems Command
Holloman Air Force Base, New Mexico

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FOREWORD

This Air Force Report is based upon the actual radar cross section measurements made at the Radar Target Scatter Division (RAT SCAT), of AFMDC. RAT SCAT is located on the Alkali Flats, Holloman AFB, New Mexico. This Facility is operated and maintained by the General Dynamics Corporation, Fort Worth Division, and under the specific direction of the Air Force Missile Development Center. The Project or Program Monitor is Major Harold C. Marlow. Correspondence pertaining to this report should be addressed to the attention of MDRT.

This technical report has been reviewed and is approved.

Walter L. Carss

WALTER L. CARSS, Colonel, USAF
Director of Technical Support

UNCLASSIFIED ABSTRACT

Static radar cross section data of plumes from small liquid and solid propellant rocket motors were obtained at RAT SCAT, Air Force Missile Development Center, Holloman Air Force Base, New Mexico. A total of 42 monostatic measurements were made at UHF and upper L-band frequencies. These measurements are believed to be the first true radar cross section measurements of actual rocket plumes.

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SECTION I

INTRODUCTION

This report documents radar cross section measurements of exhaust plumes from small liquid and solid propellant rocket motors under RAT SCAT Control Number 017-2. A total of 42 measurements were made at 450 and 2000 megahertz. Measurements were made using different aluminum contamination seeding rates carefully controlled as shown in Table II, Page 8 and 9, three incidence angles, and two exit pressures to determine the reflectivity effects. Specific test conditions are presented in Section II along with the reproduced rectilinear data plots.

A general description of the RAT SCAT site and operational procedures are included in Appendices A and B.

The measurements made and data contained herein are certified as to quality, repeatability, and accuracy by Air Force representatives on site (AFMDC, MDRT).

The data contained herein was requested by REFSRAM 017-2 as submitted by the Rocket Test Facility at Edwards AFB, RPMCP (RTD).

SECTION II

TEST CONDITIONS AND RESULTS

Test Conditions

Radar cross section measurements were made in support of an Aerochem Research Laboratory contract with RTD. Rocket motor firings were conducted by Thiokol Chemical Company, Reaction Motors Division.

The rocket exhaust plumes measured were generated by small rocket motors of the approximately 2000 pound thrust. Thiokol TU-168 motors were used for the solid propellant plumes. These motors are of the AP composite type. Two each center perforated, end burning sections were used to obtain a constant burn rate during the three second burn time. The liquid propellant tests were performed with a mixed hydrazine fuel (MHF-5) and nitrogen tetroxide oxidizer (N_2O_4).

The rocket motors with their associated test stand had to be shielded in order to isolate the plume radar reflection from the motor test stand and associated equipment. Ground plane effect made it difficult to use the RAT SCAT pits for this purpose as it was desired to have strong illumination over the entire rocket exhaust plume. A shaped gypsum baffle was used to shield the rocket motors, placing the nozzle at a height of 10 feet above ground level. The plume was directed upwards and was about 4 feet long for the liquid propellant motors and about 9 feet for the solid propellant motors. The shaped gypsum mound, shown in Figures 1 and 2, had a rounded cross section with a peak height of 10 feet, a width of 30 feet and a length of 80 feet. A wire cage capped the rear of the baffle to minimize reflection from the discontinuities and equipment at the rear of the mound. The wire was faired into the earthwork to provide a smooth electrical transition. The scheme gave background returns of around -35 to -40 dbsm both

at 2000 MHz and at 450 MHz. While the background was generally acceptable the ground plane reflections from the baffle itself perturbed the field in the target (plume) area. We did try the use of a peaked (triangular cross section) baffle and it did not significantly improve the energy distribution. Radar absorption material (RAM) fences on the earthwork baffle improved vertical field distribution somewhat at the expense of background. In the tradeoff between background level and target illumination the low background was judged the more important at 2000 MHz; consequently, a probe of the 2-way field pattern shows an amplitude variation across the target zone. Calibration was performed with a precision sphere located in the plume target zone.

At 450 MHz, for the liquid propellant rocket plume measurements, absorber fences were used on the earthwork baffle to improve the illumination pattern without a serious increase in background return. The vertical field pattern with this configuration was acceptable for the 4 foot target zone.

For the solid propellant rocket plume measurements at 450 MHz the rocket motors were placed behind a stack of radar absorption material with the nozzle at a height of 5 feet in order to obtain an acceptable vertical field pattern over the 9 foot target zone.

Boxcar detector output (wide pulses representing the amplitude of the gated video pulses) was monitored to obtain the amplitude of each reflected pulse. This increased the information bandwidth to approximately 500 cycles per second as compared to approximately 3 cycles per second for the normal system recording. This signal was recorded on a user provided special ampex tape recorder.

The radar measurement parameters are given in Table I.

Table I MEASUREMENT PARAMETERS

Firing No.	Range	Ant. Height	Cal. Height	Nozzle Height	Pulse Width	Peak Power
5-9	1500 ft.	9 ft.	11.5 ft.	10 ft.	.2 μ sec	1kw
10-14	1500	9	11.5	10	.2	1kw
15-21	1500	9	11.5	10	.2	1kw
22-25	1500	9	11.5	10	.2	1kw
26-30	1500	9	11.5	10	.2	1kw
31-41	600	24	14	11	.1	1kw
42-47	500	24	11	5	.2	1kw
48	500	24	11	5	.2	1kw

The pulse repetition frequency was 1000 pulses per second and the range gate width was 0.1 microsecond for all firings. Firings through #41 were done using the earthwork baffle. Firing numbers 5 through 30 were at 2000 MHz and numbers 31 through 48 at 450 MHz.

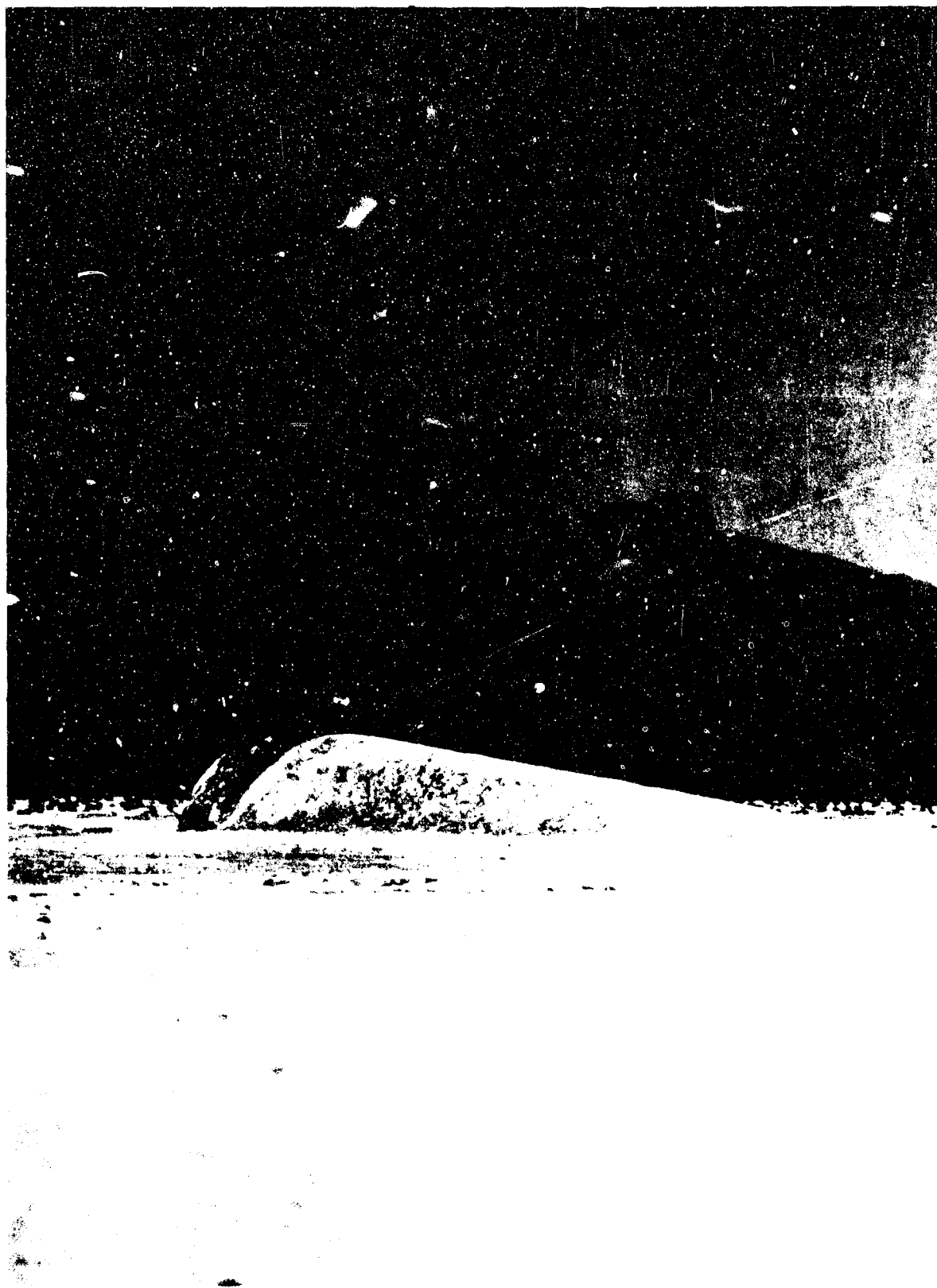


Figure 1 EARTHWORK BAFFLE WITH TYPICAL LIQUID
PROPELLANT ROCKET PLUME



Figure 2 TYPICAL SOLID PROPELLANT ROCKET PLUME

Data Section

Pertinent rocket motor parameters and radar data are given in Table II, the Data Plot Index.

The abscissa does not represent azimuth, but time. The rectilinear recorder was run at a constant speed during each firing. The nominal speeds in degrees per second are given in the Data Plot Index. Ignition is on the right hand side of the plots, and burnout is on the left.

Background levels may be read directly from each data plot as the level before and after the firing. The background was often different from run to run due to movement of the rocket motor from one pitch angle to another. Motion occurring during the firing, however, was negligible. Fine adjustments in radar absorption material position and in the position of a fixed scatterer at the same range as the target were also made between runs to lower background return. Although the rocket plume is basically of a cylindrical shape, the backscattered energy from this non-conductive target can not be considered to be coherent. Therefore, the interference between the background and target is quite low for all measurements (reference Figure A-2).

The run numbers in this report are not necessarily sequential. Setup runs (calibration, post calibration, preliminary background runs, etc.) are necessary but are not included.

CONTROL NUMBER 017-2

TABLE II DATA PLOT INDEX SHEET 1

PAGE NO.	RUN	FREQ (MHz)	POLARIZATION	PITCH ANGLE	ROLL ANGLE	TARGET CONFIGURATION		
						Firing No.	Seed (Al)	Exit Press
10	88	2000	H	90 (Plume Vertical)		5 Liquid	1000 ppm	3.4
11	90	2000	V	90		6 Liquid	1000 ppm	3.4
12	92	2000	V	90		8 Liquid	1000 ppm	3.4
13	93	2000	HV	90		9 Liquid	1000 ppm	3.4
14	103	2000	H	90		10 Liquid	1000 ppm	0.86
15	104	2000	H	60 (Pitched away		11 Liquid	1000 ppm	0.86
16	105	2000	H	60 from radar)		12 Liquid	1000 ppm	3.4
17	106	2000	H	60		13 Liquid	100 ppm	3.4
18	107	2000	H	60		14 Liquid	100 ppm	0.86
19	111	2000	H	90		15 Liquid	100 ppm	0.86
20	112	2000	H	90		16 Liquid	100 ppm	0.86
21	114	2000	H	90		17 Liquid	100 ppm	3.4
22	115	2000	H	120 (Pitched to-		18 Liquid	100 ppm	3.4
23	116	2000	H	120 ward radar)		19 Liquid	100 ppm	0.86
24	117	2000	H	90		20 Liquid	0 ppm	3.4
25	118	2000	H	90		21 Liquid	0 ppm	0.86
26	123	2000	H	90		23 Solid	16 percent	0.86
27	124	2000	H	90		24 Solid	16 percent	0.86
28	125	2000	H	90		25 Solid	16 percent	3.4
29	128	2000	H	90		26 Solid	5 percent	0.86
30	131	2000	H	120		27 Solid	5 percent	0.86
31	132	2000	H	60		28 Solid	5 percent	0.86
32	133	2000	H	60		29 Solid	16 percent	0.86
33	134	2000	H	120		30 Solid	16 percent	0.86
34	139	450	H	90		31 Liquid	0 ppm	0.86
35	140	450	H	90		32 Liquid	0 ppm	3.4
36	141	450	H	90		33 Liquid	1000 ppm	3.4
37	142	450	H	90		34 Liquid	1000 ppm	0.86
38	143	450	H	60		35 Liquid	1000 ppm	3.4
39	144	450	H	60		36 Liquid	1000 ppm	

TABLE II DATA PLOT INDEX SHEET 1

VARI- ATION	PITCH ANGLE	ROLL ANGLE	TARGET CONFIGURATION AND REMARKS			
			Firing No.	Seed (A1)	Exit Press Atm.	Nominal Recorder Speed
	90 (Plume Vertical)		5 Liquid	1000 ppm	3.4	180 deg/sec
	90		6 Liquid	1000 ppm	3.4	180 deg/sec
	90		8 Liquid	1000 ppm	3.4	180 deg/sec
	90		9 Liquid	1000 ppm	3.4	180 deg/sec
	90		10 Liquid	1000 ppm	0.86	84 deg/sec
	60 (Pitched away		11 Liquid	1000 ppm	0.86	180 deg/sec
	60 from radar)		12 Liquid	1000 ppm	3.4	180 deg/sec
	60		13 Liquid	100 ppm	3.4	180 deg/sec
	60		14 Liquid	100 ppm	0.86	180 deg/sec
	90		15 Liquid	100 ppm	0.86	180 deg/sec
	90		16 Liquid	100 ppm	0.86	180 deg/sec
	90		17 Liquid	100 ppm	3.4	180 deg/sec
	120 (Pitched to-		18 Liquid	100 ppm	3.4	180 deg/sec
	120 ward radar)		19 Liquid	100 ppm	0.86	180 deg/sec
	90		20 Liquid	0 ppm	3.4	180 deg/sec
	90		21 Liquid	0 ppm	0.86	180 deg/sec
	90		23 Solid	16 percent	0.86	25 deg/sec
	90		24 Solid	16 percent	0.86	25 deg/sec (repeat of 23)
	90		25 Solid	16 percent	3.4	25 deg/sec
	90		26 Solid	5 percent	0.86	25 deg/sec
	120		27 Solid	5 percent	0.86	25 deg/sec
	60		28 Solid	5 percent	0.86	25 deg/sec
	60		29 Solid	16 percent	0.86	25 deg/sec
	120		30 Solid	16 percent	0.86	25 deg/sec
	90		31 Liquid	0 ppm	0.86	180 deg/sec
	90		32 Liquid	0 ppm	3.4	180 deg/sec
	90		33 Liquid	1000 ppm	3.4	180 deg/sec
	90		34 Liquid	1000 ppm	0.86	180 deg/sec
	60		35 Liquid	1000 ppm	3.4	180 deg/sec
	60		36 Liquid	1000 ppm	0.86	180 deg/sec

AFEL-ASP-1

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2

TABLE II DATA PLOT INDEX SHEET 2

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Q. dbsm

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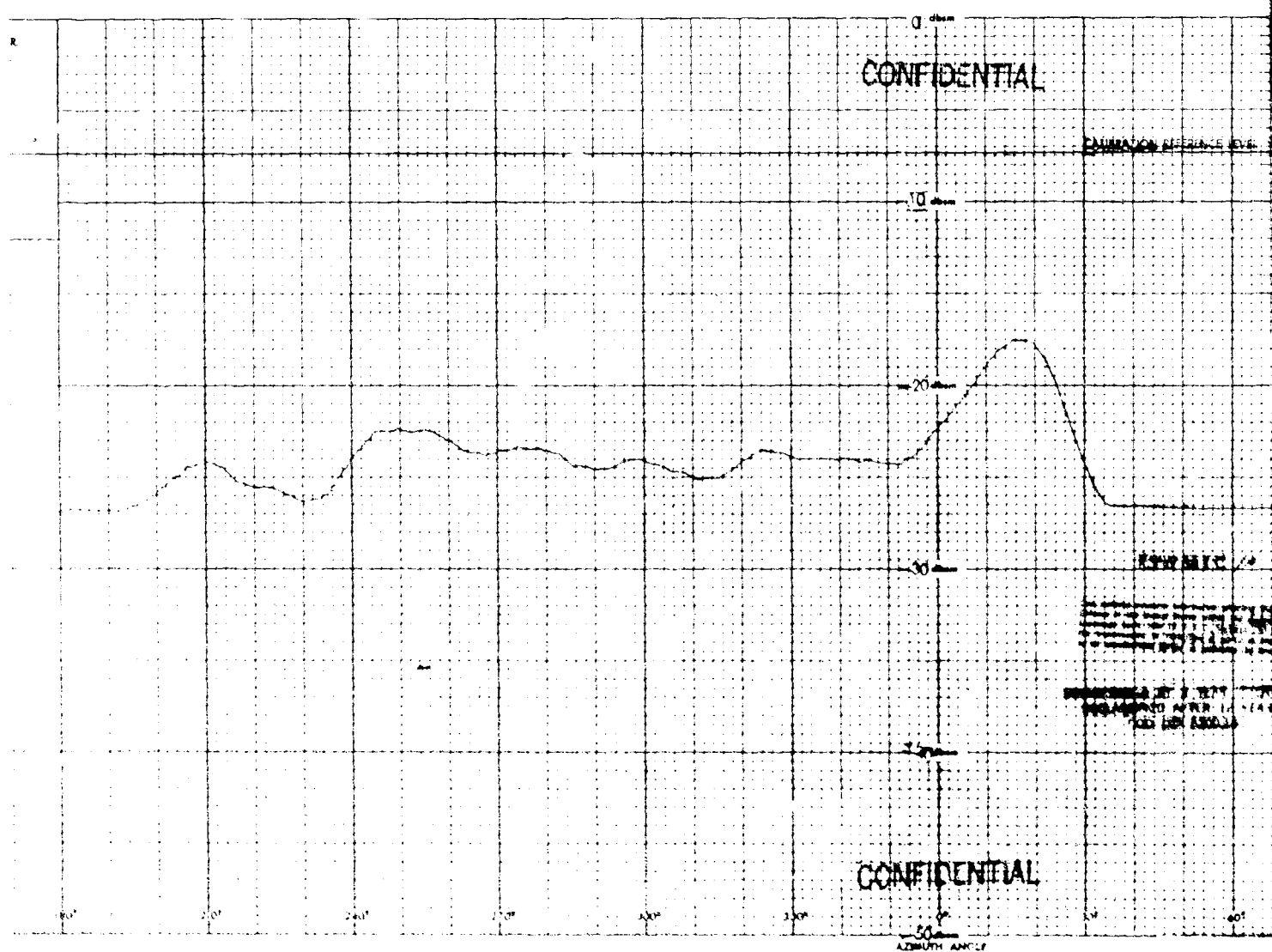
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Firing No. 5

23

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7



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REMARKS

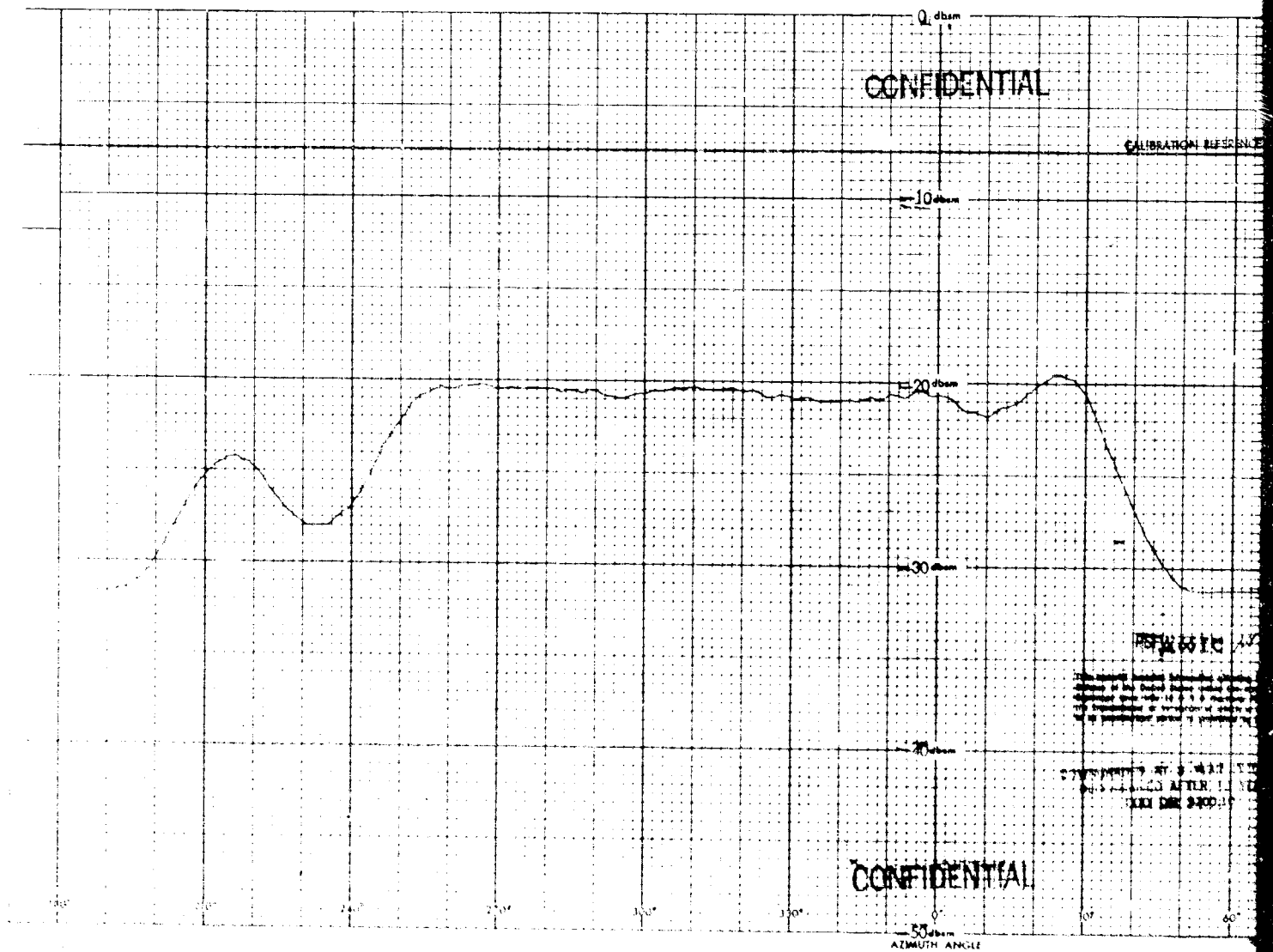
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CALIBRATION REFERENCE LEVEL - 7.3 dbm

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Page 12

REMARKS

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and the radar return was very good. The
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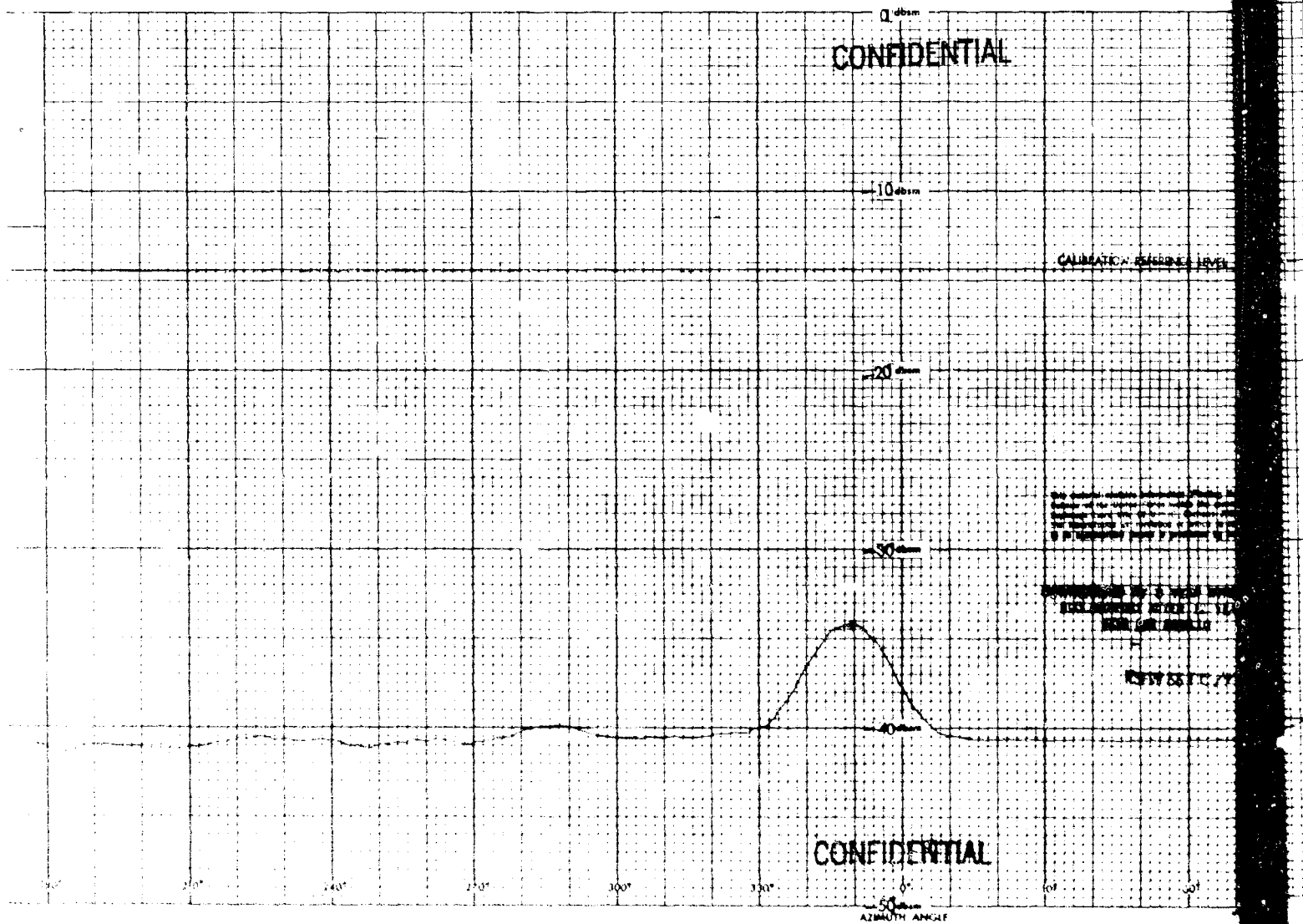
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AZIMUTH ANGLE

