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To: Holographers

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Subject: Holography Feed Phase: Measurements and Model

The antenna surface has been rigged using holographic measurements made at 12 GHz. These measurements have been corrected for radome and subreflector diffraction. So far, we have assumed that the feed used for holography introduces negligible errors. To check out this assumption we have used the Lincoln Laboratory's antenna range to measure the feed phase pattern.

Measurement Set-up

The holographic feed was mounted on a 3 axis mount (see Figure 1) at one end of an anechoic chamber. At the other end of the chamber a standard gain horn provided a linearly polarized test signal. A sample of the transmitted signal and the signal received by the holography feed were compared in phase (and amplitude). The holographic feed signal was peaked up in elevation. The "polarization" axis was adjusted to center the phase response. Pattern scans were taken by rotating the azimuth axis whose motion was synchronized with the chart recording of phase. For the scans taken on 7 April, the center of azimuth rotation was 3.3 inches behind the front of the feeds, while those taken on 10 April had the azimuth axis centered on the front of the feed.

The following scans were taken:

	Chart #	Date	Rotation Axis Offset
E-plane	145474	7 Apr	3.3
H-plane	145466	7 Apr	3.3
45-plane	145472	7 Apr	3.3
-45-plane	145470	7 Apr	3.3
E-plane x-pol	145492	10 Apr	0
H-plane x-pol	145493	10 Apr	0
45-plane x-pol	145491	10 Apr	0

Xerox copies of the scans with model fit overlays are attached. The original chart recordings with color traces have been safely archived - no digital data was available from the range chamber used for these measurements.

Model

The measurements were fit to the following model:

> Radiation from TE_{10} mode electric field across rectangular aperture of the pyramidal horn with wavefront radius curvature of 60". The aperture dimensions which fit the measurements (without polarizer) best were as follows:
>
> | | |
> |---|---|
> | Best fit openings | 10.02" x 7.08" |
> | Physical openings | 10.02" x 7.07" |

The polarizer was modelled as a forward motion of the phase center by 4" for patterns in a plane perpendicular to the plane of the vanes. That is, the polarizer effectively extends the rectangular horn in one 45 degree plane but not in the other. In addition, the vanes modify the field distribution across the horn aperture.

This modified field distribution constrains the electric field along the vanes to zero and reduces the effective aperture size. The model fits for the feed with polarizer were:

Aperture for polarizer along slats -	10.52 x 7.36
Aperture for polarizer perpendicular to slats -	10.82 x 7.50

Figure 2 summarizes the model amplitudes and phases for the E, H, +45, -45 degree planes for the feed without polarizer and the feed with polarizer in two linear polarizations (along and normal to the vanes). Table 1 gives the measured and model phases at 6.7° along with model values.

Feed astigmatism

The holography feed model with polarizer observing a horizontally polarized satellite can be fit with an astigmatism of 19 mils peak-peak surface deviation at the edge of the dish in the vertical direction. The sense is such that the holographic maps (uncorrected for feed phase) will result in rigging the antenna with the top and bottom of the dish high. There is also a small amount of 45 degree astigmatism (10 mils peak-peak) induced by the polarizer. Figure 3 shows the surface deviation, which the model predicts, has been rigged into the antenna as a result of ignoring the feed phase. Most of the error is astigmatism which can be corrected with the new subreflector leaving a residual rms error of 2.62 mils for 10 dB illumination.

Figure 4 shows the surface deviation, which the model predicts, would be rigged into the antenna with the use of the feed without polarizer oriented with horizontal polarization.

Feed asymmetries

The feed phase patterns with polarizer (especially the 45 degree x-pol) show some asymmetry. There is