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Firing No. 9

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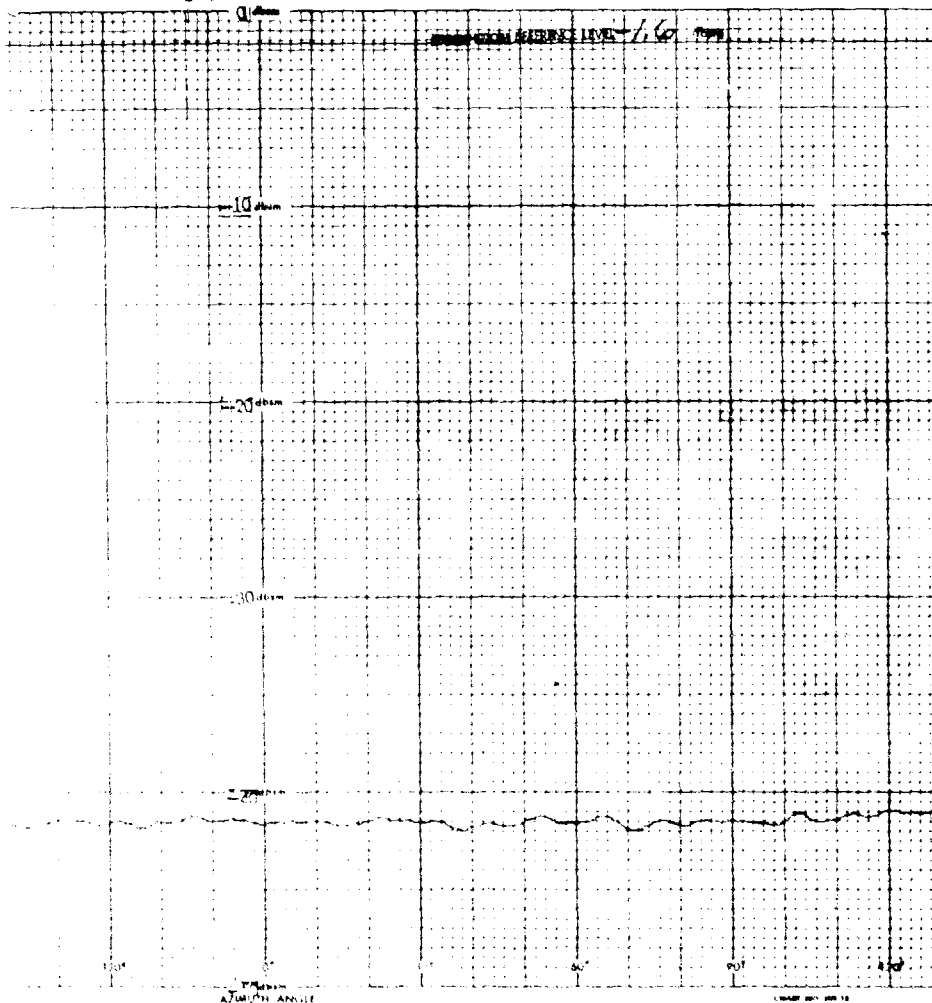
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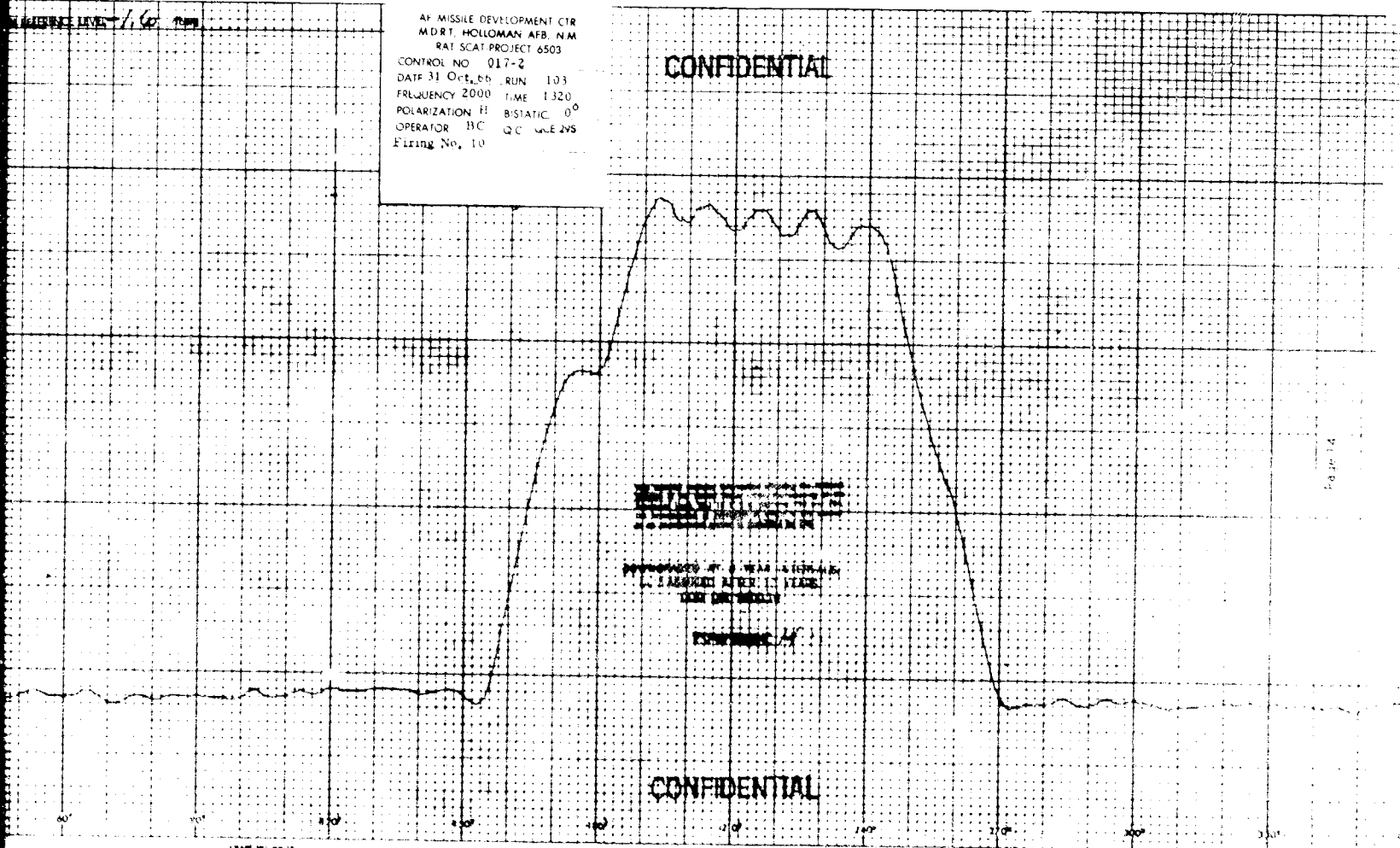
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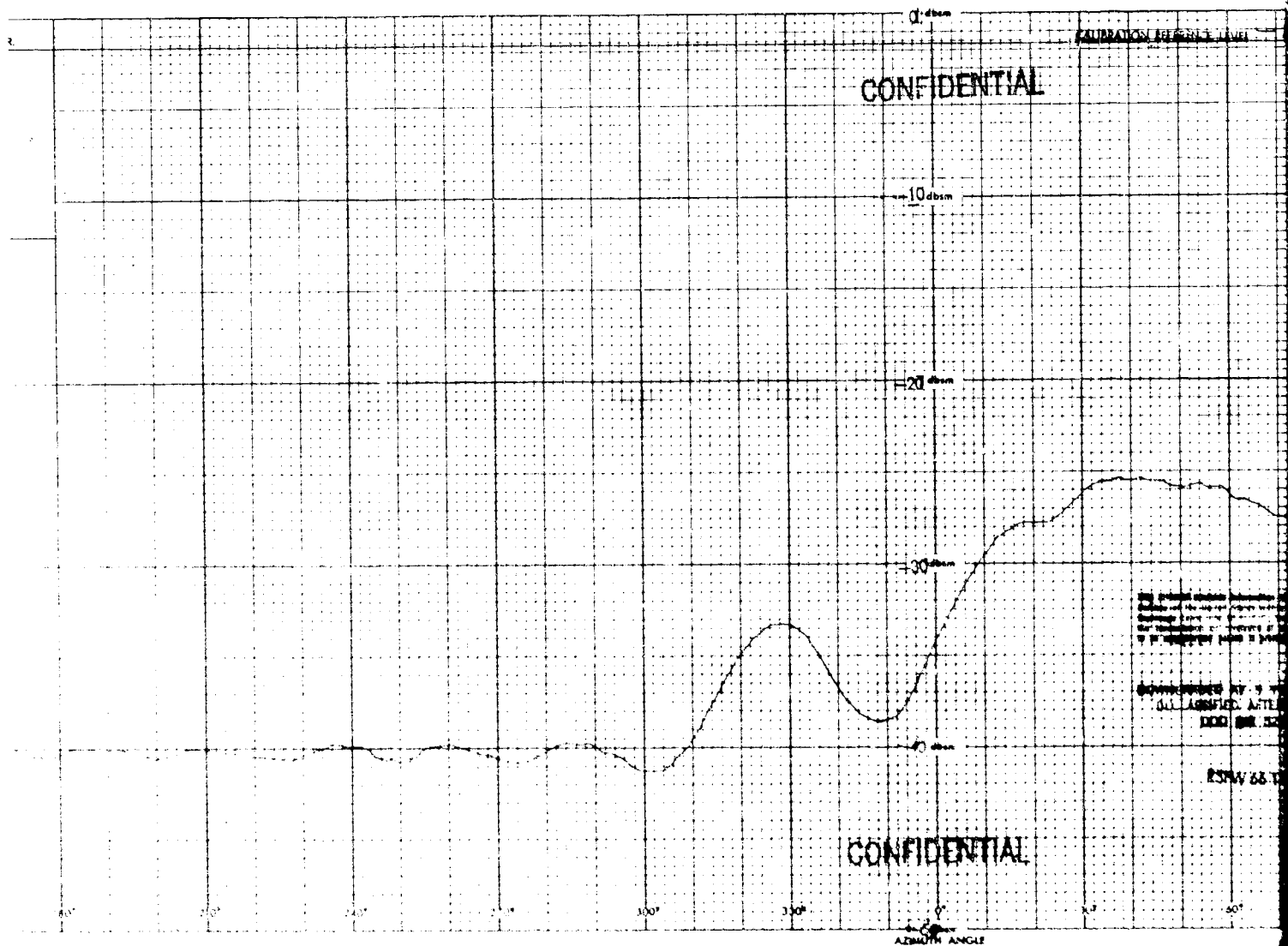
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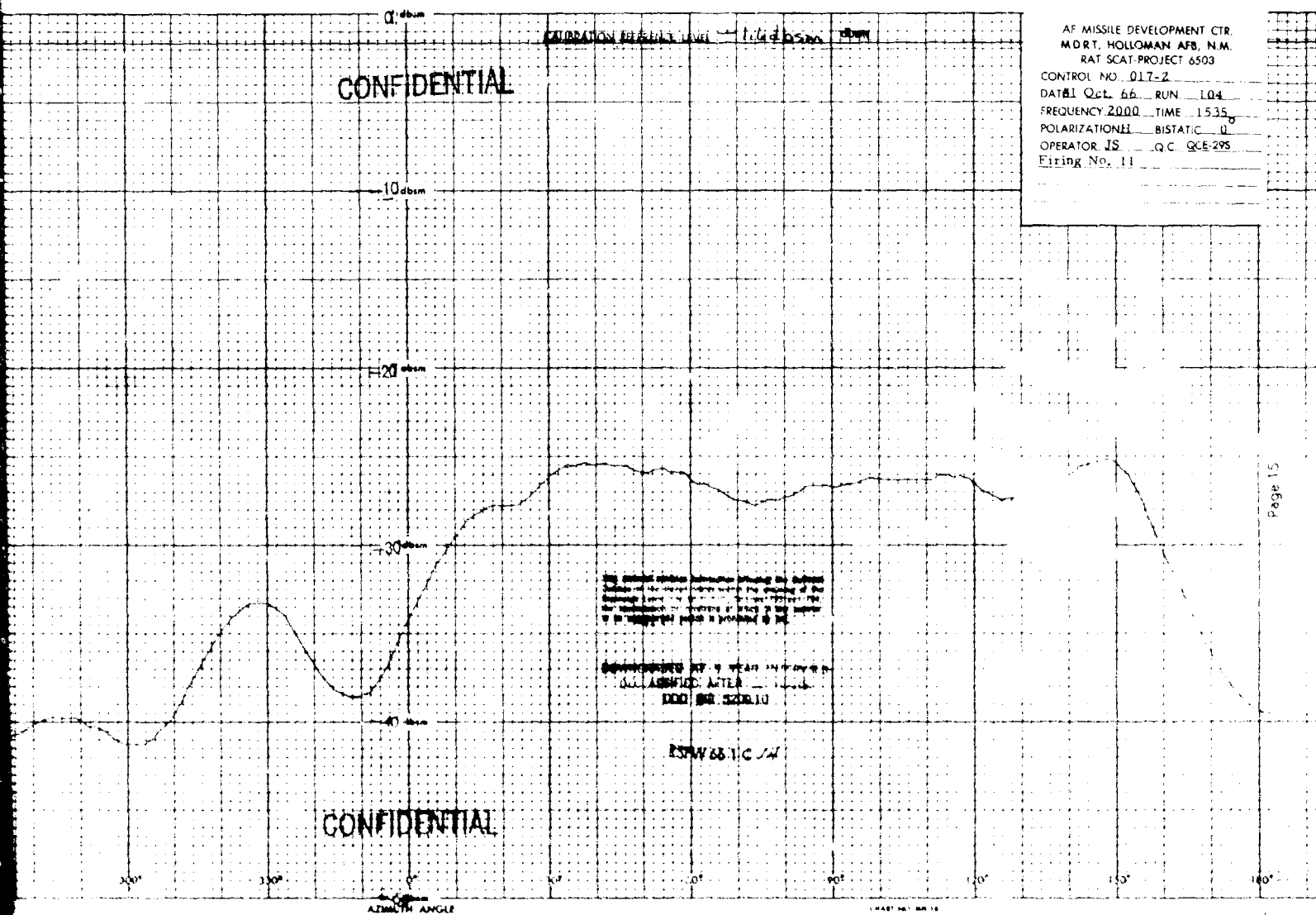


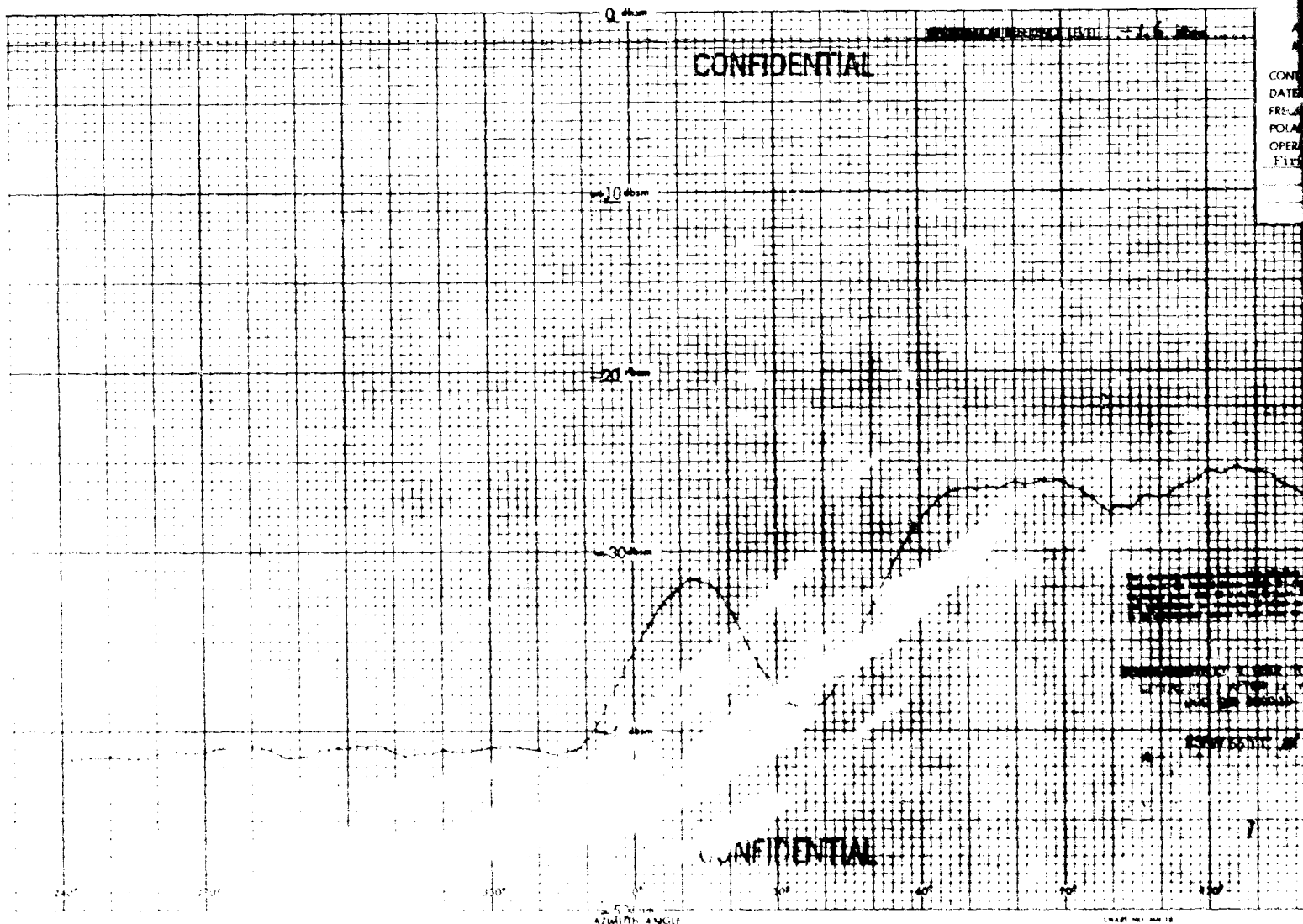
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Firing No. 11





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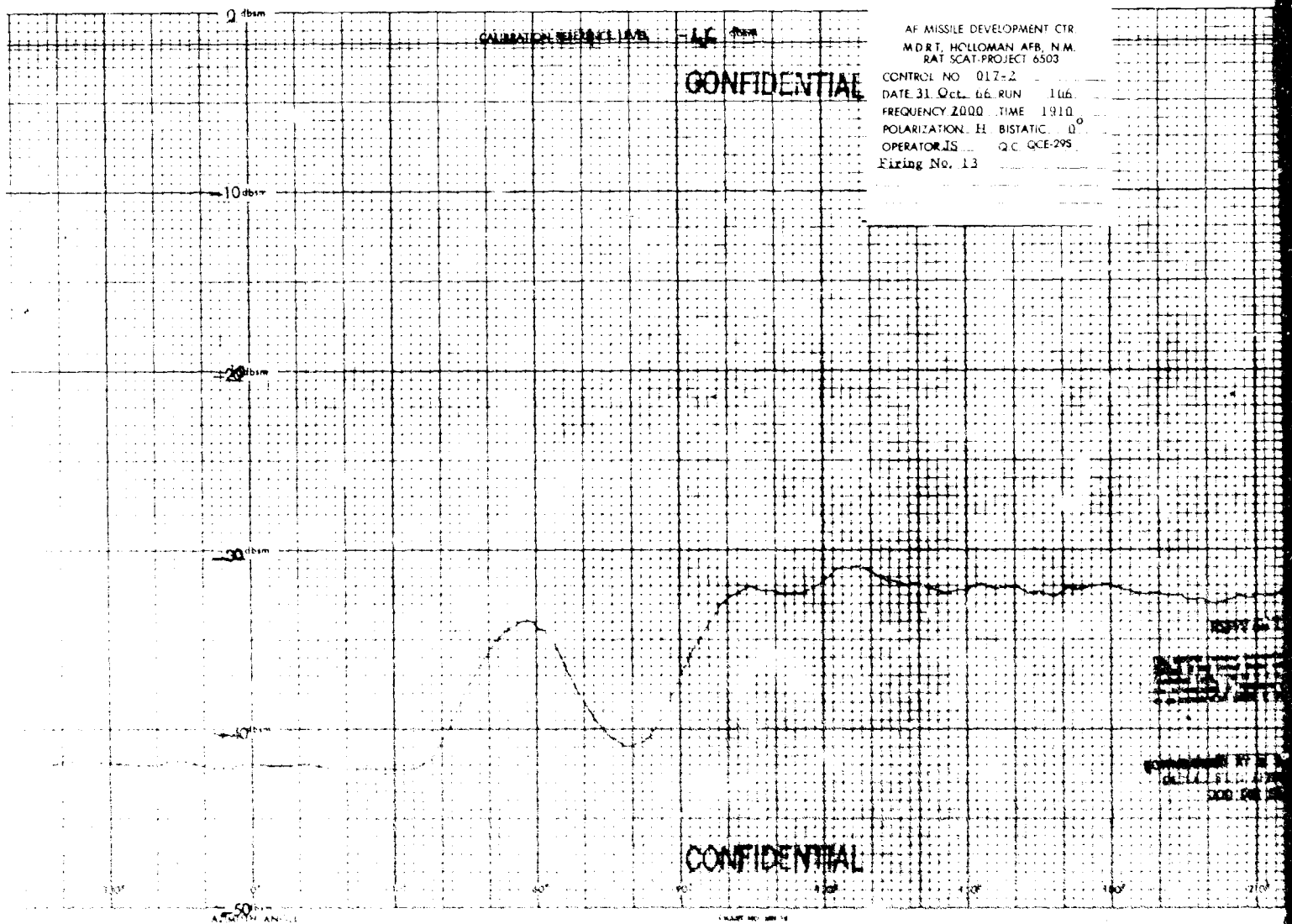
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AZIMUTH ANGLE

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Firing No. 13

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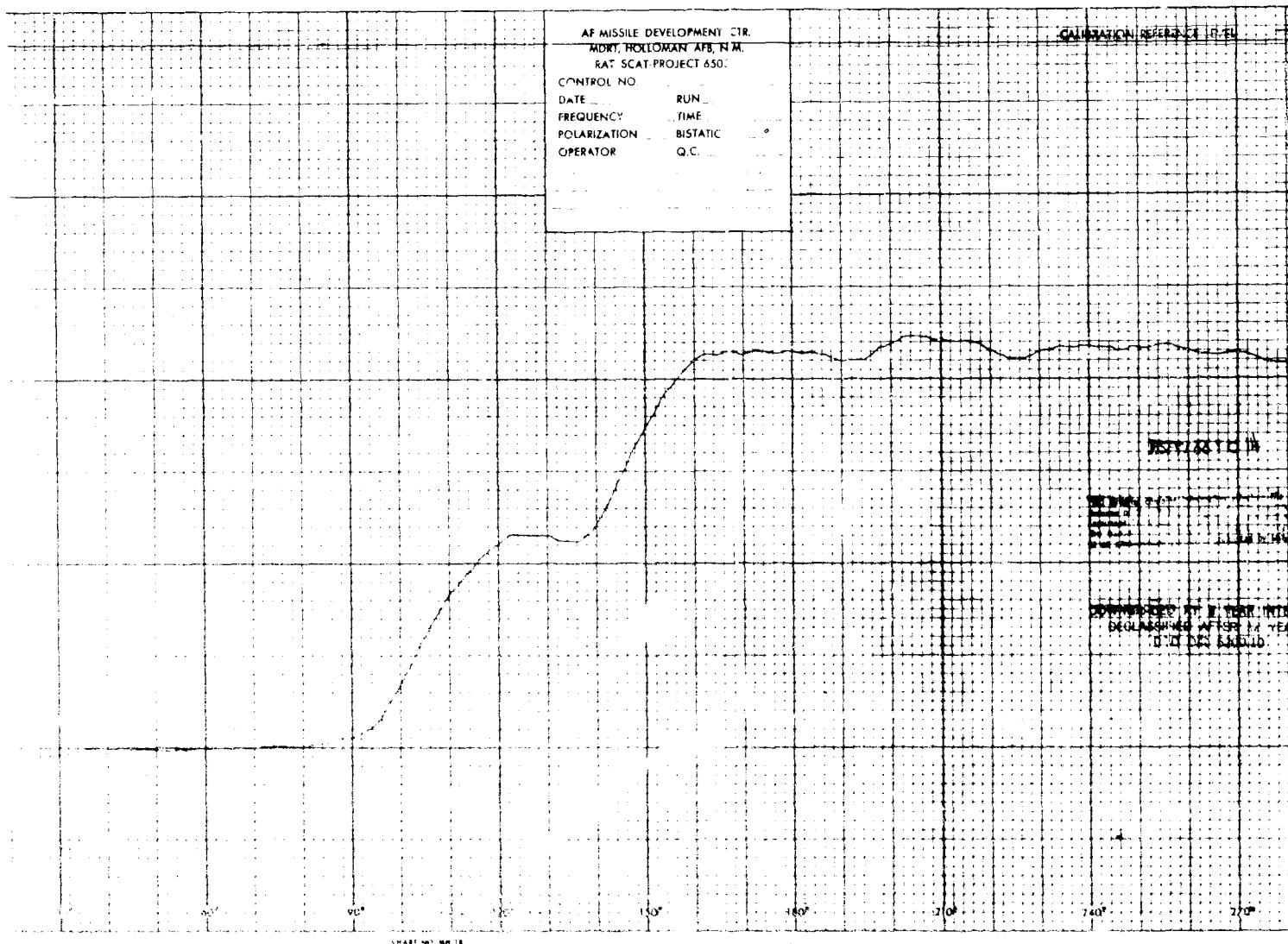
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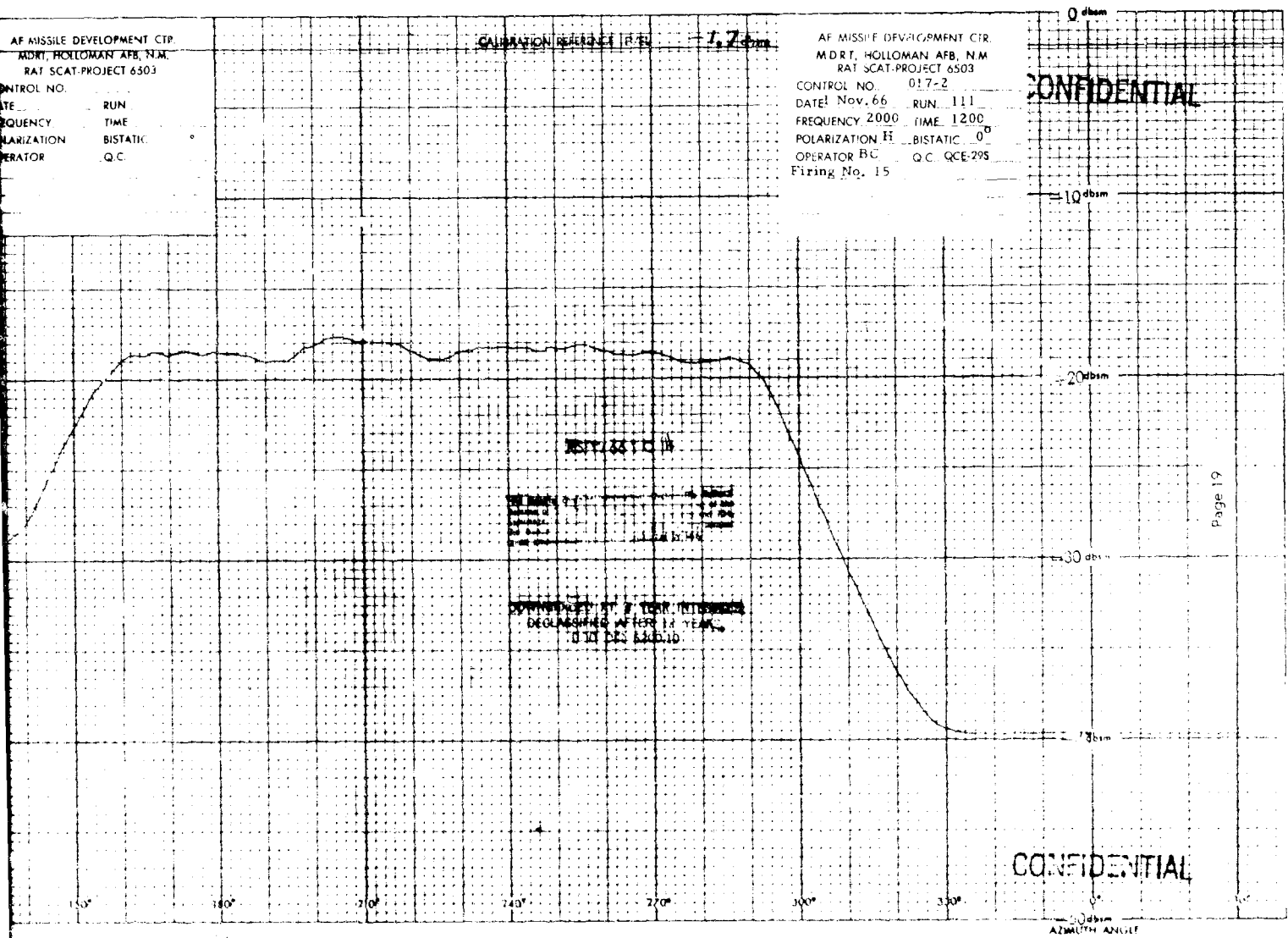
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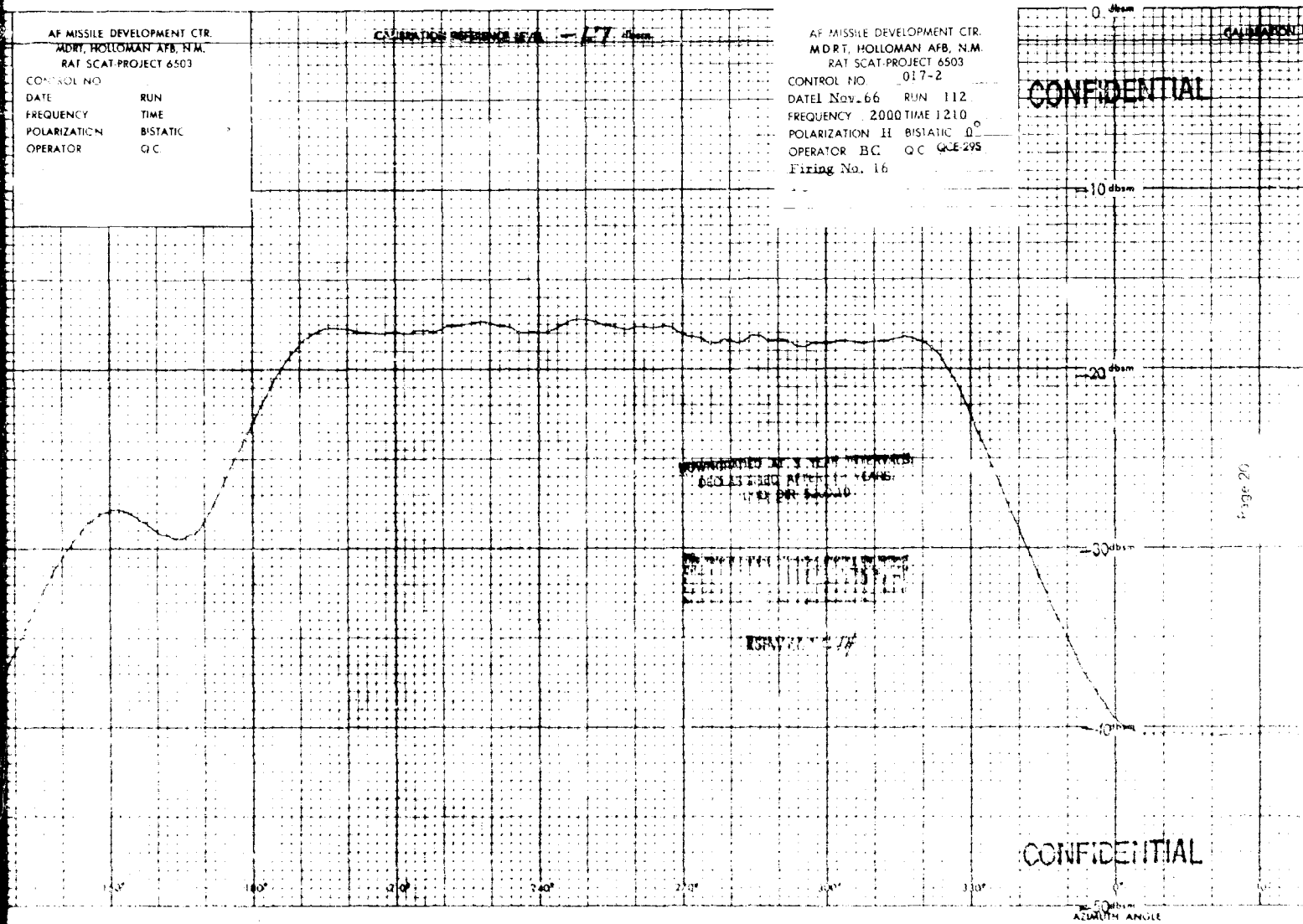
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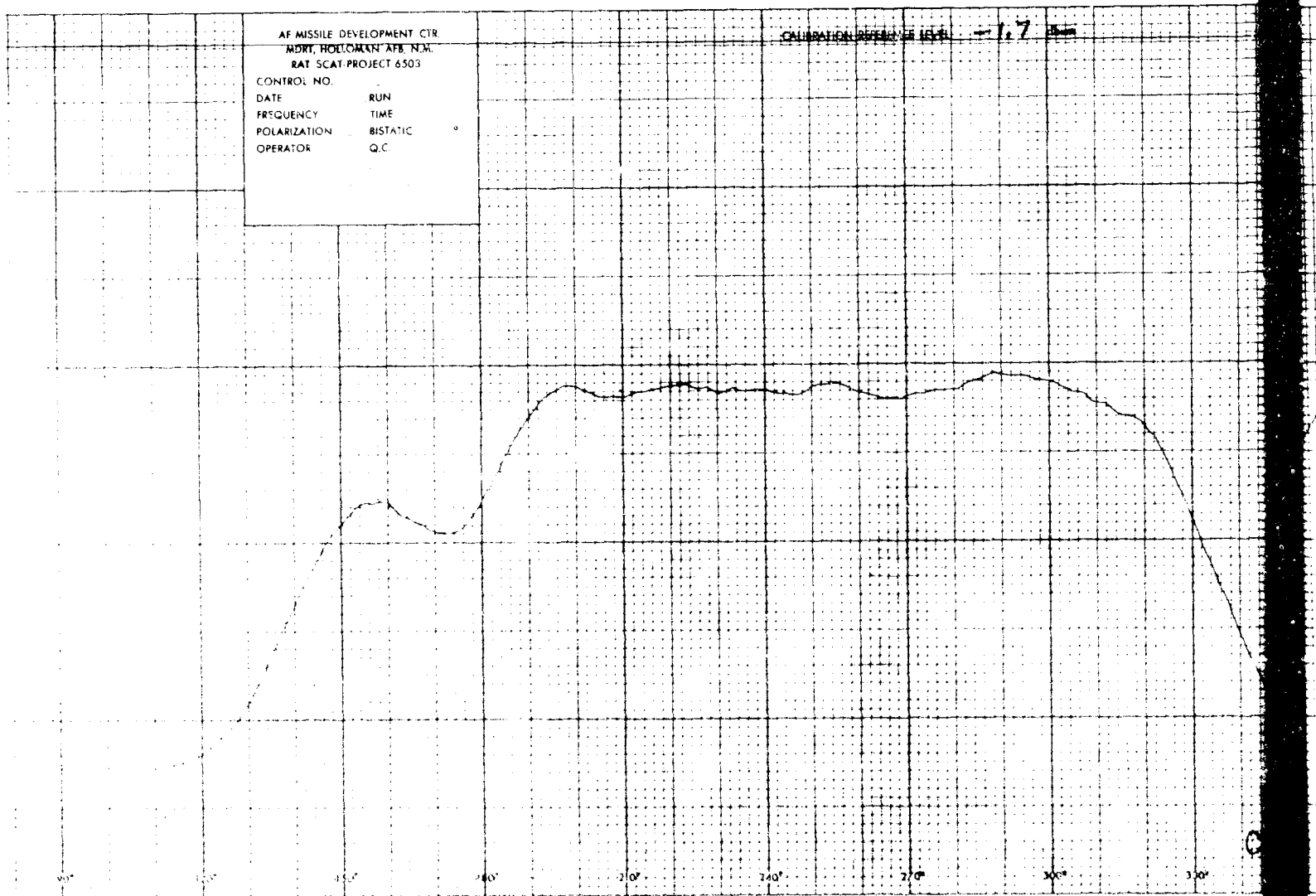
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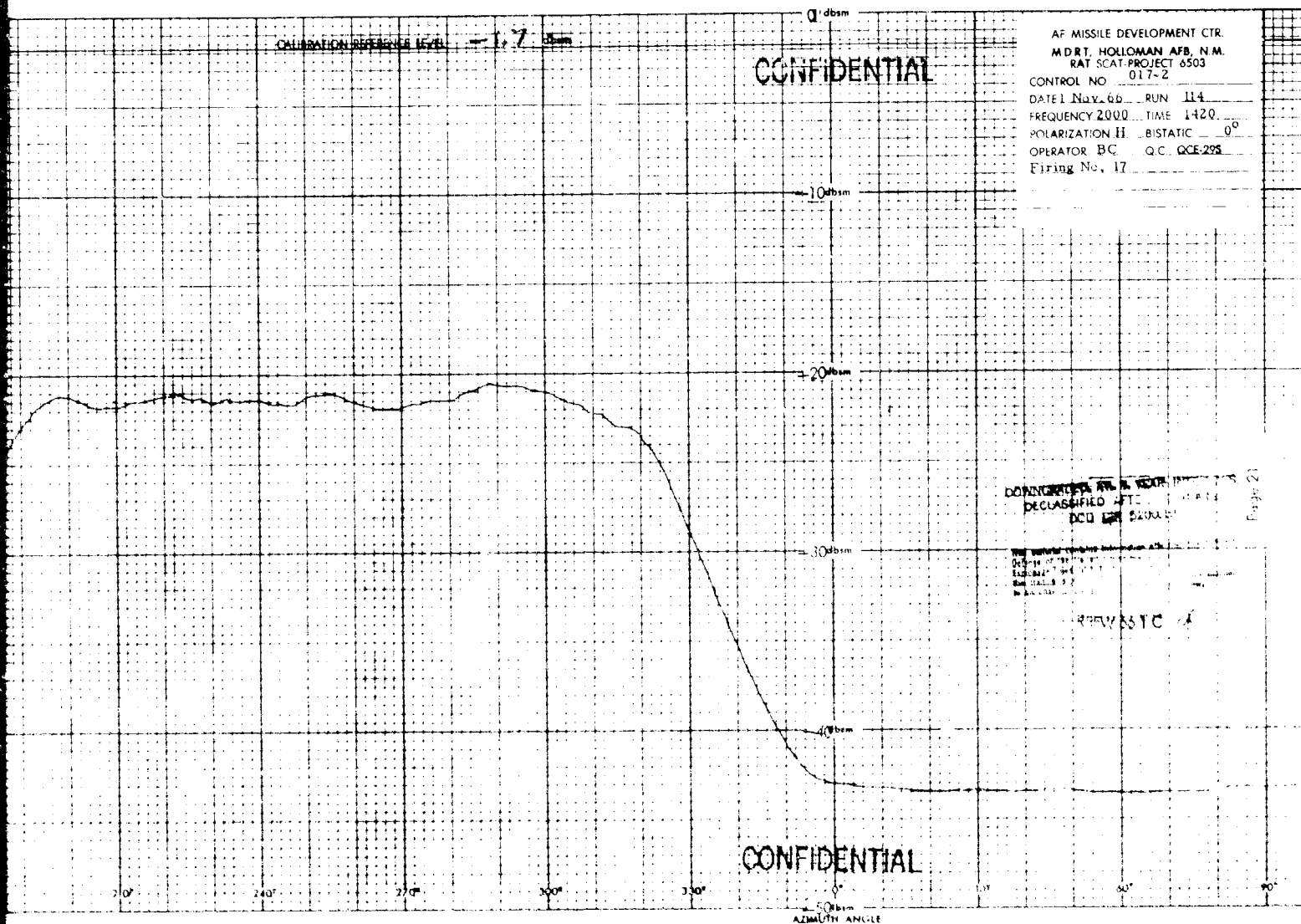




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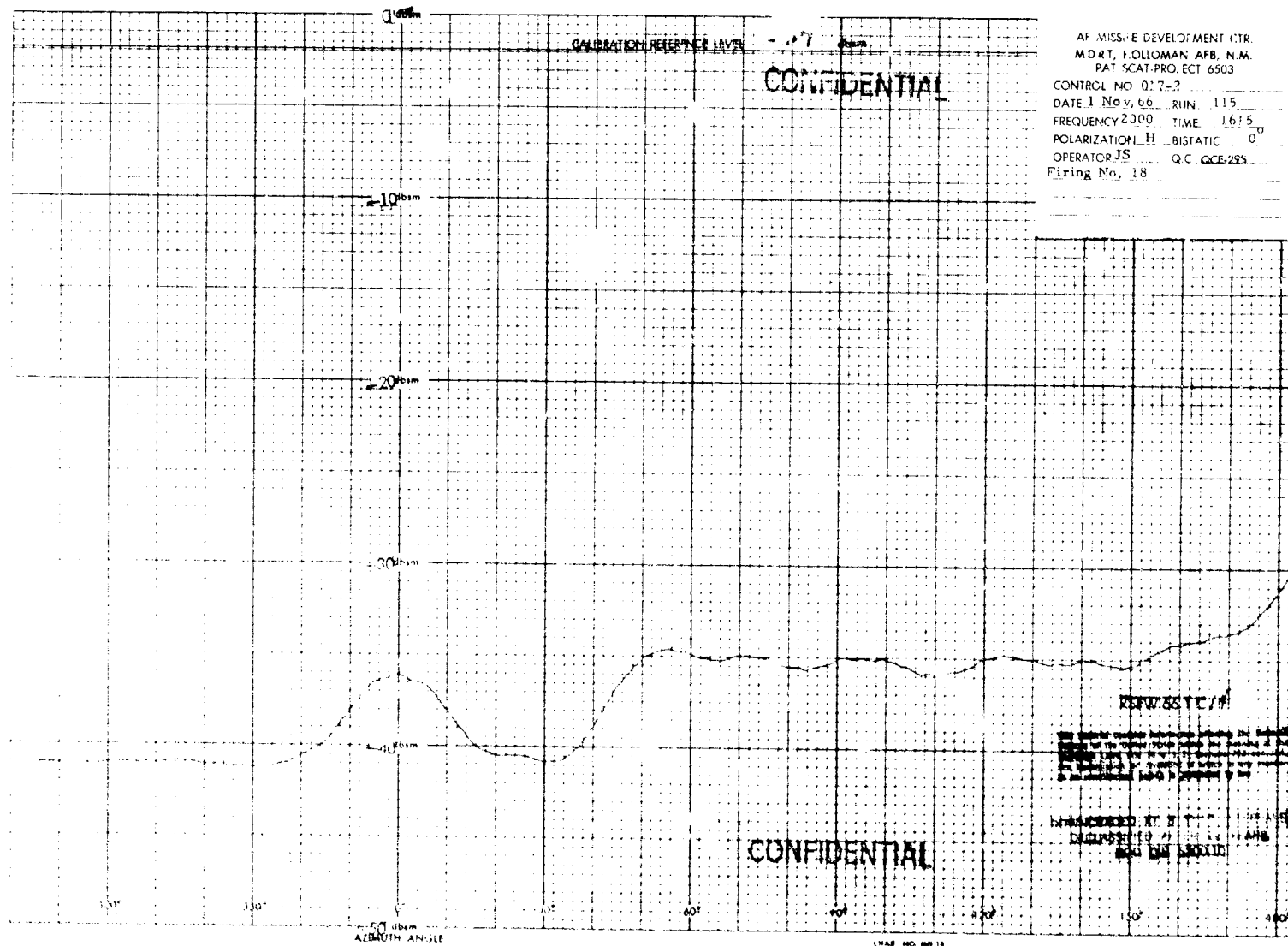
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CONTROL NO. 017-2
DATE 1 May 66 RUN 114
FREQUENCY 2000 TIME 1420
POLARIZATION H BISTATIC 0°
OPERATOR BC Q.C. QCE-295
Firing No. 17



CONTROL NO 017-2
DATE 1 Nov 66 RUN 115
FREQUENCY 2300 TIME 1615
POLARIZATION H BISTATIC C
OPERATOR JS Q.C. QCE-255
Firing No. 18

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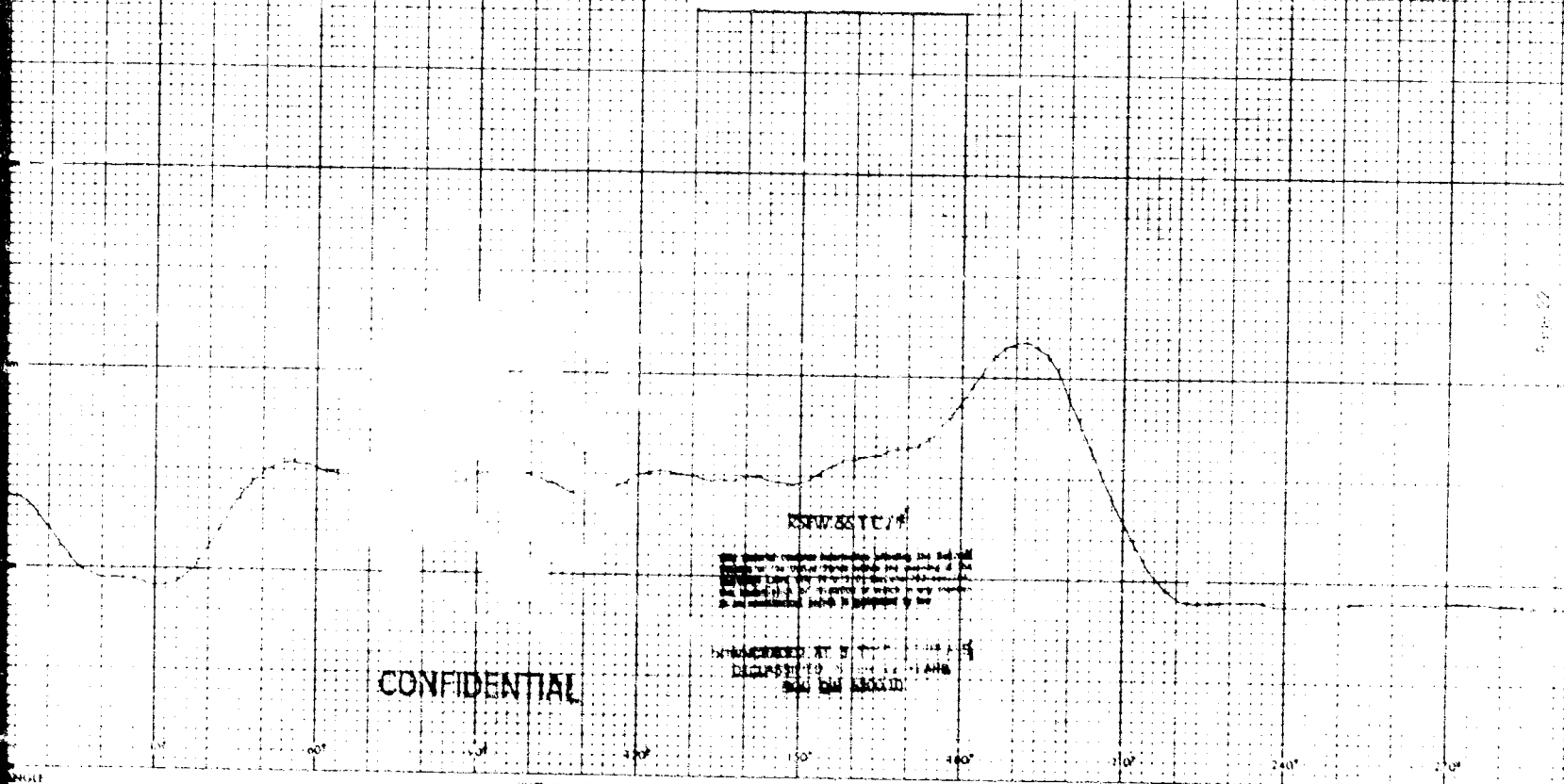


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AF MISSILE DEVELOPMENT CTR
MDRT, HOLLAMAN AFB, N.M.
RAI SCAT-PROJECT 6503
CONTROL NO 017-2
DATE 1 Nov 66 RUN 115
FREQUENCY 2000 TIME 1015
POLARIZATION H BISTATIC 0
OPERATOR JS QC QCE-295
Firing No. 18



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ADRT, HOLLAMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 017-2
DATE 1 Nov. 66 RUN 116
FREQUENCY 2000 TIME 1815
POLARIZATION H BISTATIC 0
OPERATOR JS GCE-295
Firing No. 19

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CHART NO. 18

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AZIMUTH ANGLE

CHART NO. 10118

AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLAMAN AFB, N.M.
RAT SCAT. PROJECT 6503
CONTROL NO. 017-2
DATE 1 Nov. 66 RUN 117
FREQUENCY 2000 TIME 2140
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OPERATOR JS Q.C. 295
Firing No. 20

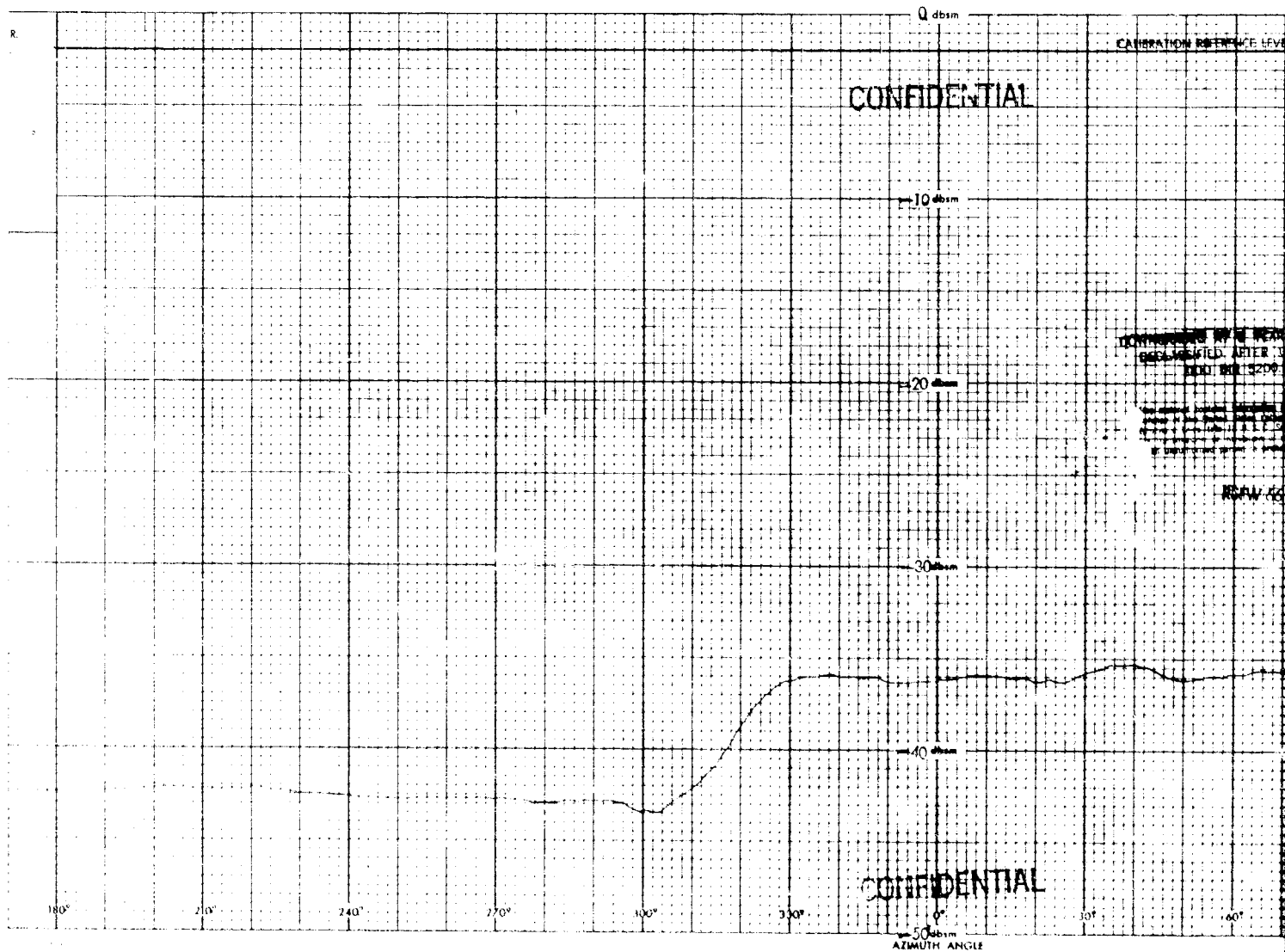
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MDRT, HOLLoman AFB, N.M.
RAT SCAT-PROJECT 6503

CONTROL NO. 017-2
DATE 1 Nov. 66 RUN 118
FREQUENCY 2000 TIME 2210
POLARIZATION^H BISTATIC 0
OPERATOR JS Q.C. QCE-295
Firing No. 21

CONTINUOUS WAVE BEAM INTERFEROMETER
OBSERVED AFTER 10 YEARS
DOO: BIC 320919

THIS SCATTERING MEASUREMENT WAS MADE AT THE
HOLLoman AFB, N.M. ON 11 NOV 66 BY
J.S. Q.C. QCE-295

REF: 001-14

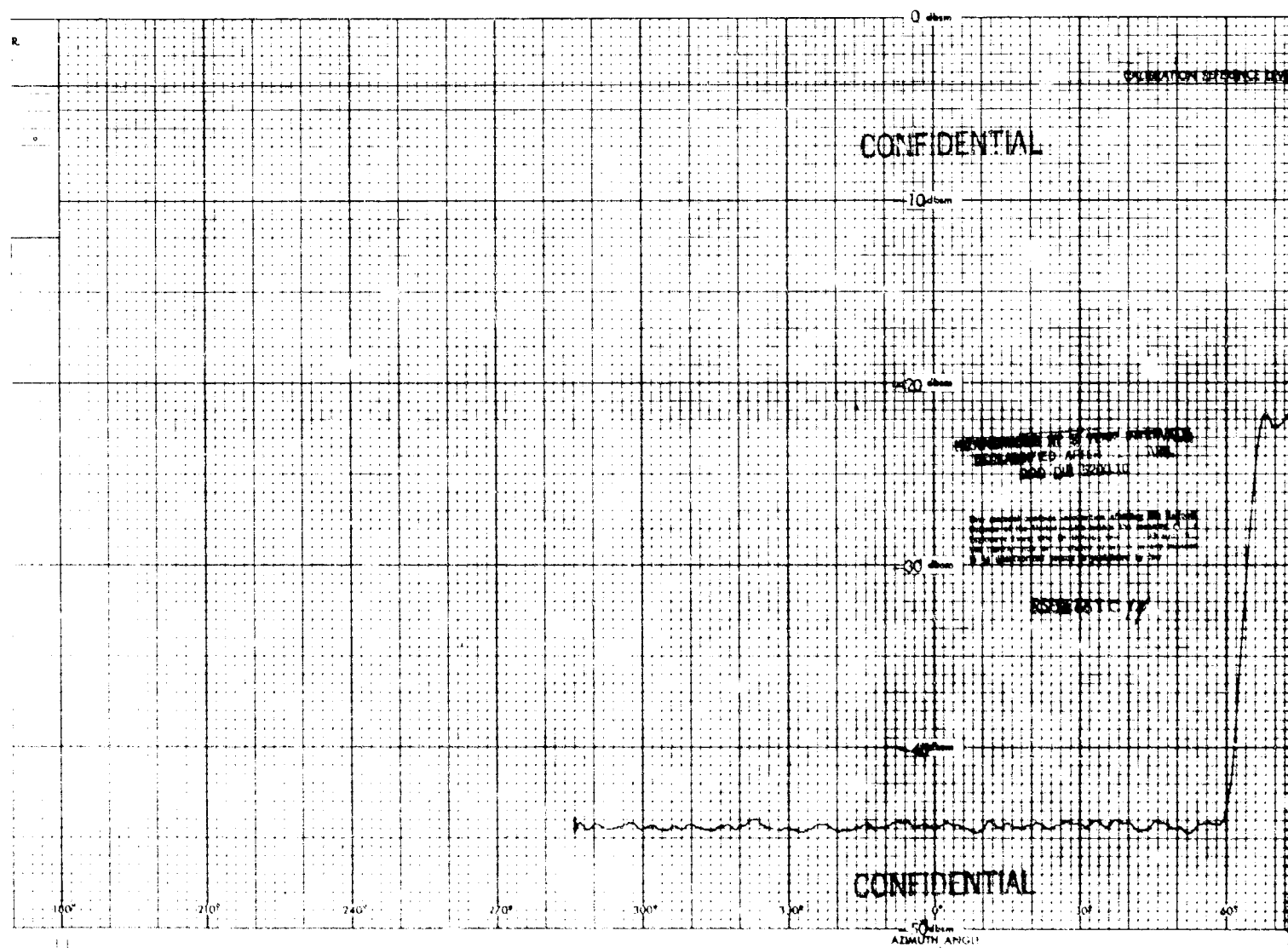
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AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
PAT SCAT-PROJECT 6503
CONTROL NO. 017-2
DATE Nov. 66 RUN 123
FREQUENCY 2000 TIME 1625
POLARIZATION II BISTATIC 0
OPERATOR JS G.C. QCE-295
Firing No. 23

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CHART NO. 10

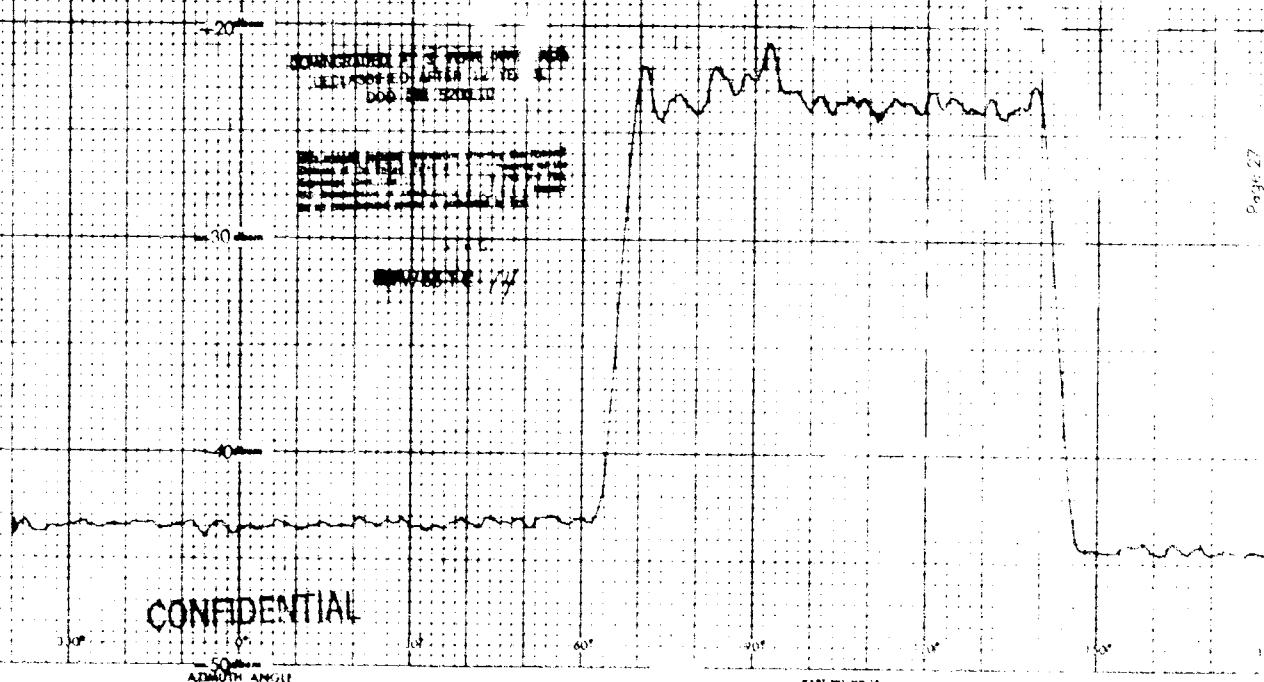
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CALIBRATION REFERENCE LEVEL -37 dbm

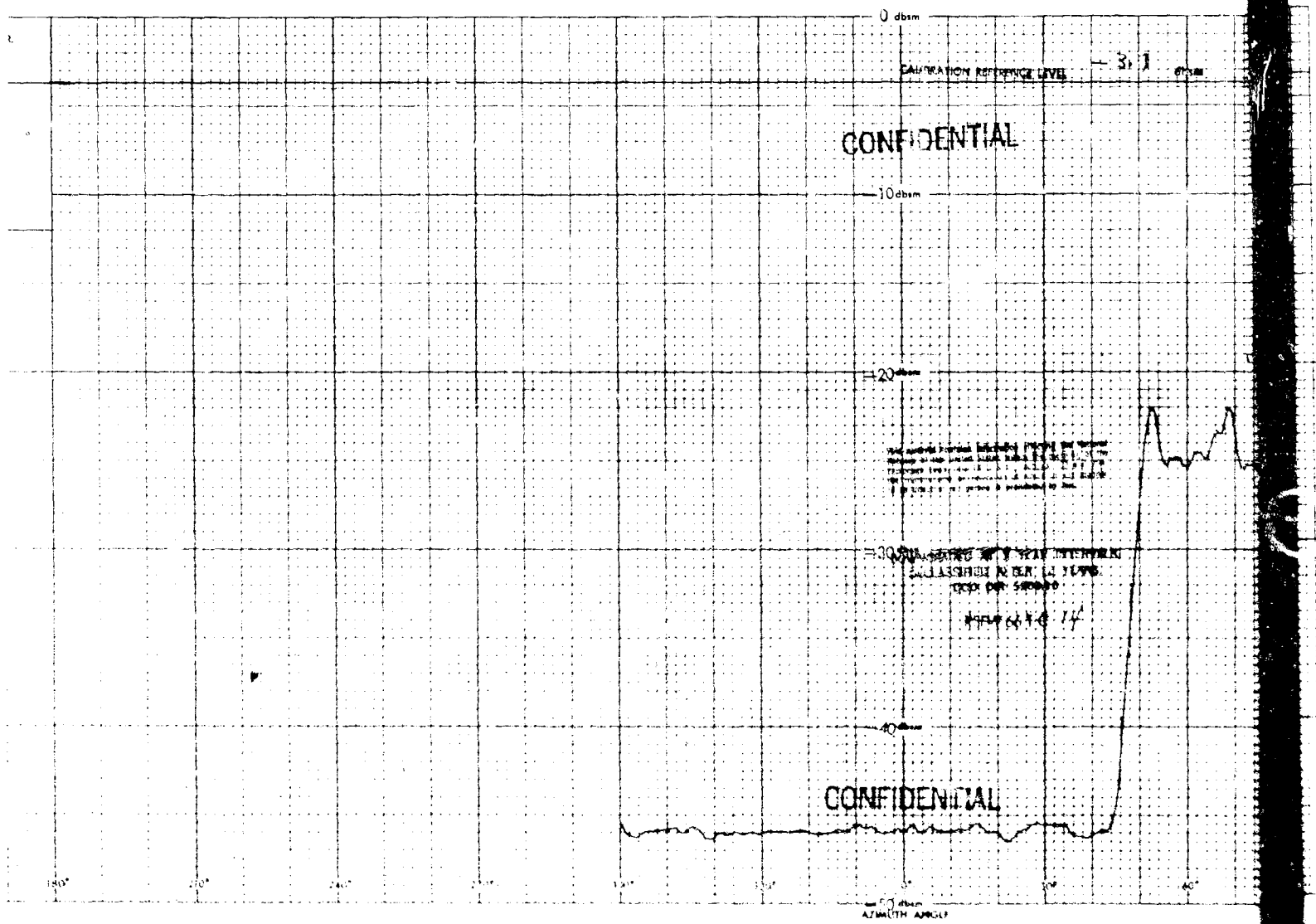
AF MISSILE DEVELOPMENT COR.
WPAFB, OHIO 43085-5000

CONTROL NO. 11-2
DATE 2 Nov. 68 RUI 74
FREQUENCY 2000 TIME 1745
POLARIZA H BISTATIC 0
OPERATOR S C G 2VS
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Page 22

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CALIBRATION REFERENCE LEVEL -1.6 dbm

AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLAMAN AFB, N.M.
RAT SCAT PROJECT 6503
CONTROL NO. 017-2
DATE 3 Nov. 66 RUN 12a
FREQUENCY 2000 TIME 1100
POLARIZATION H BISTATIC 0
OPERATOR BC Q.C. QCE-295
Firing No. 26

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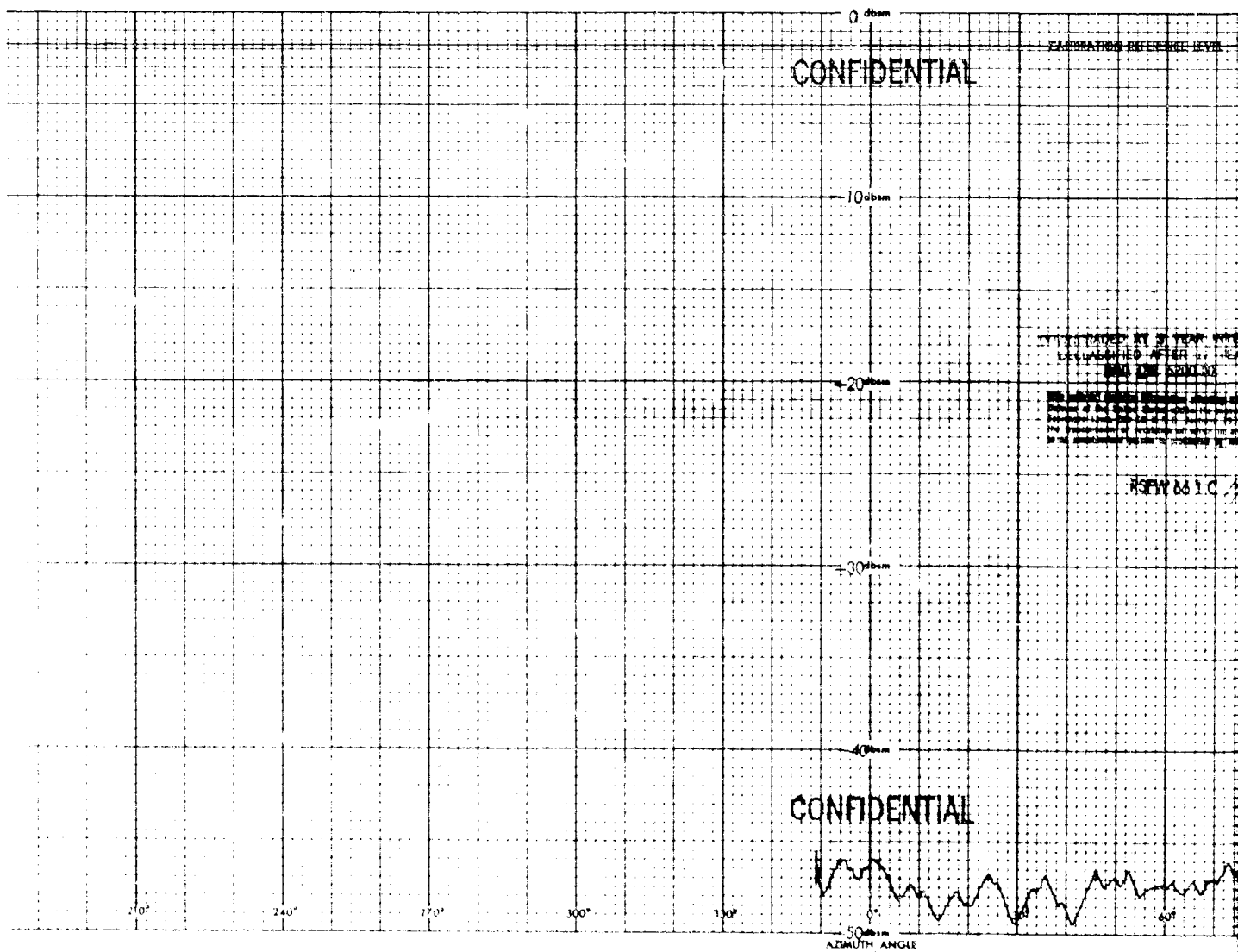
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AZIMUTH ANGLE

CHART NO. 10

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EXAMINATION OF THE NEW LEVIN

AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOWMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 017-2
DATE 3 Nov, 66 RUN 131
FREQUENCY 2000 TIME 1240
POLARIZATION: H BISTATIC 0°
OPERATOR: JBC Q.C. QCE-295
Firing No. 27

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1941 ON 5200 MO

REF ID: A66107

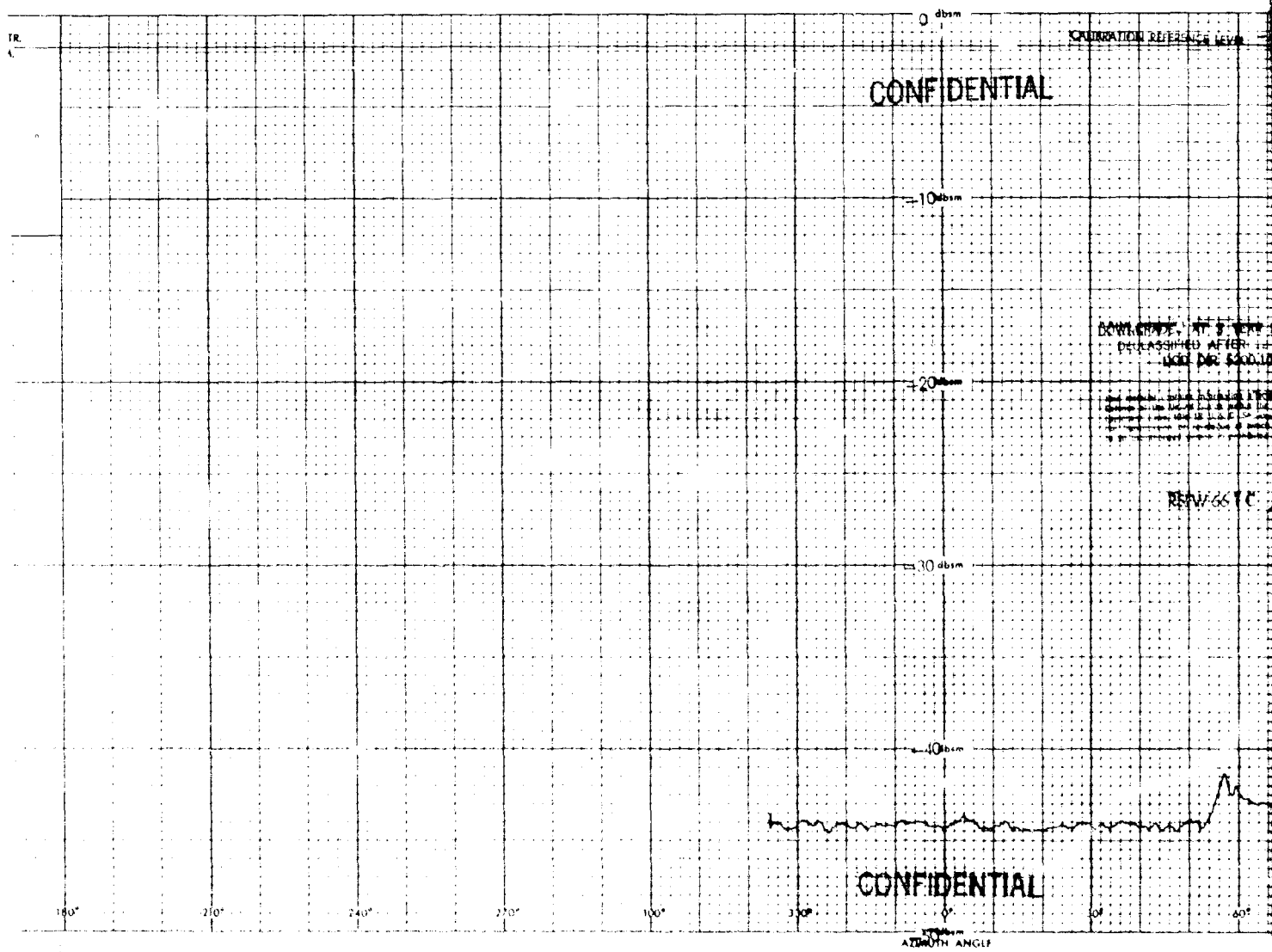
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CHART NO. 85-10

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AF MISSILE DEVELOPMENT CTR
MDRT, HOLLOWAY AFB, NM
RAT SCAT PROJECT 6503
CONTROL NO 017-2
DATE 3 Nov 66 RUN 132
FREQUENCY 2000 TIME 1540
POLARIZATION II BISTATIC 0
OPERATOR JS QC GLE245
Firing No. 28

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300° 330° 0° 90° 120° 150° 180°

ATBOOTH ANGLE

CHART NO. 101-1

11

2

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AF MISSILE DEVELOPMENT CTR
MDRT, HOLLAMAN AFB, NM
RAT SLAT PROJECT 4503
CONTROL NO. 017-2
DATE 3 Nov 66 RUN 133
FREQUENCY 2000 HZ TIME 1630
POLARIZATION H BISTATIC 0°
OPERATOR JS Q C QUE 295
Firing No. 29

10 dbm

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INTERFERING

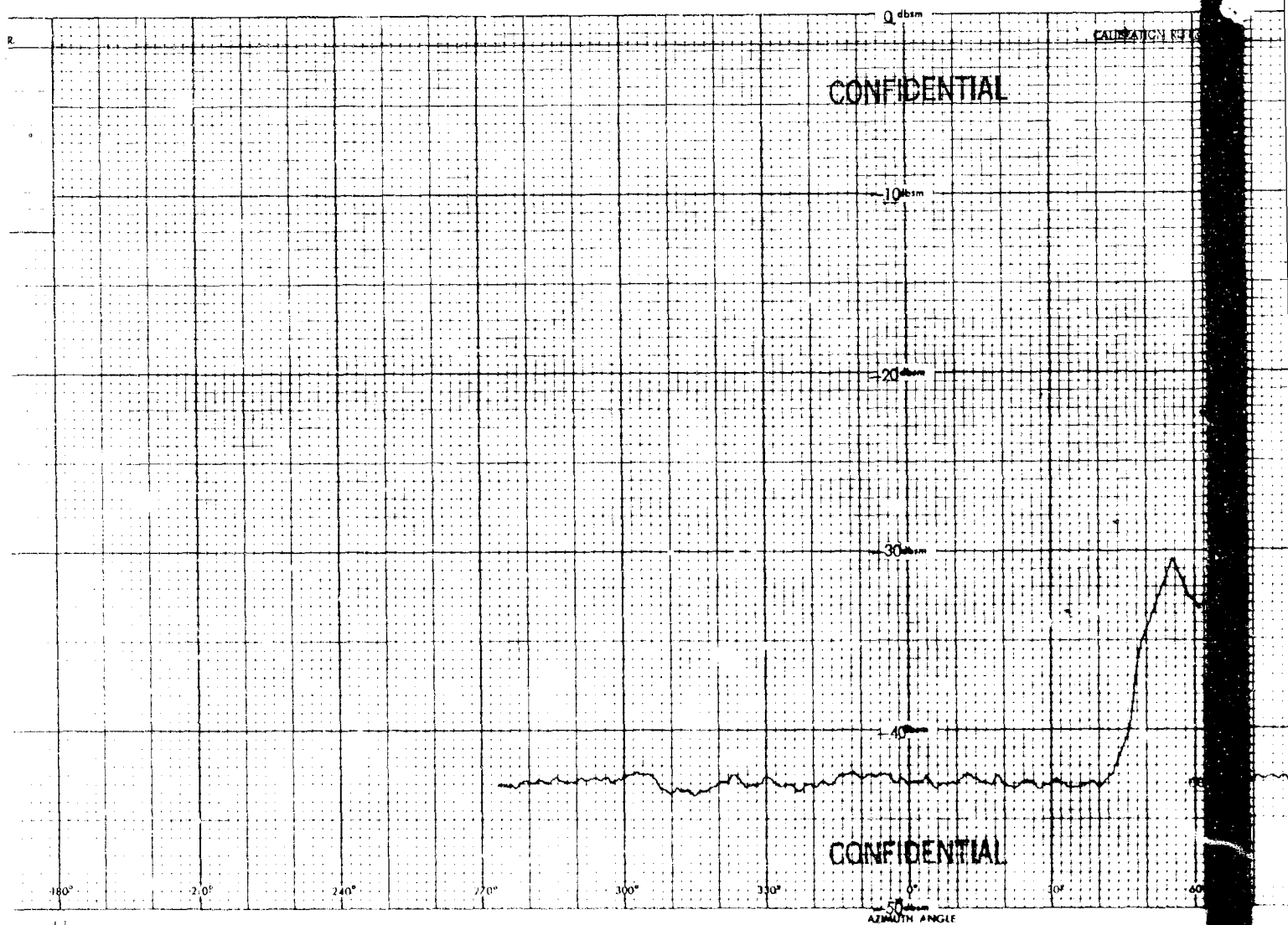
THE FOLLOWING INTERFERING SIGNALS WERE OBSERVED
DURING THE TESTS OF THE RAT SLAT PROJECT 4503
ON 3 NOV 66 AT 1630 HZ

INTERFERING BY 3 WAP ANTENNAS
OPERATING AT 1000 HZ
DOW FOR STATION

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ASSEMBLY ANGLE

SLAT NO. 101



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AF MISSILE DEVELOPMENT CTR
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT PROJECT 6503
CONTROL NO. 017-2
DATE 3 Nov. 66 RUN 134
FREQUENCY 2000 TIME 1710
POLARIZATION H BISTATIC 0
OPERATOR JS Q.C. QCE-295
Firing No. 30

Page 33

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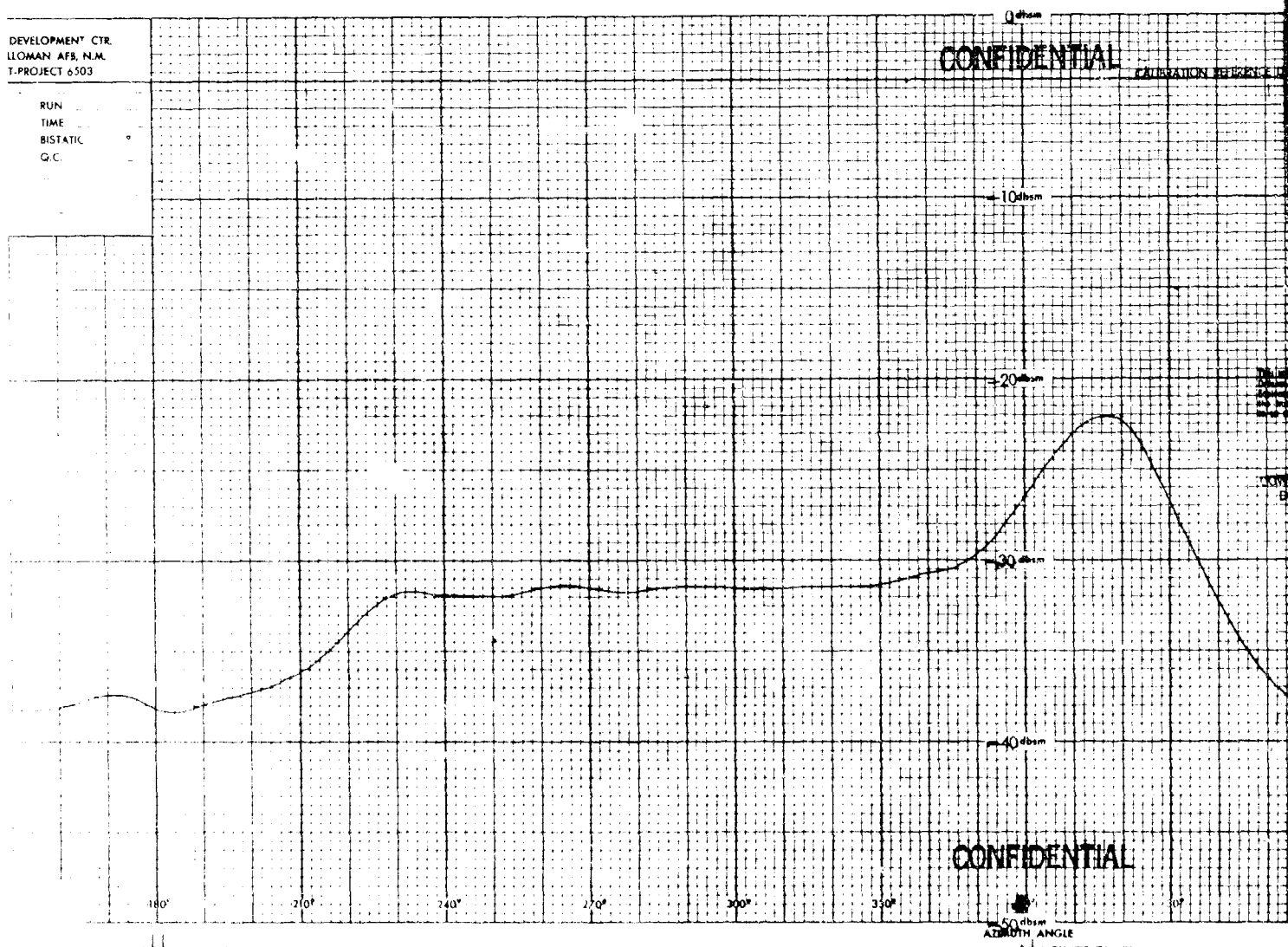
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AZIMUTH ANGLE

CHART NO. 10118

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DEVELOPMENT CTR
LOWAN AFB, N.M.
T-PROJECT 6503

RUN
TIME
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Q.C.



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CALIBRATION REFERENCE LEVEL -3.4 dbm

AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 017-2
DATE 0 Nov. 66 RUN 139
FREQUENCY 450 TIME 1440
POLARIZATION H BISTATIC 0
OPERATOR BC Q.C. WCE-298
Firing No. 31

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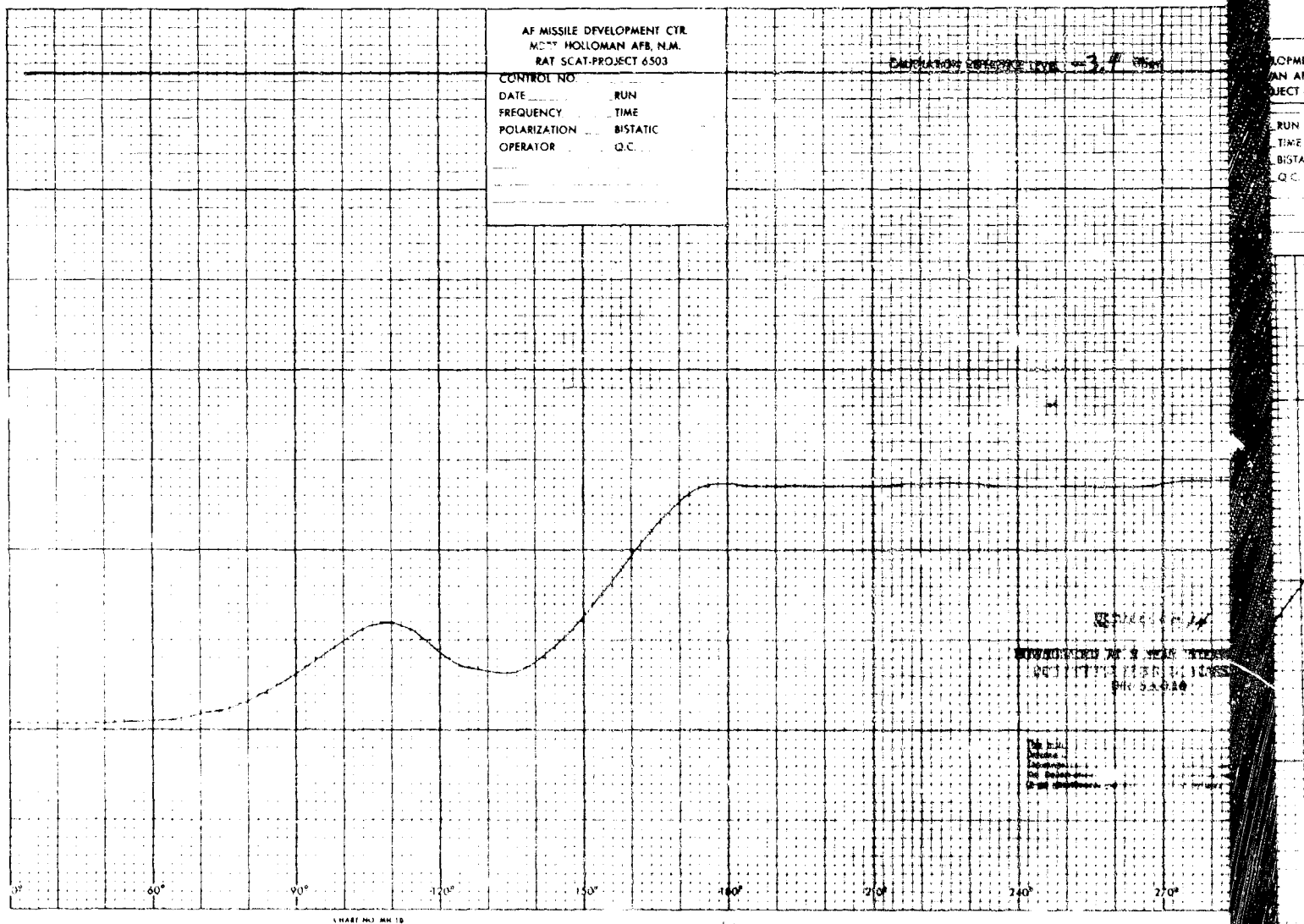
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CHART NO. MM 14

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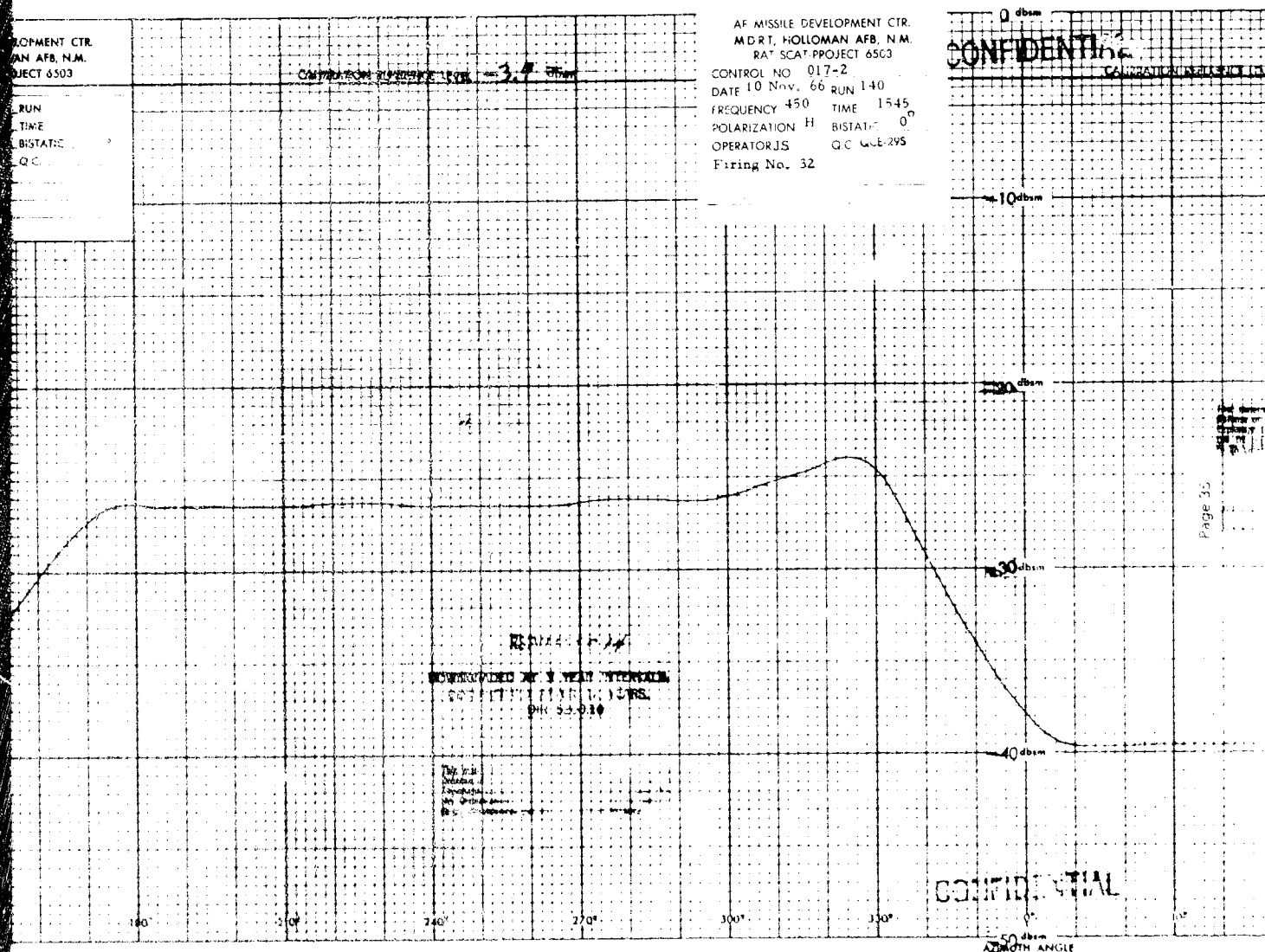
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HOLLAND AFB, N.M.
PROJECT 6503

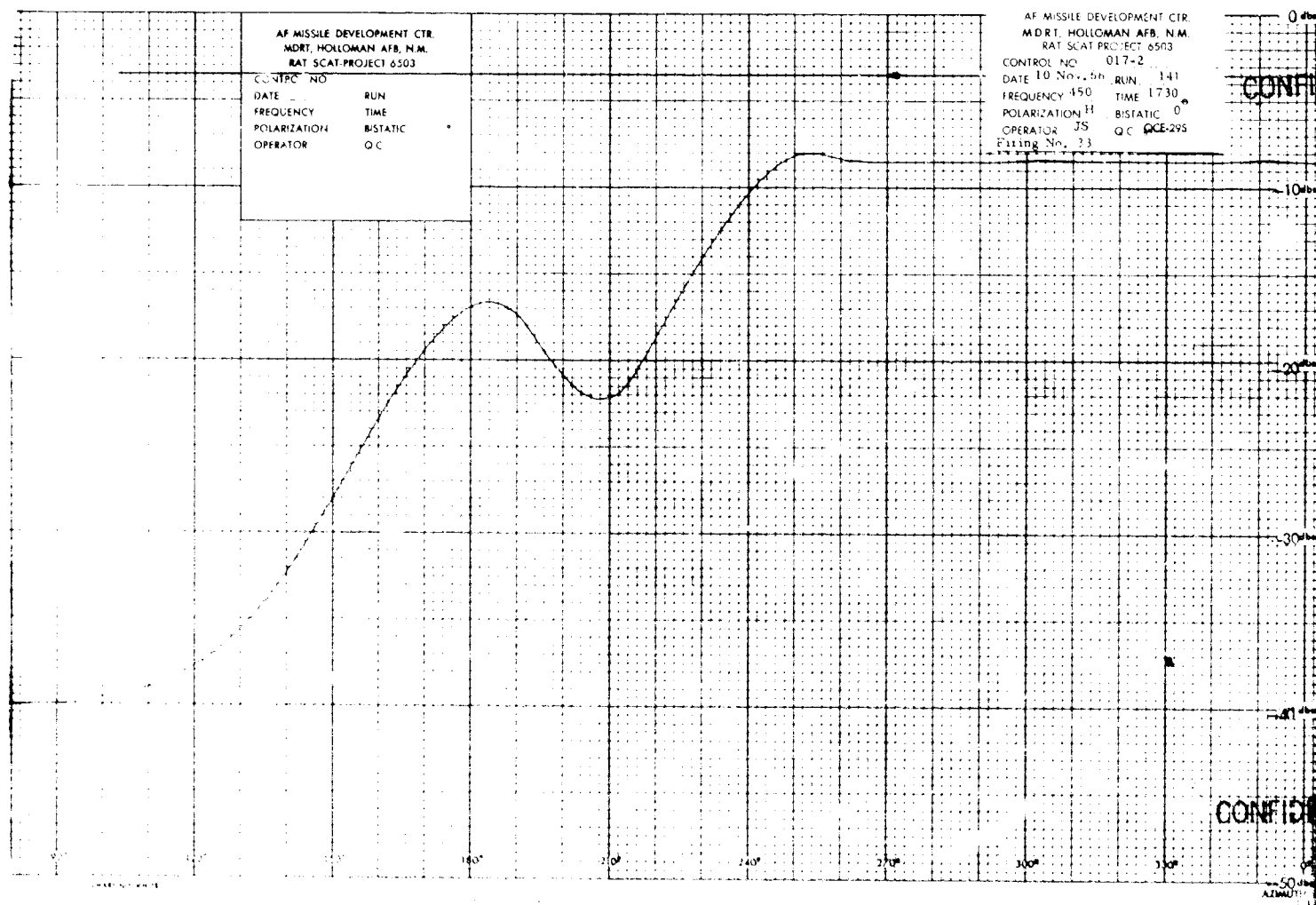
RUN
TIME
BISTATIC
Q.C.

AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLAND AFB, N.M.
RAT SCAT-PROJECT 6503

CONTROL NO 017-2
DATE 10 Nov. 66 RUN 140
FREQUENCY 450 TIME 1545
POLARIZATION H BISTATIC 0°
OPERATOR JS Q.C. QCE-295
Firing No. 32

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 MDRT, HOLLOMAN AFB, N.M.
 RAT SCAT PROJECT 6503
 CONTROL NO 017-2
 DATE 10 Nov, 66 RUN 141
 FREQUENCY 450 TIME 1730
 POLARIZATION H RISTATIC 0
 OPERATOR JS QCC QCE-295
 FIELD No. 33

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Page 33

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AZIMUTH ANGLE

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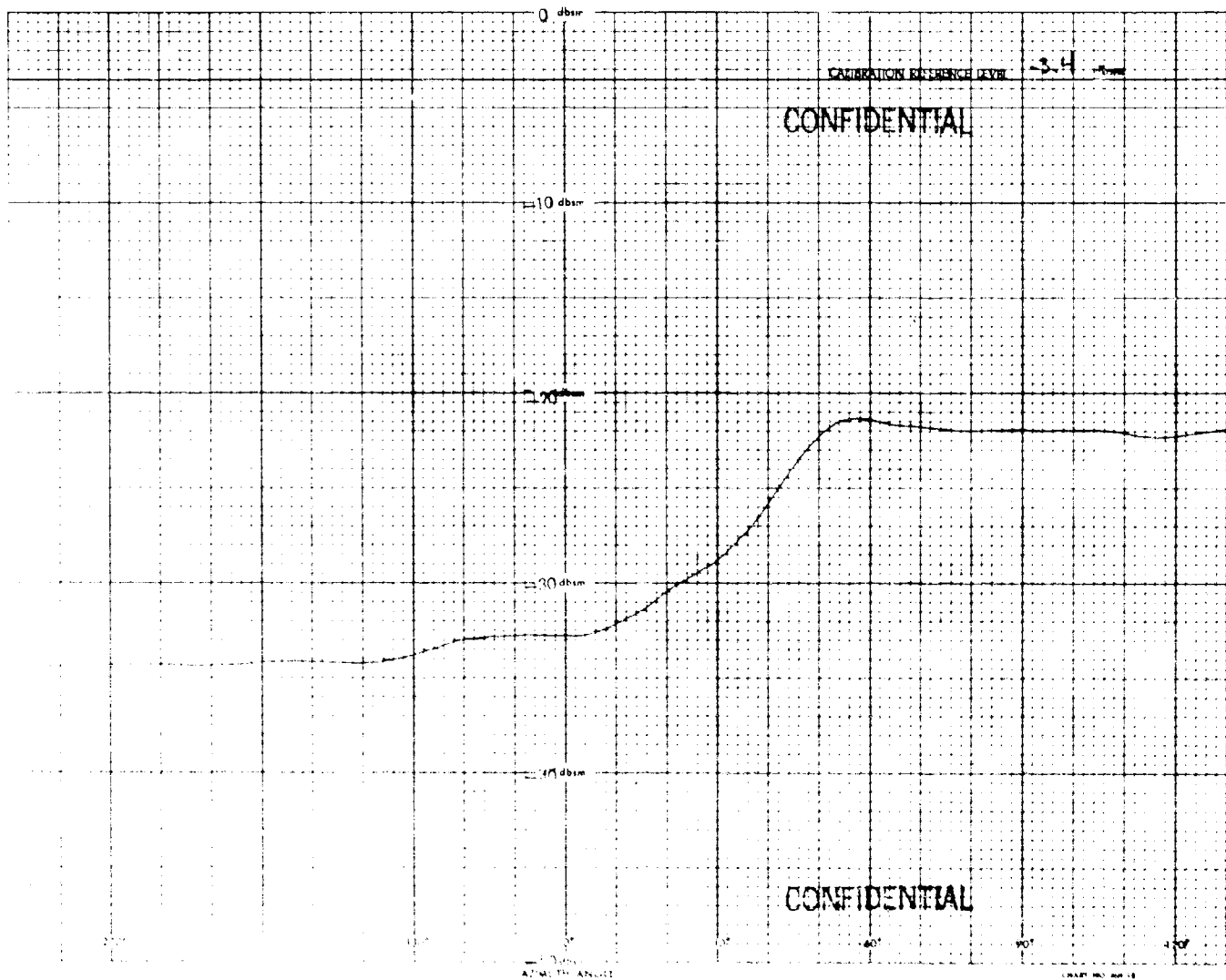
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RAT SCAT-PROJECT 6503
CONTROL NO. Q17-2
DATE 10 Nov 66 RUN 142
FREQUENCY 450 TIME 1805
POLARIZATION H BISTATIC Q
OPERATOR JS QCC QCE-295
Firing No. 34

Page 37

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RAT. SC
CONTROL NO.
DATE 0 Nov
FREQUENCY
POLARIZATION
OPERATOR. J
Firing No.

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AF MISSILE DEVELOPMENT CTR
MDRT, HOLLAMAN AFB, NM
RAT SCAT PROJECT 6503

CONTROL NO. 017-2
DATE 0 Nov. 66 RUN 143
FREQUENCY 450 TIME 1315
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OPERATOR JS Q C OCE-062
Firing No. 35

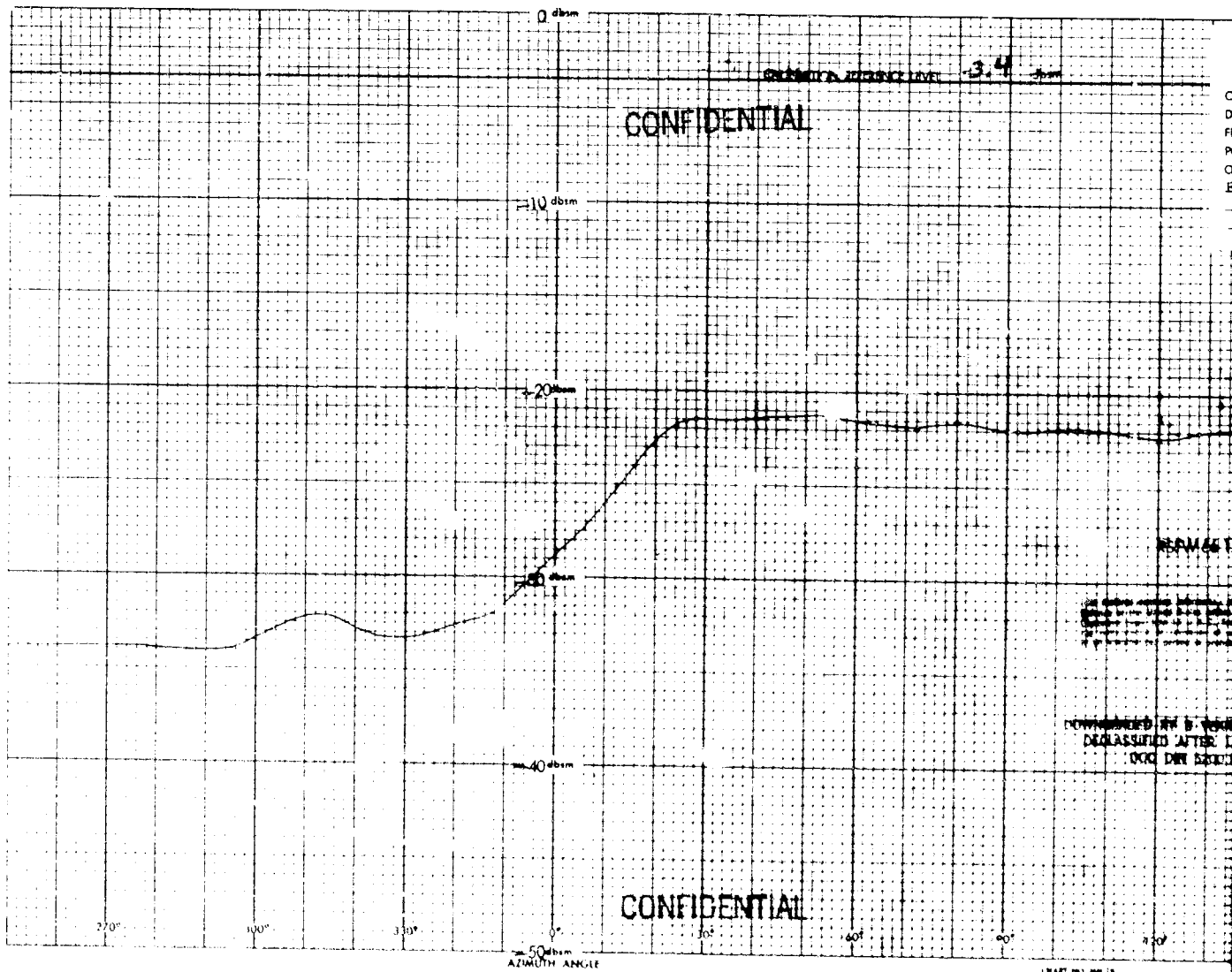
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RAT SCAT PROJECT 6503

CONTROL NO. 017-2
DATE 10 Nov. 66 RUN 141
FREQUENCY 450 TIME 2000
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Firing No. 36

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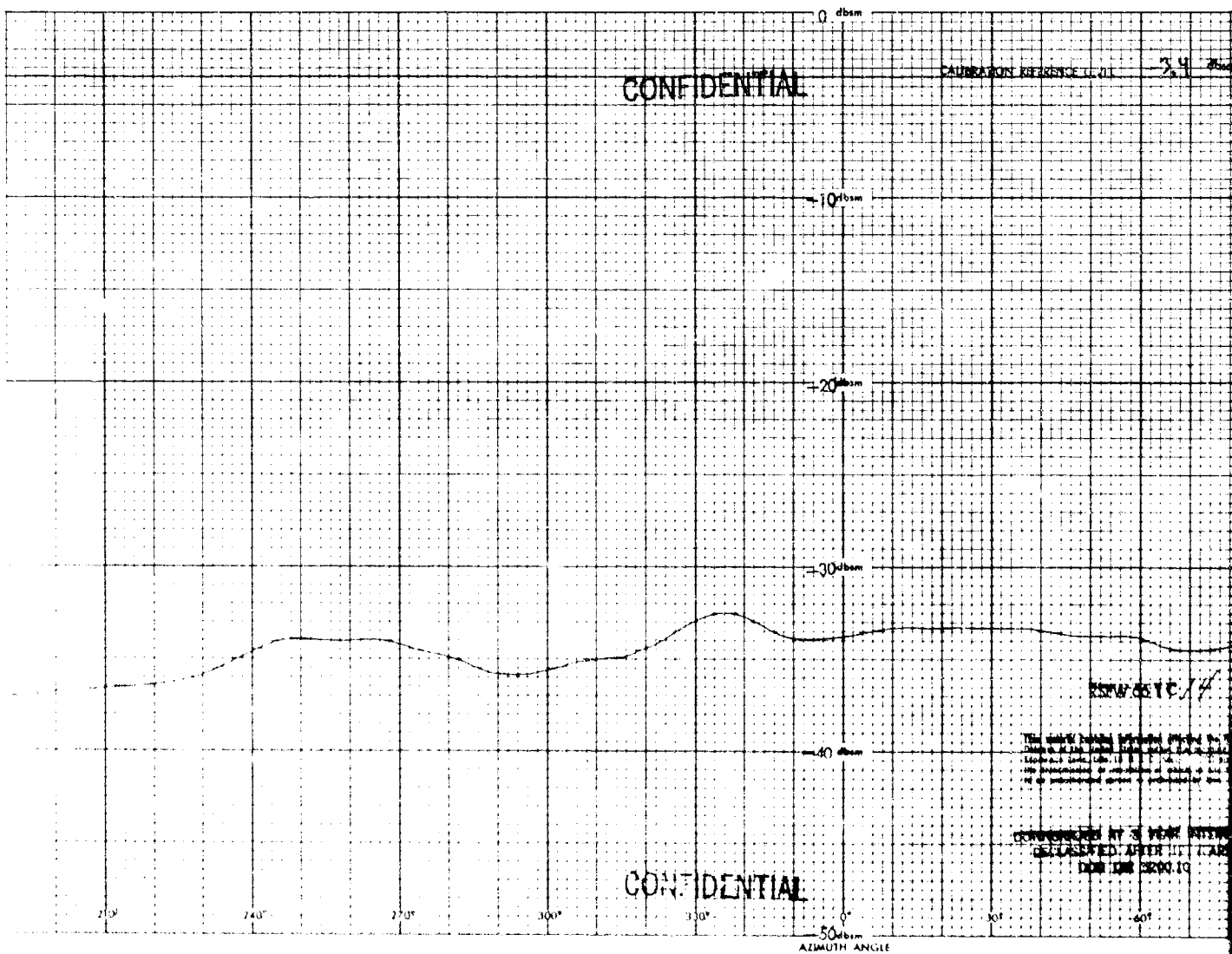
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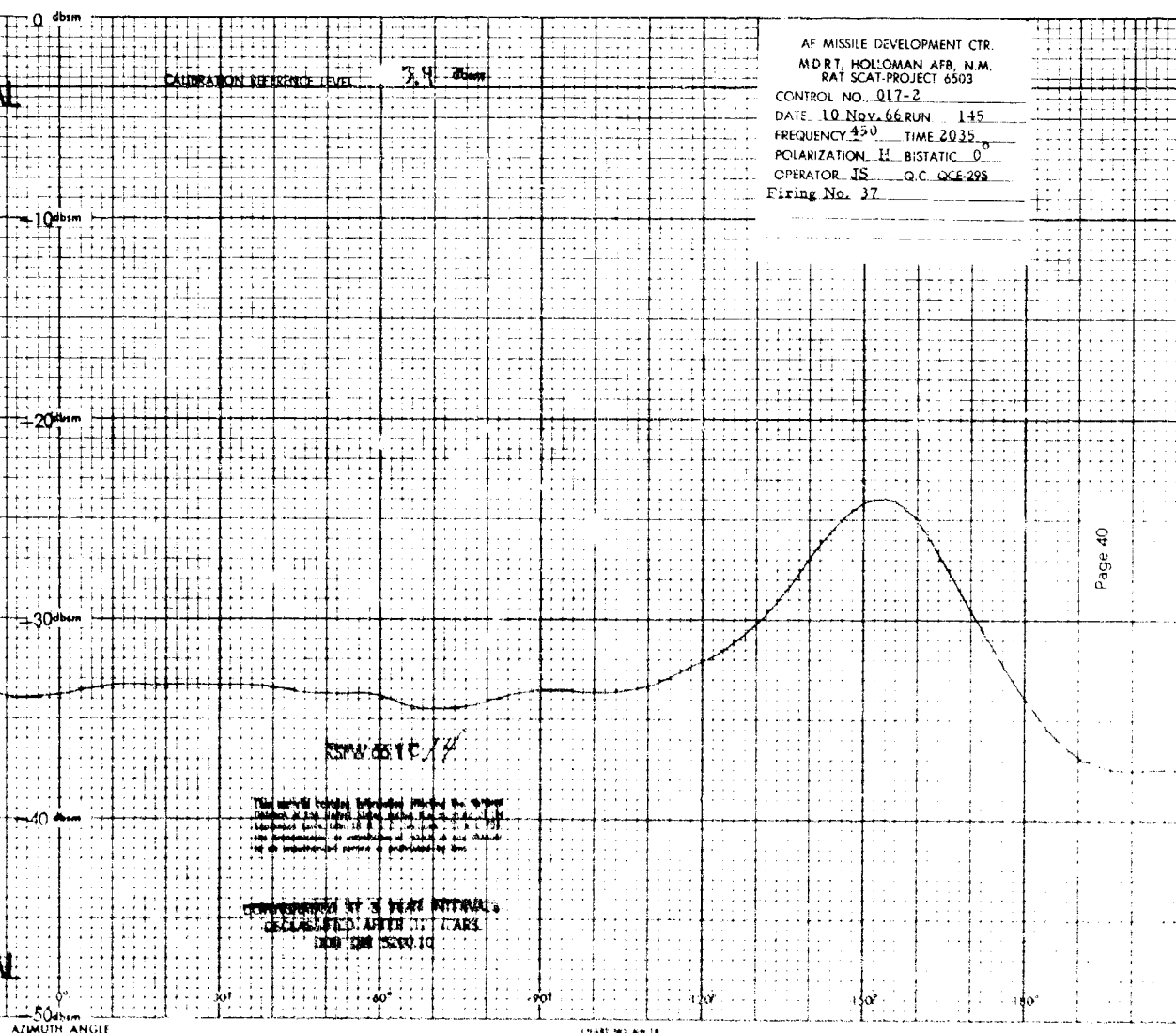


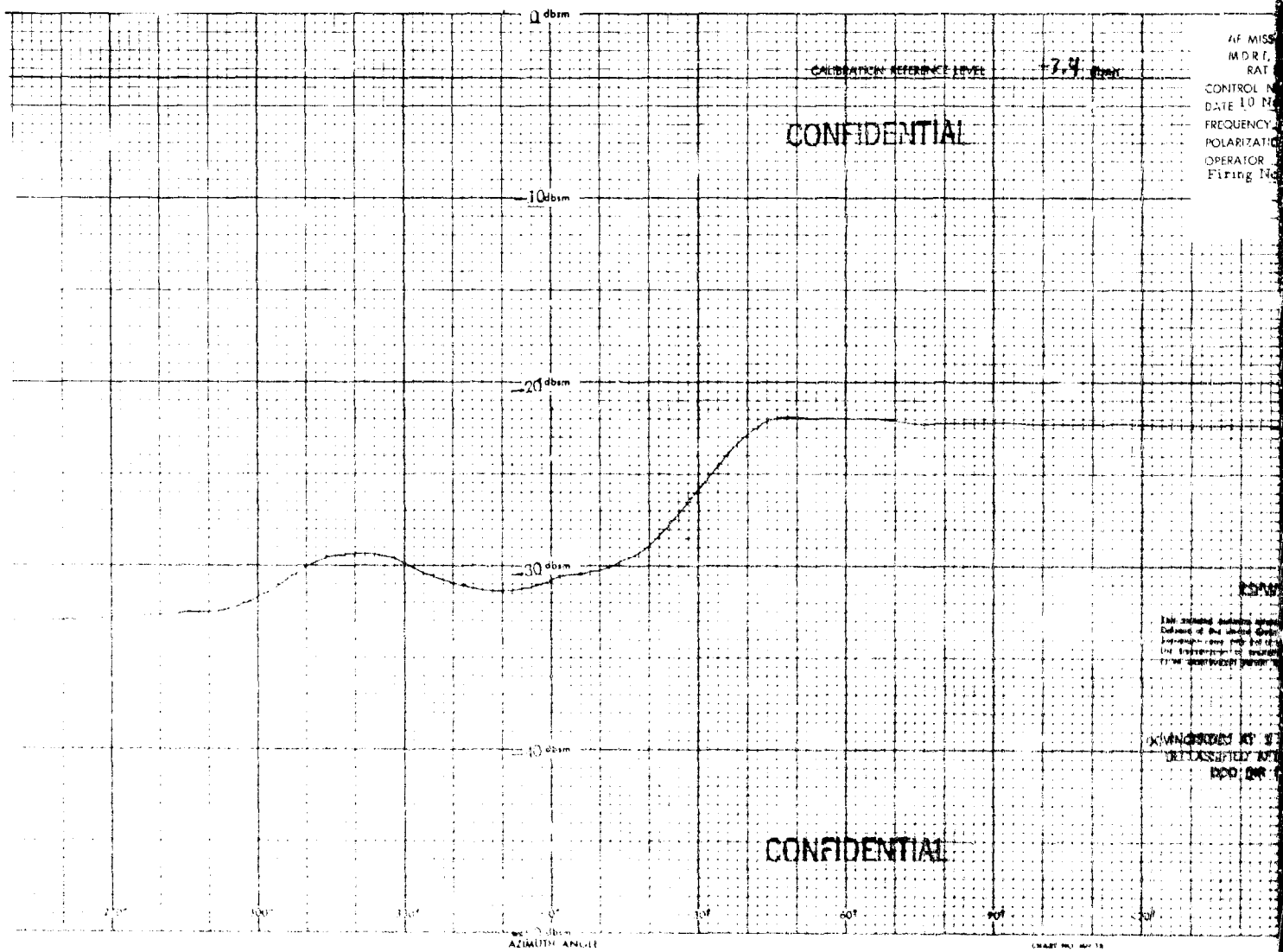
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MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 017-2
DATE 10 Nov. 66 RUN 145
FREQUENCY 430 TIME 2035
POLARIZATION H BISTATIC 0
OPERATOR JS Q.C. QCE-295
Firing No. 37

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RAT SCAT-PROJECT 6503
CONTROL NO 017-2
DATE 10 Nov. 66 RUN 146
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Firing No. 38

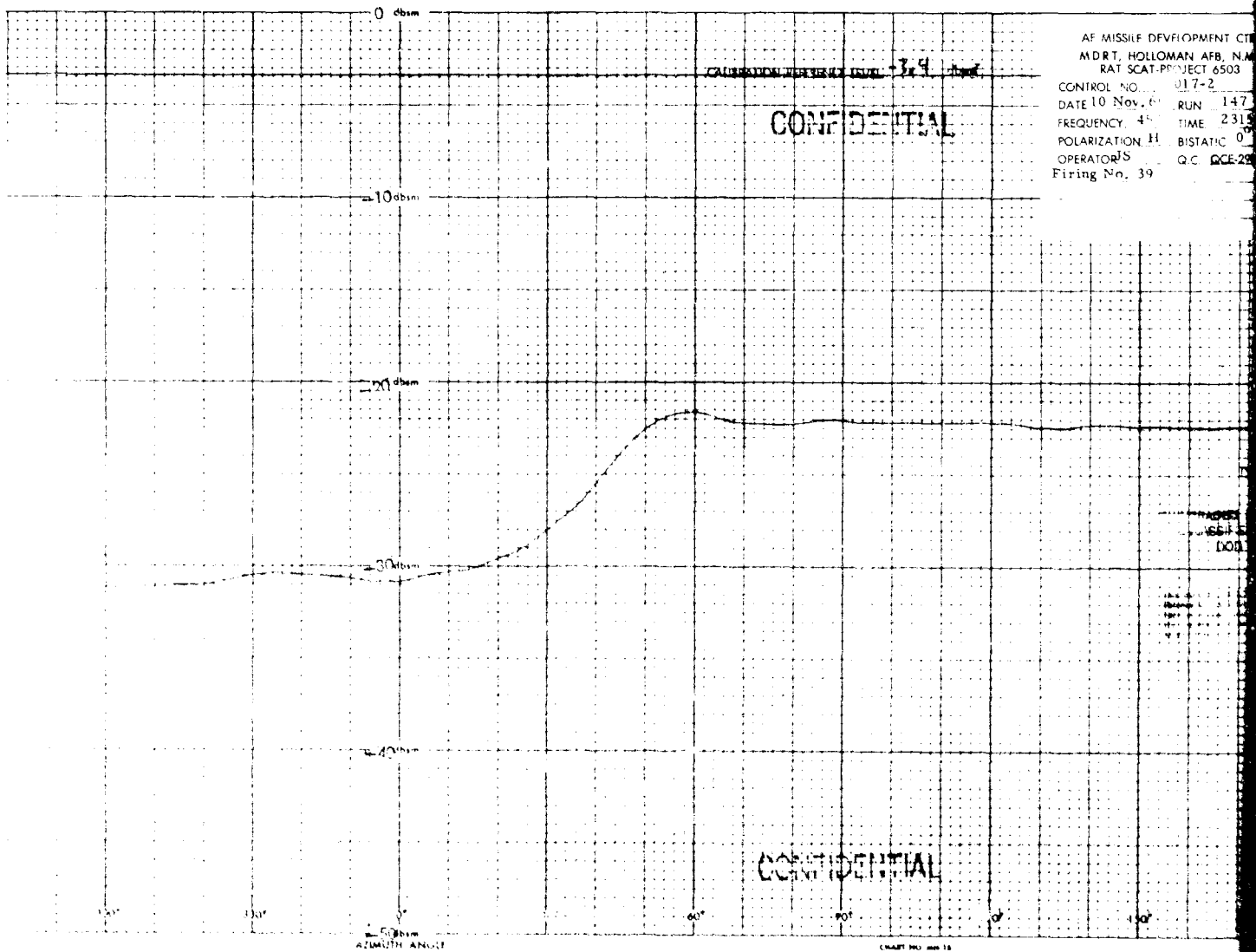
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RAI SCAT-PROJECT 6503

CONTROL NO 011-2
DATE 10 Nov. 66 RUN 147
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Firing No. 39

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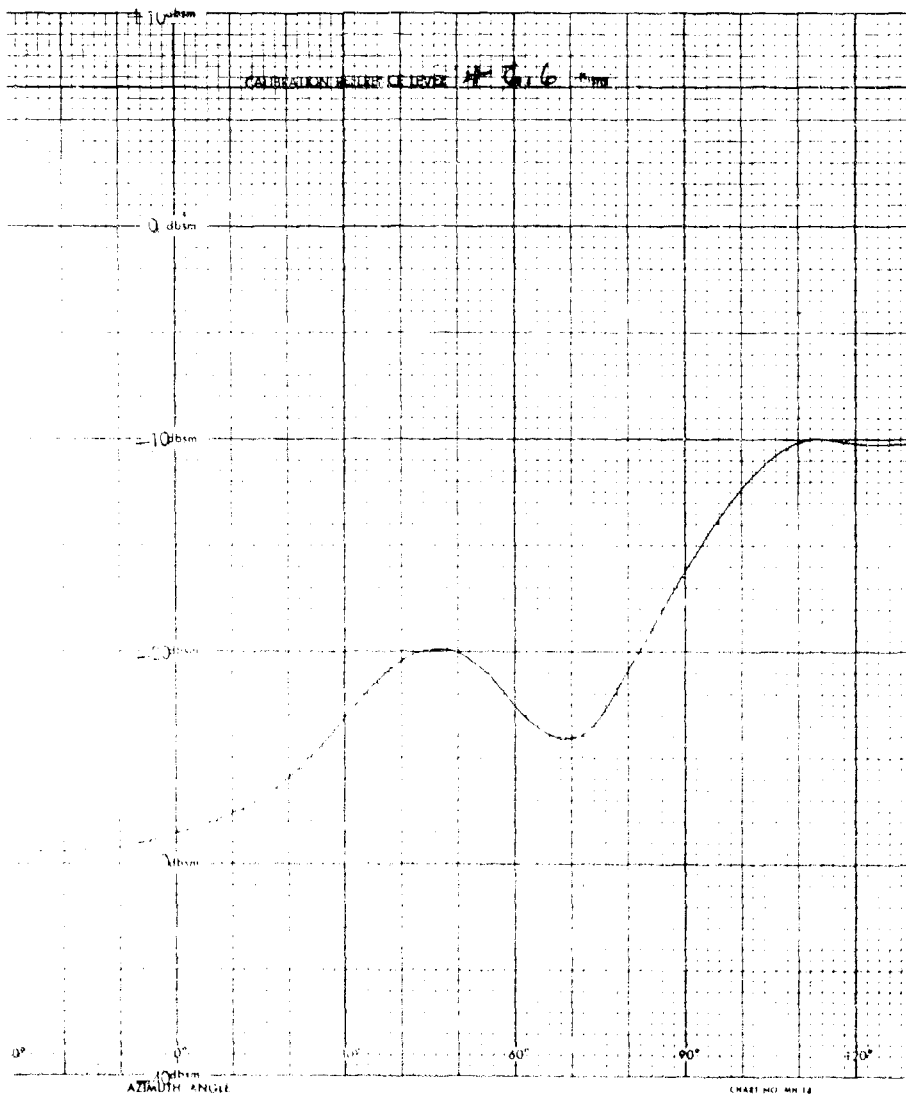
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RAT SCAT-PROJECT 6503

CONTROL NO. 017-2	
DATE 10 Nov. 66	RUN 148
FREQUENCY 450	TIME 345
POLARIZATION 1'	BISTATIC 0°
OPERATOR JS	Q.C. RCE-295
Firing No. 40	

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MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 017-2
DATE 10 Nov. 66 RUN 148
FREQUENCY 450 TIME 2345
POLARIZATION H BISTATIC 0°
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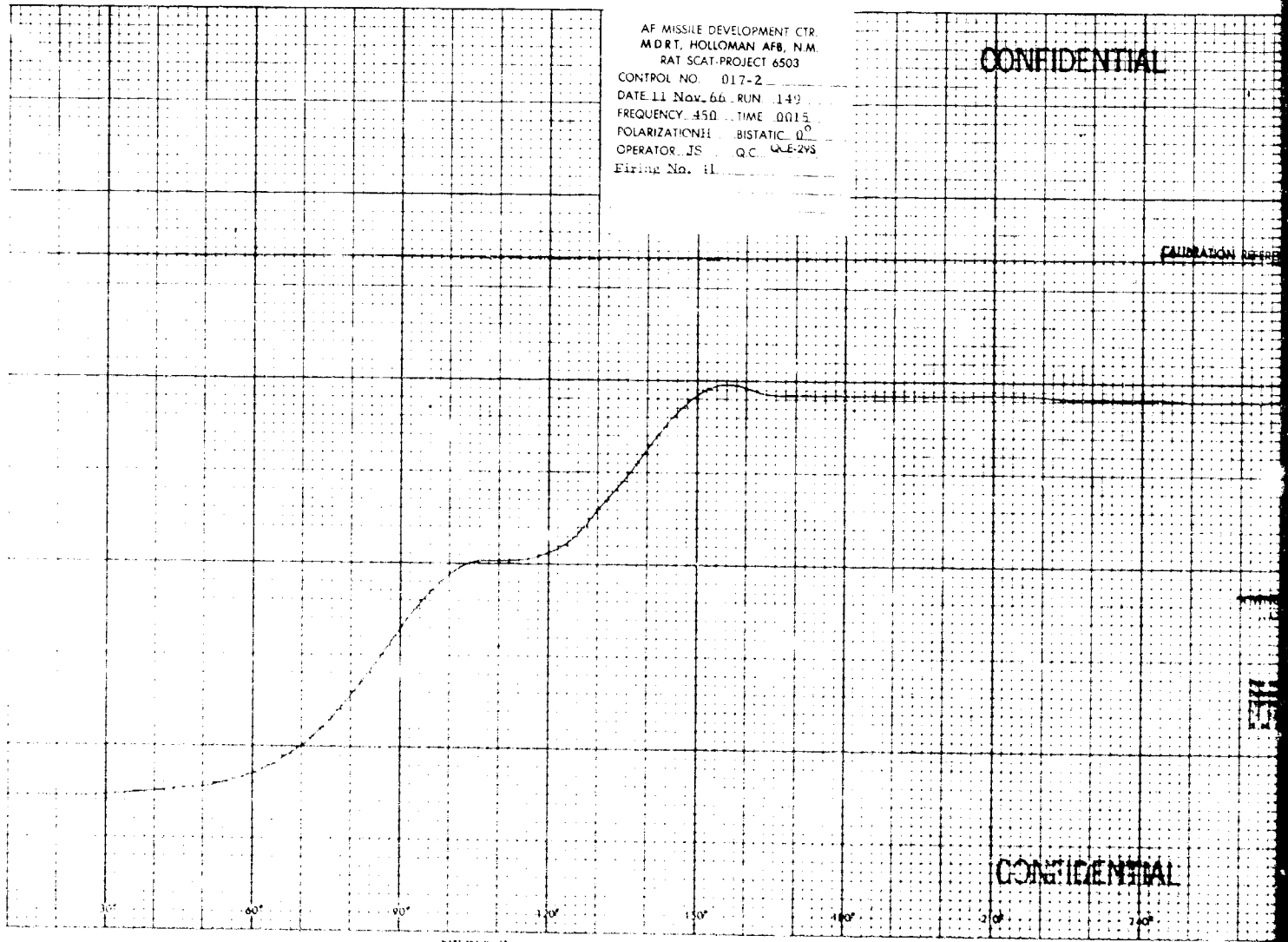
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Sample 43

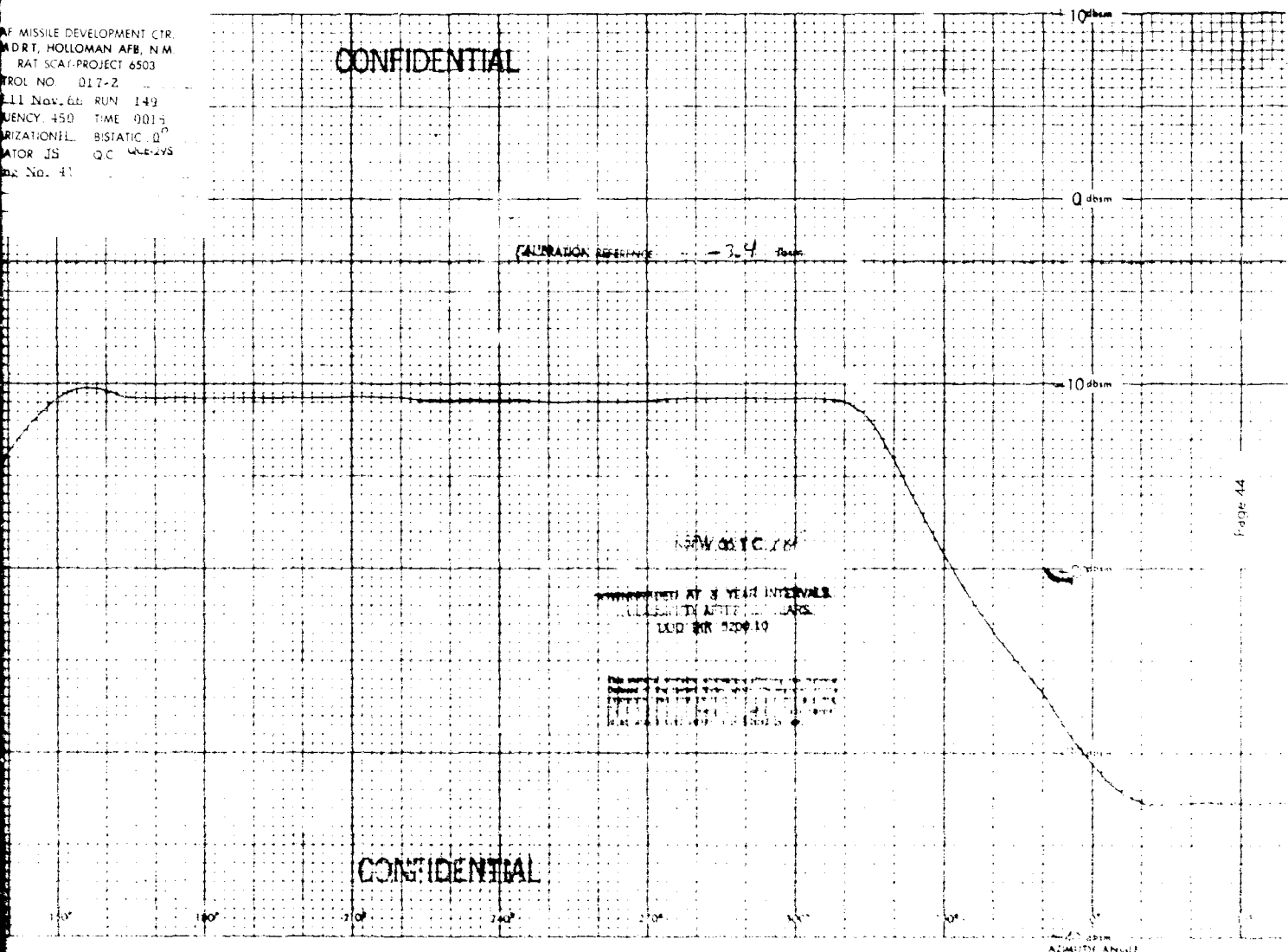
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AF MISSILE DEVELOPMENT CTR.
 WRIGHT PATTENSON AFB, OHIO
 PROJECT 6503
 CONTROL NO. 017-2
 11 Nov. 66 RUN 149
 FREQUENCY 450 TIME 0015
 ORIENTATION BISTATIC 0°
 TARGET JS QC 000-258
 Page No. 41

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Page 44

DEVELOPMENT CTR.
KLOMAN AFB, NM.
T-PRC JECT 6503

RUN
TIME
BISTATIC
Q.C.

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RAT SCAL PROJECT 6503
CONTROL NO. 01742
DATE 11/16/61 RUN 177
FREQUENCY 450 TIME 1555
POLARIZATION BISTATIC
OPERATOR TS GCM WCE-45
Firing No. 42

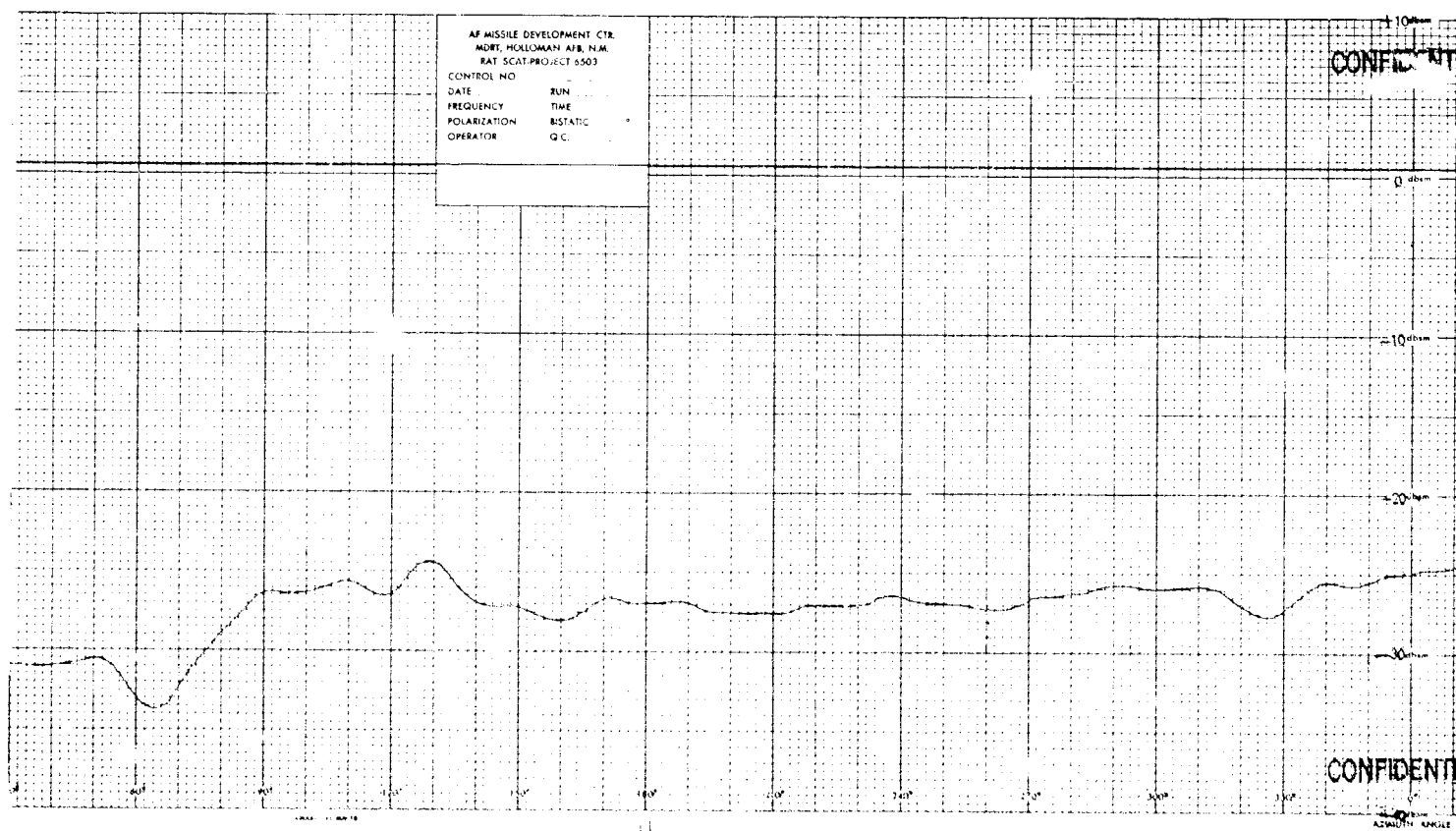
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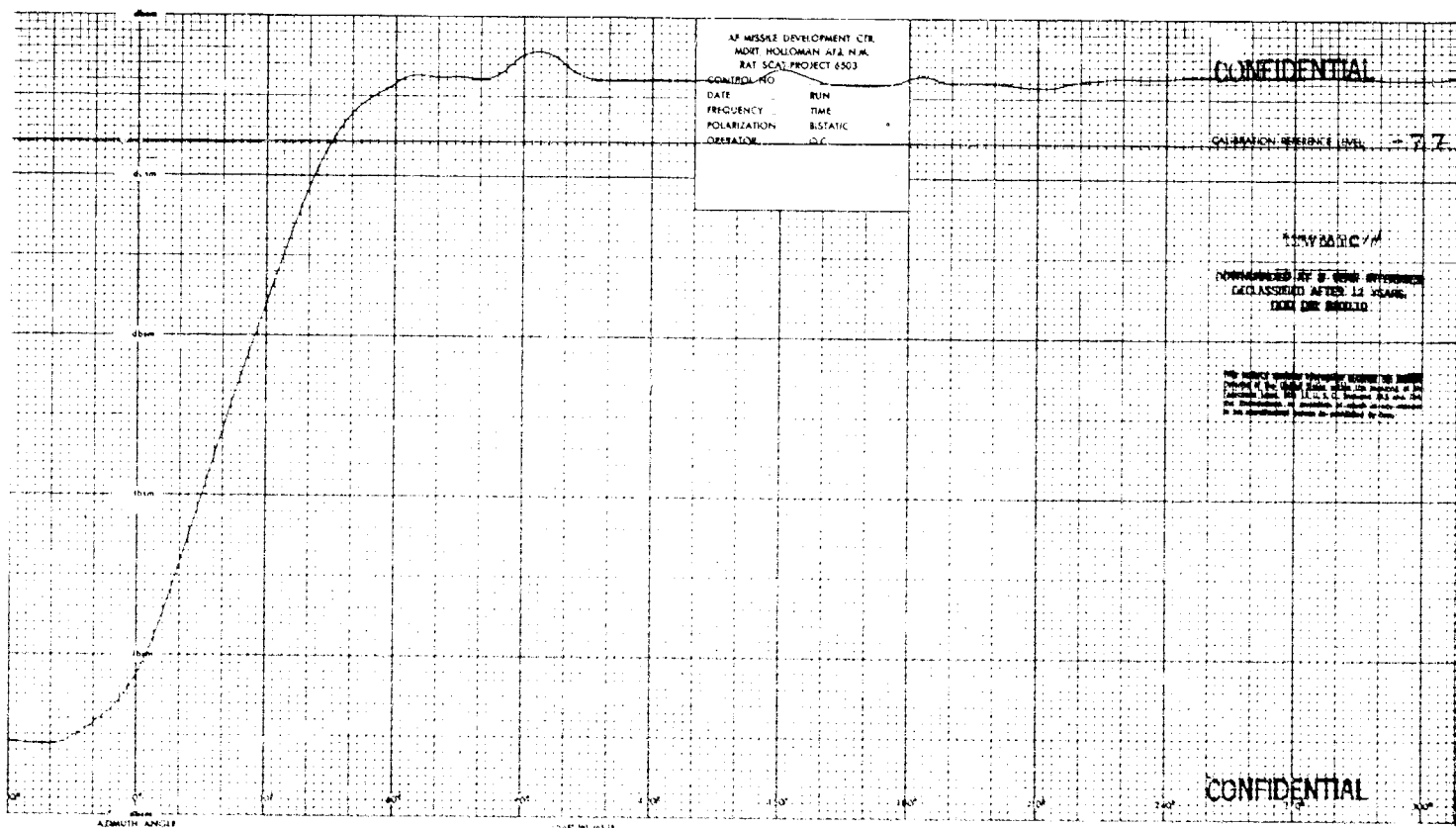
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MORT, HOLLAMAN AFB, NM
RAI SCAT PROJECT 6503
CONTROL NO. 017-2
DATE 2 Dec 56 RUN 178
FREQUENCY 450 TIME 1655
POLARIZATION II 6 STATIC 0
OPERATOR JS Q.C. 00625
Firing No. 41

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AF MISSILE DEVELOPMENT CTR
MORT, HOLLOWAY AFB, NM
BAT SCAT PROJECT 6503

CONTROL NO.
DATE RUN
FREQUENCY TIME
POLARIZATION BISTATIC
OPERATOR Q.C.

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BAT SCAT PROJECT 6503

CONTROL NO. 017-2
DATE 12 Dec 95 RUN 182
FREQUENCY 450 TIME 2045
POLARIZATION H BISTATIC 0
OPERATOR JS QC QCE275
Firing No. 44

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ANGLE

GRAPH NO. 65-15

2

CONTROL NO	
DATE	RUN
FREQUENCY	TIME
POLARIZATION	BISTATIC
OPERATOR	O.C.

REF ID: A66666

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OFFICE OF THE ATTORNEY GENERAL
WASHINGTON, D. C. 20530
JAN 10 1964
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SUBJECT: [illegible]

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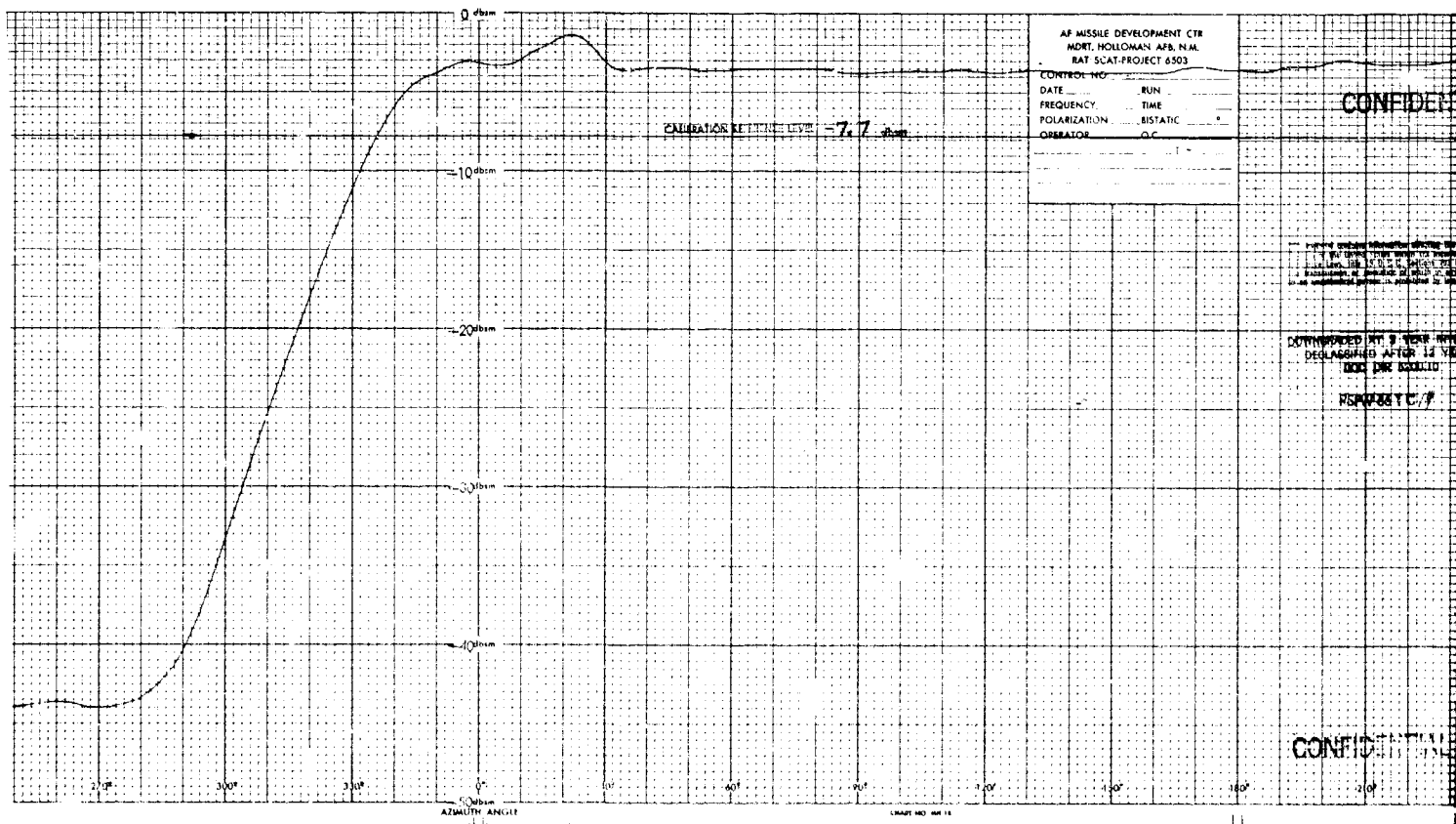
DECLASSIFIED AT 5 YEAR INTERVALS
DECLASSIFIED AFTER 12 YEARS
DDO DMS 1000.10

CALIBRATION REFERENCE IS -7.7 dBm

AF MISSILE DEVELOPMENT CTR
AFB, HOLLAMAN AFB, NM.
RAT SCAT-PROJECT 6503
CONTROL NO. 017-2
DATE 12 Dec 68 RUN 183
FREQUENCY 350 TIME 2135
POLARIZATION H BISTATIC 2
OPERATOR JS Q.C. 0625
FIELDING NO. 45

Page 48

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1

CONTROL NO. _____

DATE _____	RUN _____
FREQUENCY _____	TIME _____
POLARIZATION _____	% STATIC _____
OPERATOR _____	A/C _____

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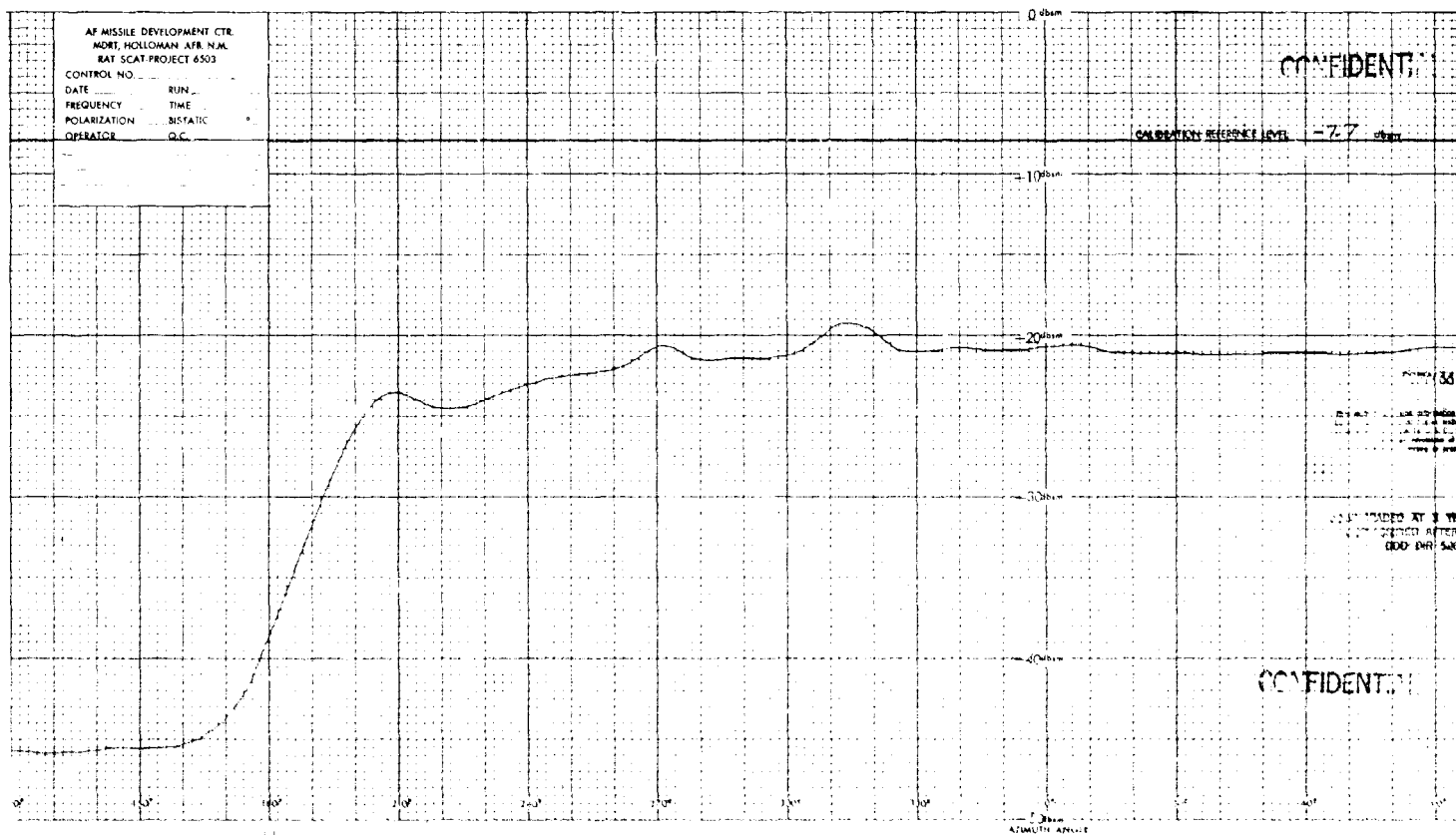
RESPONSE C

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CONTROL NO. 017-2
DATE 12 Dec. 66 RUN 184
FREQUENCY 450 TIME 2230
POLARIZATION H BISTATIC 0
OPERATOR JS QC QCE-295
Firing No. 46

2000 49

2



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CALIBRATION REFERENCE LEVEL -7.7 dbm

AT MISSILE DEVELOPMENT CTR
MCRT, HOLLAMAN AFB, NM
RAY SCAT PROJECT 6553
NTRN NO. 017-2
DATE 12 DAYS OF RUN 1955
BASED ON 1952 TIME 1730
POLARIZATION 18 STATION
CONVEXION 18 2.0 QKE-45
Firing No. 47

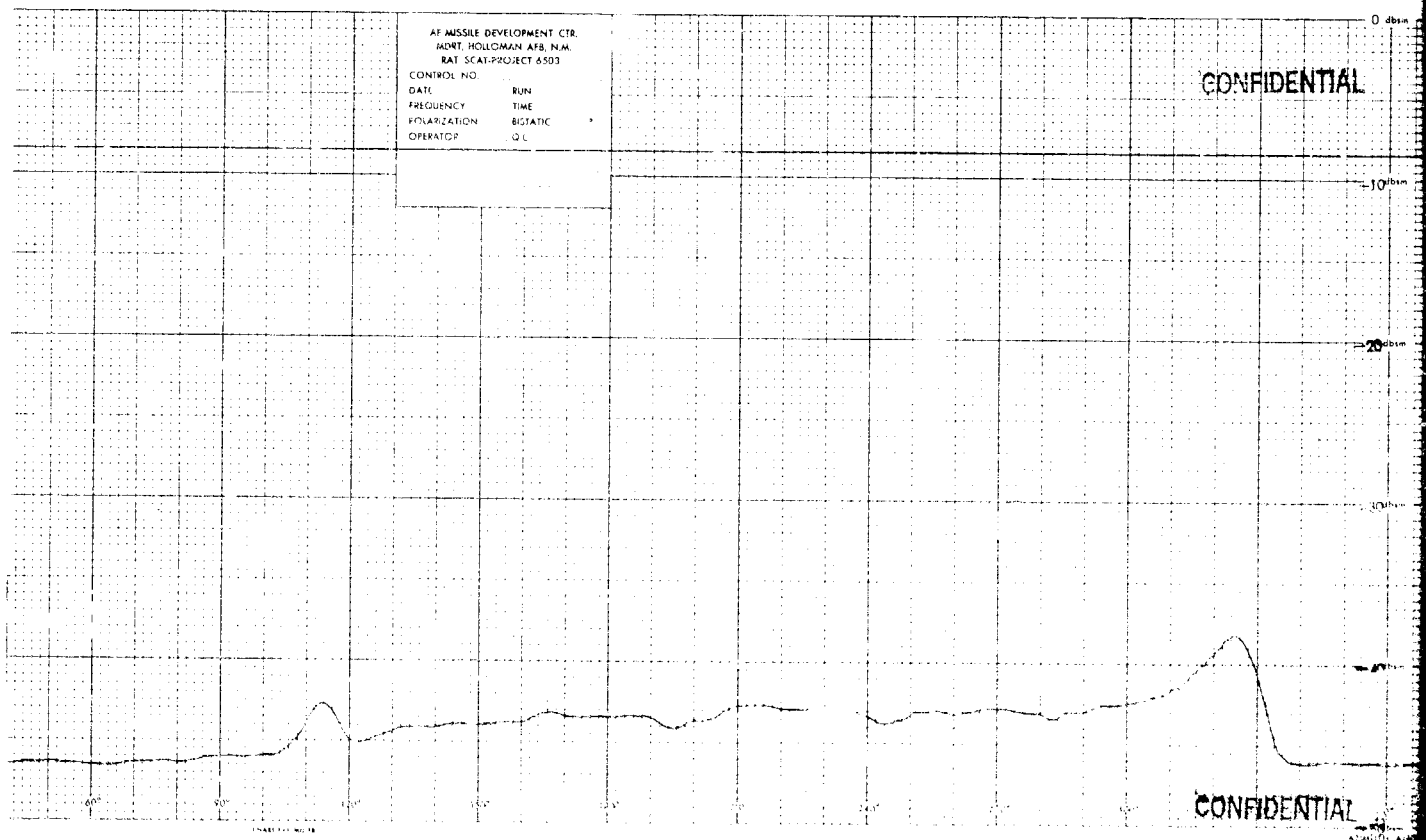
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0 dbm

CALIBRATION REFERENCE LEVEL -2.9 dbm

FORMERLY C-10

DECLASSIFIED BY 5 YEAR INTERVAL
DECLASSIFIED AFTER
600 DAY 5000

AF MISSILE DEVELOPMENT CTR
MDRT, HOLLAMAN AFB, N.M.
RAT SCAT PROJECT 6503
CONTROL NO 017-2
DATE 14 Dec 66 RUN 189
FREQUENCY 450 TIME 1300
POLARIZATION H BISTATIC 0
OPERATOR B.C. Q.C. Q.E. 2V8
Filing No. 48

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2

APPENDIX A

SITE INTRODUCTION

General

RAT SCAT is a static ground plane radar cross section measurement site, located on Alkali Flats near Holloman Air Force Base, New Mexico. It is authorized by the DOD for use by governmental agencies. It is under the auspices of Air Force Missile Development Center, HAFB, New Mexico.

A ground plane range utilizes radar energy reflected from the earth as well as radar energy traveling directly to the target through the atmosphere. When the antennas and target are adjusted to proper heights, coherent phase addition of these electromagnetic waves into a flat wave front, enhances the system sensitivity. Radar returns from objects near the earth's surface are reduced thus suppressing target area interference. Target area interference is reduced further through the use of special polyfoam mounting platforms, radar absorptive materials (RAM), and rotators located below the earth's surface (in pits).

Pulsed transmitters are employed to enable utilization of the range gated receiving system, which can selectively measure radar returns from the target area or the range displaced transfer standard. Background interference outside the target range is eliminated by range gating. Operation without background cancellation is therefore practical.

Capabilities

The RAT SCAT electronic equipment and controls are housed in a permanent building. Three separate range lengths (458 feet, 1158 feet, and 2458 feet) are provided for range variation as shown in Figure A-1. This allows the use of convenient antenna and target heights while satisfying the far field criterion for most targets. (Special 40-foot antenna towers

are attached to the building for antenna height positioning.) Further versatility is provided by two mobile equipment vans, one for monostatic range length variation and one for bistatic measurements. A duplicate set of control and data consoles in the main building enables simultaneous operation of any two of the three ranges. A summary of the RAT SCAT characteristics is contained in Table A-1.

Calibration

The normal method of calibration at RAT SCAT is to mount a primary standard (precision sphere) scatterer with radar cross section and record the corresponding signal level. Then the return from another secondary standard (corner or Luneberg lens) scatter displaced in range is recorded as a transfer standard. Both the precision standard return and the transfer standard return are recorded on the same plot. Thereafter, radar cross section calibration is determined by referencing the transfer standard return for every run. Thus every run is recalibrated. The comparisons of primary and transfer standards accomplished before and after each measurement series are identified respectively as calibration and post-calibration. If the direct ratio of primary to secondary readings is not maintained before and after the measurement series, then all runs between are invalid and must be repeated.

The calibration reference level marked on each data plot is related to the transfer standard level. This reference level may under controlled conditions differ from the actual transfer standard signal level since precision calibrated attenuation is sometimes inserted in the receiver line. When such attenuation is inserted, returns from the transfer standard are reduced to a level compatible with the scale used for the target measurements. The 50 db dynamic range of the plot is placed to include the range

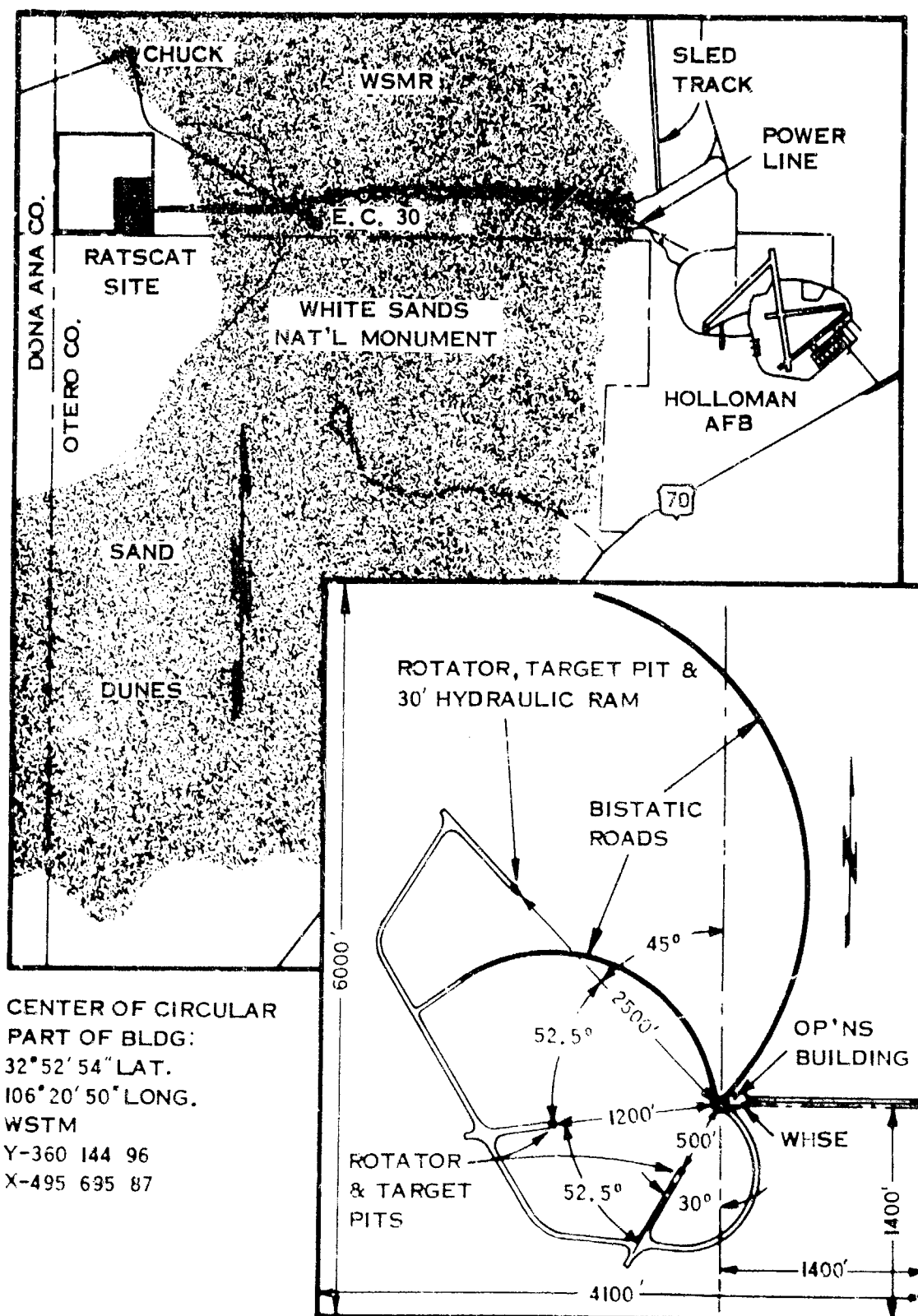


FIGURE 1: RATSCAT PROJECT 6503

TABLE A-1 RAT SCAT CHARACTERISTICS OF ELECTRONIC EQUIPMENT

Power Output	1 KW minimum
Pulse Width	0.1 to 1.0 microsecond
Pulse Repetition Frequency	500 to 5000 pps
No. of Receiving Systems	Two per Band, (one monostatic and one bistatic)
Receiver Minimum Detectable Signal	-94 to -106 dbm (proportionate to frequency)
Receiver Bandwidth	2 or 10 mc (selectable)
Range Gate Width	0.1 to 1.0 microsecond (50 to 500 feet)
Dynamic Range	50 db
Linearity	±0.5 db
Equipment Stability	0.1 db/hour (Average)
Analog Data Format	Polar and rectangular plots of cross section and phase vs aspect angle
Digital Data Format	Punched paper tape recorded at 0.1 - to 4.0 degree azimuth increments
Antennas	3-, 6-, 10-, and 16-foot parabolic dishes (smaller and larger dishes (1.5 to 30-foot for special tests)
Antenna Feeds	Log periodic and horns all with VSWR less than 2.0 to 1.0
Polarization	Horizontal, vertical, circular, elliptical in any cross combination of transmitting and receiving configuration.
Background Level	As low as -80 dbsm (frequency dependent)
Background Reduction	Tuned columns and vector subtraction by using phase and amplitude measurements to reduce background by 20 db
Phase Measurement	Unique RAT SCAT capability for vector subtraction or scattering matrix applications. Band 4 only.
Azimuth Resolution	0.1 degree
Maximum Target Weight	10,000 pounds
Target Size	Greater than 60-foot length
Bistatic capability	458-, 1158-, and 2458-foot range for 0- to 120-degree bistatic angle
Frequency Coverage	100 to 11,500 mc (7 bands)
	Band 1 - 100 to 250 mc Band 2 - 250 to 500 mc
	Band 3 - 500 to 1000 mc Band 4 - 1000 to 2000 mc
	Band 5 - 2000 to 4000 mc Band 6 - 4000 mc to 8000 mc
	Band 7 - 8000 mc to 11,500 mc
Range Length	300 feet minimum
	Building/Pit 1 - 458 ft Building/Pit 2 - 1158 ft
	Building/Pit 3 - 2458 ft Monostatic Van/Pits 1, 2, or 3 - variable Range length

of returns expected from the vehicle being measured. In some cases 2 runs are necessary to be plotted for direct overlay to include the dynamic range of the vehicle if it exceeds 50 db. Calibration plots are included with the target data when requested by the user.

The sphere calibration plots will not necessarily be straight lines. If the background return is within 20 db of the sphere return, for example, a variation in sphere return of approximately ± 1 db can result. For calibration the sphere is intentionally placed at least $1/2$ wavelength off the center of table rotation to insure sufficient phasing with the background return. The average sphere return is then chosen for a calibration level. This avoids the peak errors involved with coherent addition of sphere return and background return and allows the minimum errors involved with non-coherent addition of the returns. This is indicated in Figure A-2.

Operating Procedures

The following step-by-step procedure is standard in obtaining monostatic radar cross section measurements after frequency, feeds, antennas, antenna height, target height, and pit (range length) have been chosen:

1. Calibration - As described in previous section.
2. Horizontal and Vertical Probes (field strength measurements at the target area) - Horizontal probes at the target area have been shown to be redundant for azimuthal boresighting. For this reason, these probes are taken only upon request for examination of near field effects. Vertical probes are taken at the target area to determine power variation as a function of target height. If necessary, antenna height is varied to obtain an acceptable vertical probe which then necessitates a new calibration.

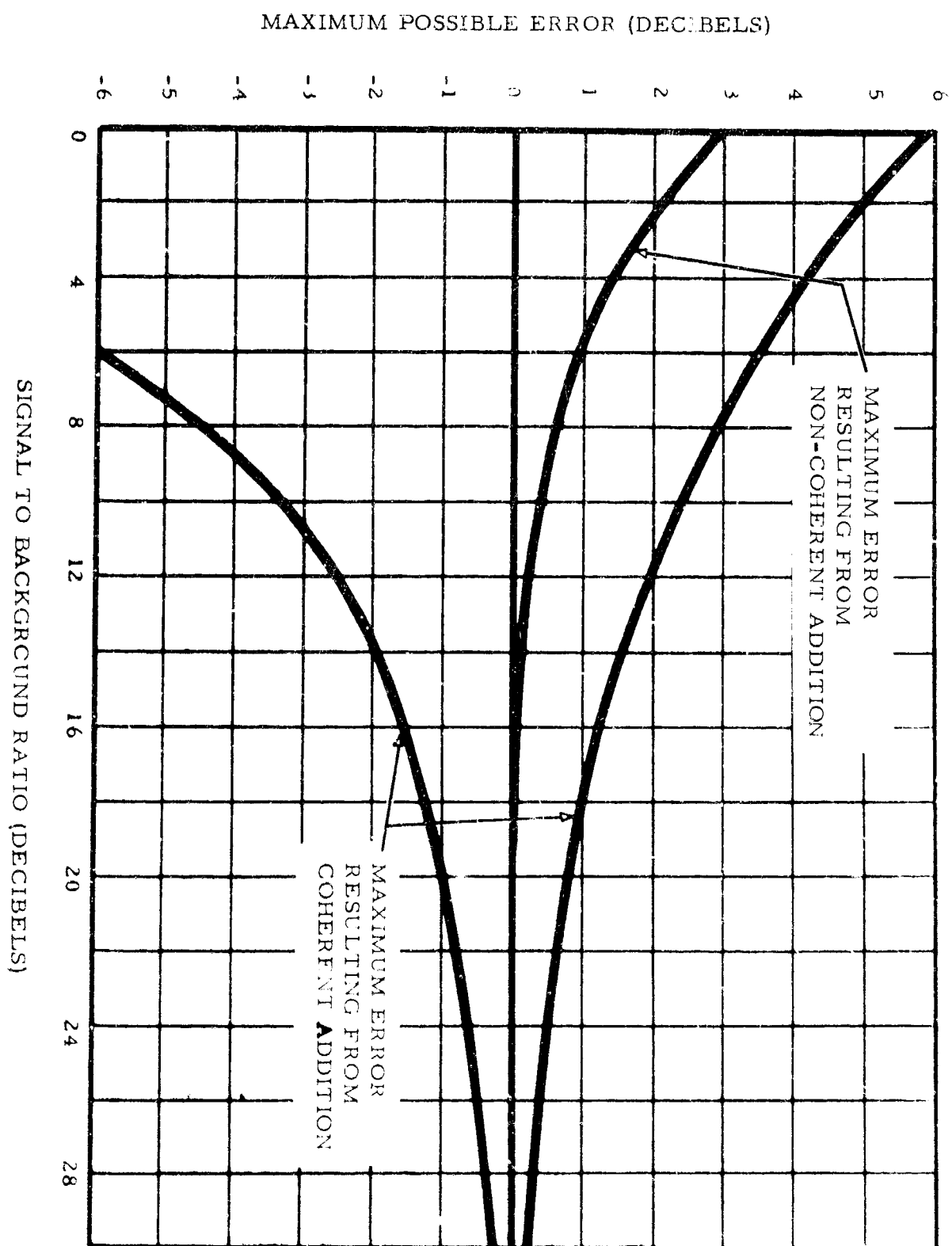


FIGURE A-2 PLOT OF ERROR INDUCED BY BACKGROUND INTERFERENCE

3. Background - The background level with the target mount in place is measured in each polarization to be used.
4. Measurement - The measurement is made with the vehicle in the position previously occupied by the primary standard.
5. Calibration - The primary calibration is repeated to verify calibration (post cal.).

APPENDIX B

TARGET ORIENTATION AND DATA FORMAT

Coordinate System

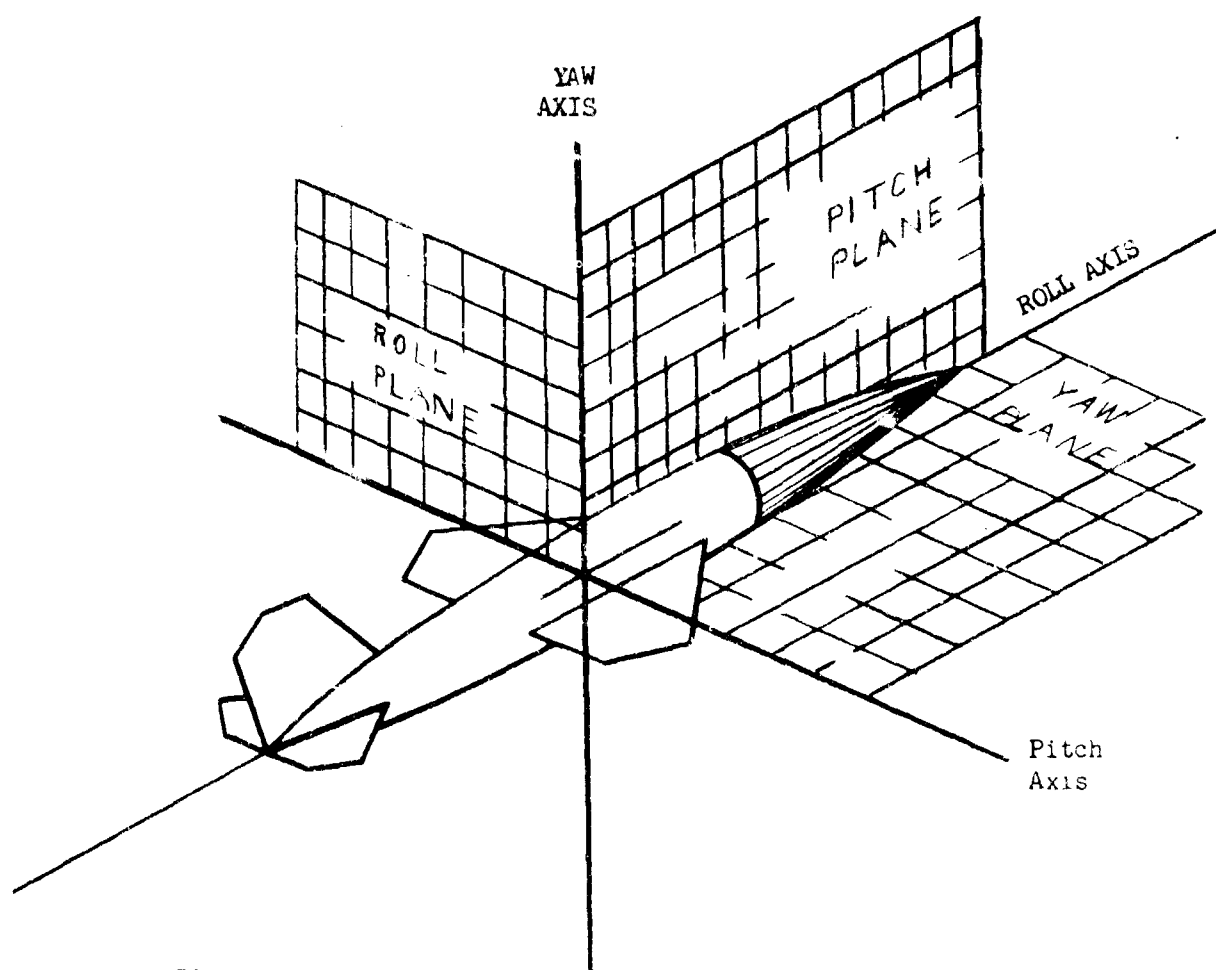
The coordinate system described herein has been adopted as a standard for RAT SCAT operations. The system is referenced both to the vehicle being measured and to the measurement site.

Vehicle Reference

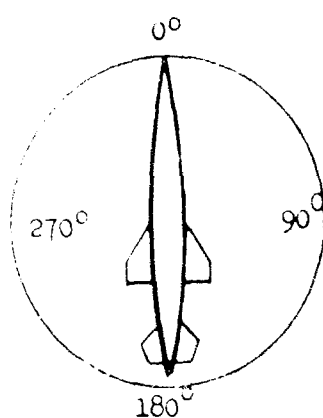
A three-axis system, referenced to an arbitrary vehicle, is illustrated in Figure B-1. In this system three mutually perpendicular planes (yaw, pitch, and roll) are passed through the vehicle so that the pitch and yaw planes mutually intersect on the longitudinal axis of the vehicle. These planes remain fixed with respect to the vehicle, regardless of vehicle rotation with respect to the radar or ground plane. The yaw plane, which includes the pitch axis and the roll axis, is numbered from 0 degrees to 360 degrees in a clockwise direction when the vehicle is viewed from the above. The nose-on aspect corresponds to 0 degrees, the starboard side of the vehicle corresponds to 90 degrees, and the port side to 270 degrees. The pitch plane, which contains the roll axis and the yaw axis is numbered from 0 degrees to ± 180 degrees; the ± 90 degree point is below the center line, and the - 90 degree point is above the center line. The roll plane contains the yaw axis and the pitch axis. It is numbered from 0 degrees to 360 degrees, and the numbers increase in a counterclockwise direction when the vehicle is viewed from the rear.

Site Reference

As previously stated the coordinate system is fixed with respect to the vehicle. It is referenced to the site by means of three index marks. The exact value of any of the three angles is determined by noting the value of the vehicle coordinate opposite the index marks. Index marks

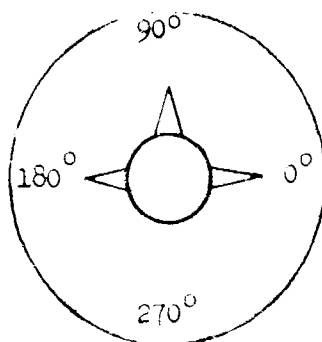


Yaw Plane



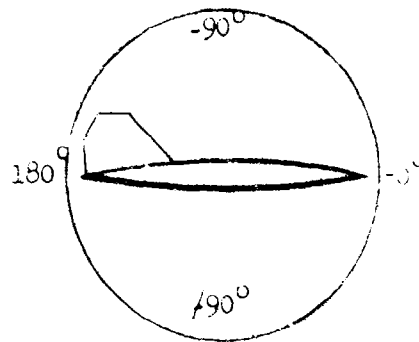
Top View
(Looking down)

ROLL PLANE



Rear View
(Looking forward)

Pitch Plane



Side View

FIGURE B-1 VEHICLE COORDINATE SYSTEM

come from such devices as bubble levels, inclinometers and transits.

As illustrated in Figure B-2, the index for roll angles is normal to the axis of rotation. As illustrated in Figure B-3, the index for pitch angles is normal to the axis of rotation and in line with the apparent source of radiation. For measurements at the RAT SCAT Site, targets can be mounted to provide desired pitch and roll angles.

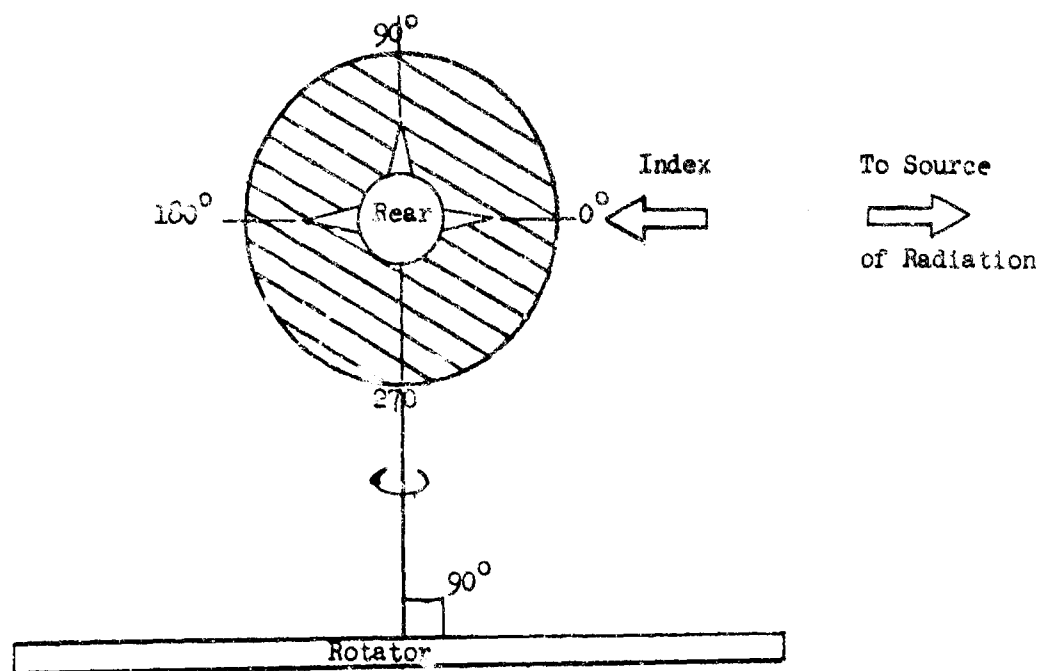
Coordinate System Tilt

For small targets another angle, tilt, can be utilized in recording useful data. This angle, equipment-limited to less than 15 degrees, is formed by the axis of rotation and the normal to the line of sight to the apparent source of radiation. Since, in a ground plane range, radiation can be considered to emanate from a point with zero height directly beneath the antennas, a zero-degree tilted axis of rotation is slightly off the geometrical vertical. This small deviation from the geometrical vertical is neglected in the following discussions.

A target mounted with a pitch angle other than zero displaces the yaw axis from the vertical, but not the axis of rotation. The axis of rotation is displaced from the vertical only when non-zero tilt is employed. Tilting toward the radar is considered positive tilt and away from the radar is negative tilt. For monostatic measurements tilt will be measured in the vertical plane containing the line of sight between the radar and the target. The difference between pitch and tilt is shown in Figure B-4.

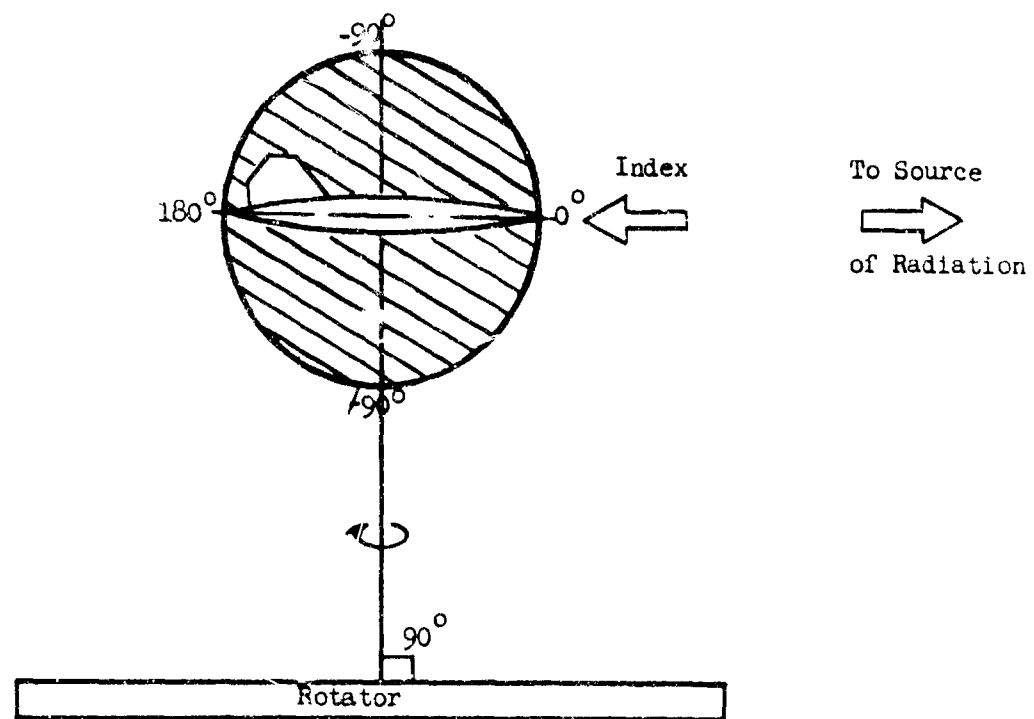
Data Format

Data recorders obtain azimuth angle information by means of precision synchro signals from the position of the rotating table. The line of sight from the antennas to the center of the rotator, as illustrated in



NOTE: The roll scale is fixed to the vehicle. The amount of roll is determined by noting the number of degrees opposite the index. Clockwise rotation of the target (when viewed from the rear) increases the roll angle.

FIGURE B-2 TARGET ORIENTATION - ROLL



NOTE: The pitch scale is fixed to the vehicle.
 The number of degrees of pitch is determined
 by noting the scale value opposite the index.

FIGURE B-3 TARGET ORIENTATION - PITCH

Figure B-5, indexes azimuth angles. As used here the term azimuth refers to the position of the target rotator table. With zero degrees of pitch and roll, azimuth and yaw are identical. It is standard practice to turn the rotator in a clockwise (cw) direction as viewed from above. Consequently, the azimuth angle varies, for example from 180 degrees (tail-on) to 90 degrees (starboard-side) to 0 degrees (nose-on) to 270 degrees (port-side).

Polar and Rectilinear Plots

Essential information pertinent to each plot is contained in the information block located in the upper right hand corner of the rectilinear plots and in the second quadrant of the polar plots. Each rectilinear plot has the recording of the return from the left side of the vehicle on the left side of the plot, 0 degrees at the center, and the recording of the return from the right side of the vehicle on the right side of the plot; 180 degrees (tail-on) appears at the right and left extremities of the plot, as shown in Figure B-6. Since the paper moves from left to right under the recorder pen, it should be noted that measurements are limited at 180 degrees in order to obtain continuous measurements on the recorder paper. The table on the polar recorder is rotated in the same directions as the target so the 90-degree point appears on the right side of the polar plot, the 270 degree point on the left, and the zero or 360 degree point at the top of the plot.

Digital Printouts

At the users request, radar cross section data are available in the digital form of punched paper tapes. The 11/16 inch tape is punched with the standard TELETYPE COMMUNICATIONS (Type 3) code in which 5-bit characters are used. Sigma servo positions, quantitized to tenths of a db, are recorded at specified azimuthal increments (.1,

- NOTE: 1) Axis of rotation is always collinear with Azimuth Axis.
2) Nose-on points towards source of radiation in both cases.

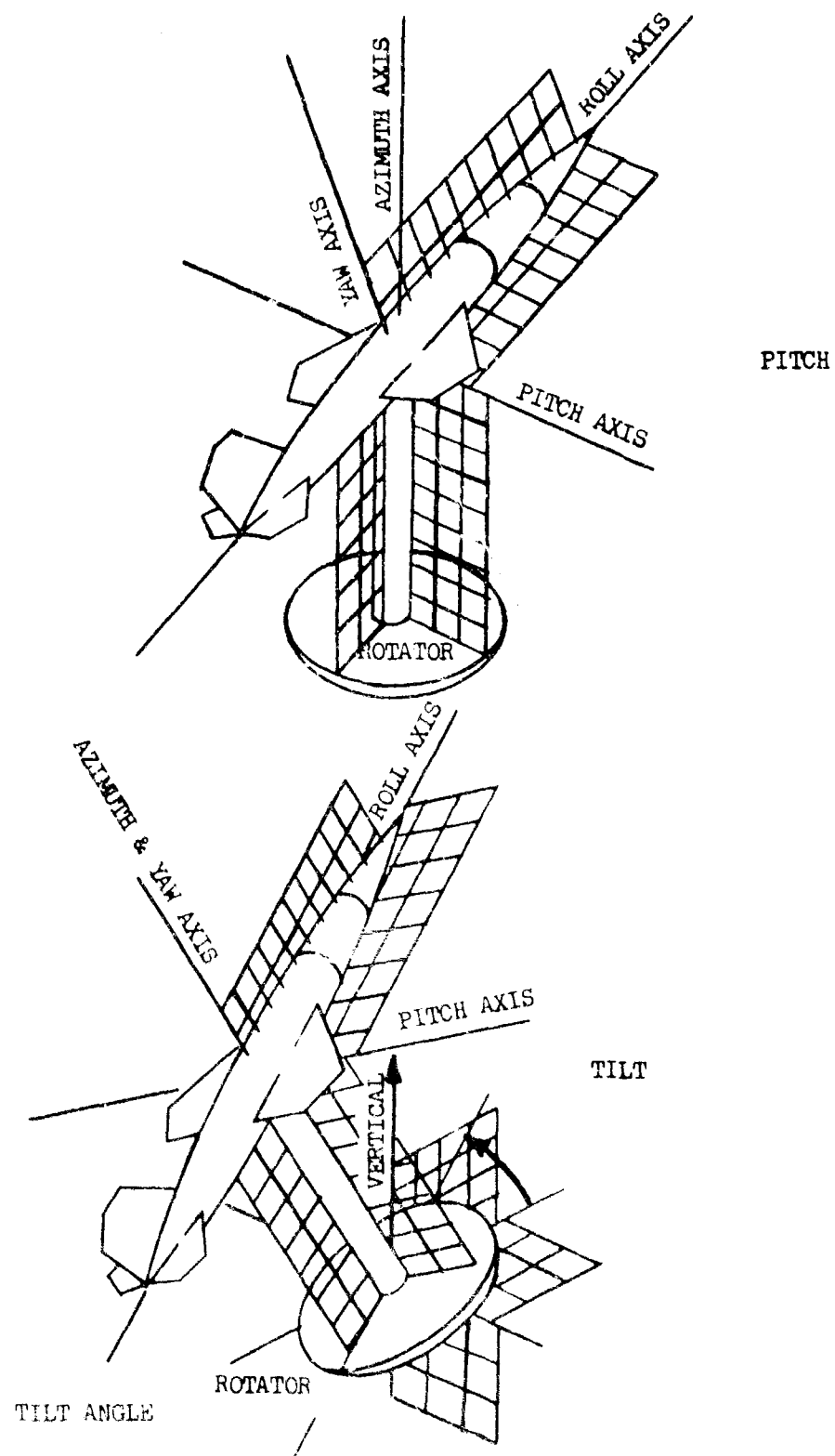
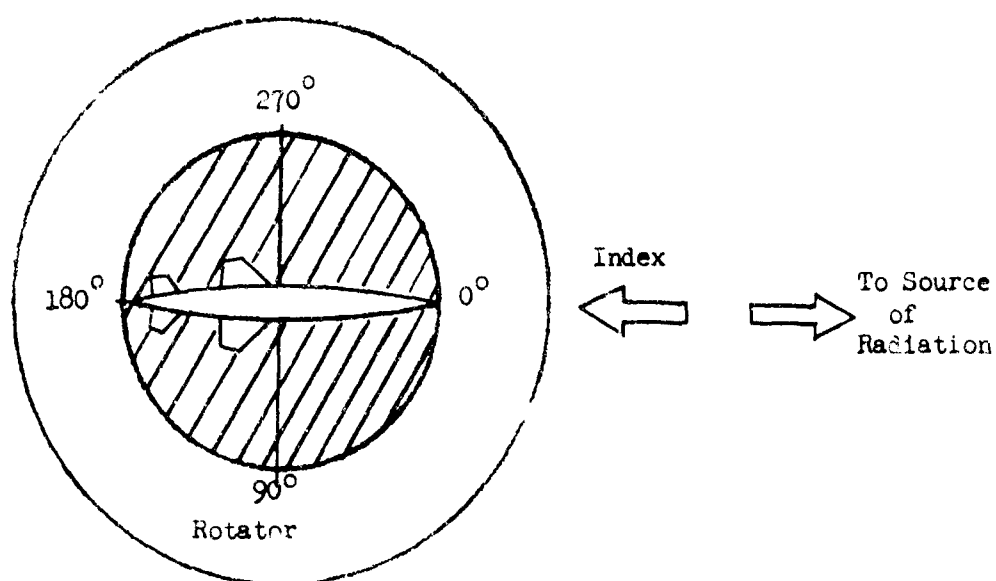


FIGURE B-4 COMPARISON OF PITCH AND TILT ORIENTATIONS



NOTE: The azimuth scale is fixed to the target rotator. The azimuth value is determined by noting the value of the scale opposite the index mark as the rotator and scale revolve. The index is the line-of-sight from the radar antennas to the center of the rotator. (Azimuth angle data are transmitted to the data recorders by means of synchro signals.) The standard direction of rotation will be clockwise.

FIGURE B-5 TARGET ORIENTATION - AZIMUTH

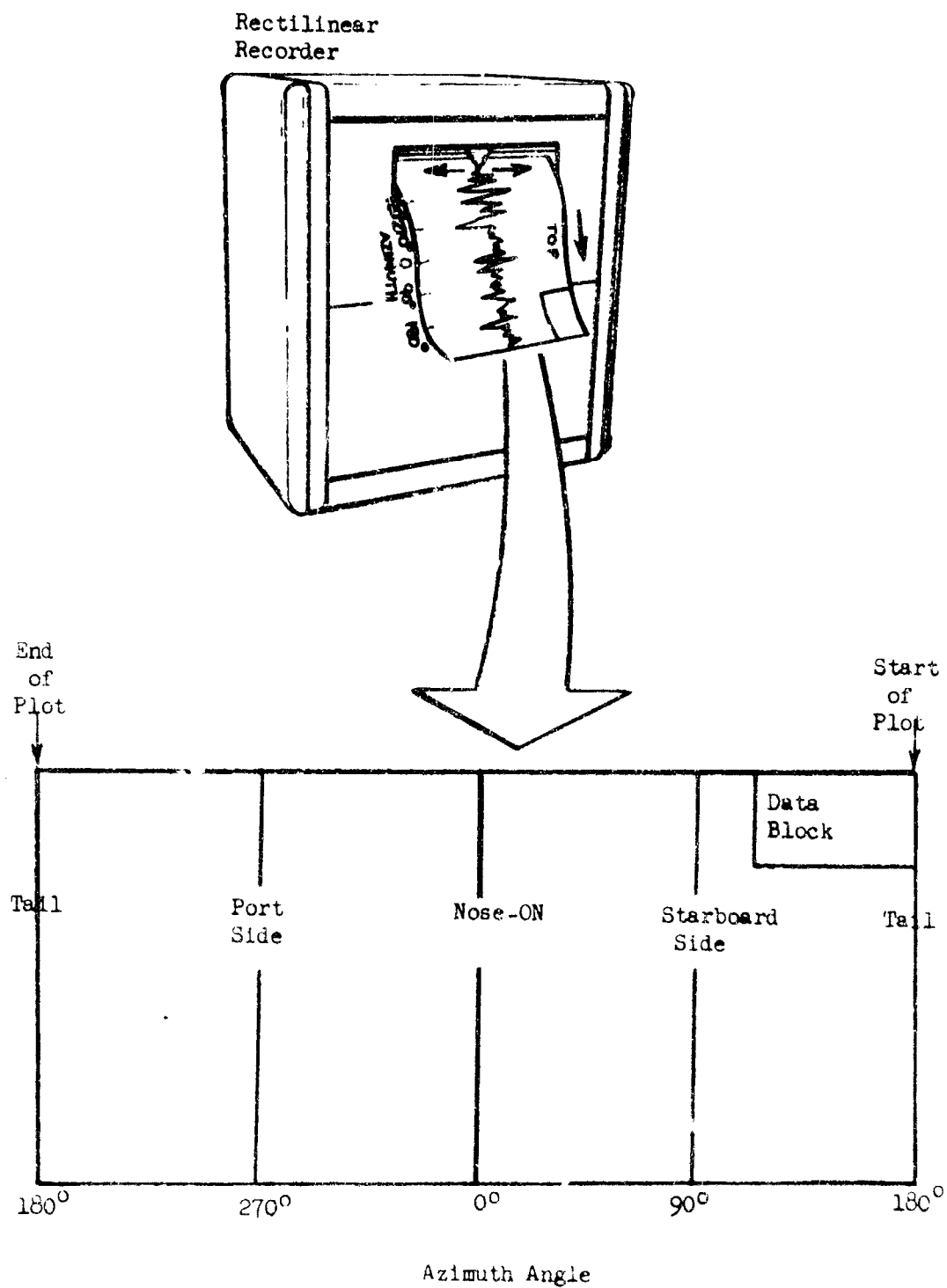


FIGURE B-6 FORMAT FOR RECTILINEAR PLOTS

.2, .4, 1.1, 2.0, or 4.0 degrees). Each of these recordings are preceded by the corresponding value of the rotator azimuth position. Since all three recorders are synchronized to azimuth positions of the rotator, the digital printouts, like the rectilinear plots, begin at the tail end of the vehicle and progress as if the vehicle were turning clockwise.

Header Format. Each digital data-run has a section of the punched paper tape, called the header, preceding it that contains information identifying the run. A format along with a standard set of symbols has been chosen which facilitates identification of different portions of the header. It also puts the paper tape in a form that could be used as an input to a digital computer. Symbols used in punched paper tape:

Carriage Return

Line Feed

Figures

Letters

Start Identification Information (

Stop Identification Information)

Start Data (exclamation point) !

Plus Sign (quotation mark) "

Minus Sign (dash) -

Secondary Standard (ampersand) &

Primary Standard (dollar sign) \$

Target (question mark) ?

The following format, consisting basically of three sections provides a uniform procedure for recording and identifying data:

a) Identification Information: This includes pertinent information applying to a particular run. This section, enclosed in parenthesis, includes control number, run number, date, time polarization, frequency, and brief description.

b) Transfer Standard Data: Data representing secondary signal levels follow the identification information. These data are preceded on the recording tape by an identifying symbol, ampersand (&), followed by a plus or minus sign, three digits, and an exclamation point, such as &" 40.0!. In this example "40.0 is a conversion constant. Conversion constants are discussed in the section below entitled Calibrating Digital Tape.

c) Target Data: Target data format is identical to transfer standard data format, with the exception that the ampersand is replaced by a dollar sign(\$) or a question mark (?), depending on the object being measured. The former is used for primary standards; the latter for vehicle, background, etc.

Calibrating Digital Tapes. Unlike the graphical forms of data, the digital printouts are not calibrated, and as such do not represent the actual radar cross sections. Information from the printouts can be calibrated, however, by subtracting the conversion constant from one-tenth the value of each digital printout. The conversion constant follows the symbol identifying the type of data. It is important to note that, as the recording tape progresses, each conversion constant supersedes all prior conversion constants. This calibration method is illustrated by the following example. Suppose one-tenth the value of the target signal level printout corresponding to 180 degrees is +58.0, and the conversion constant is "50.0 (decoded this equals 50.0 dbsm). Then the actual radar cross section of the target at 180 degrees would be +8 dbsm.

Calibration of Magnetic Tape will be as specified by each individual user.

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13. ABSTRACT Static radar cross section data of plumes from small liquid and solid propellant rocket motors were obtained at RAT SCAT, Air Force Missile Development Center, Holloman Air Force Base, New Mexico. A total of 42 monostatic measurements were made at UHF and upper L-band frequencies.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

Radar Reflection
Radar Cross Section
Static Cross section
Backscatter
Reflectivity
Radar
Radar Echo
Radar Targets
Rocket Exhaust Plumes
Ionization
Flame Temperature
Seeding

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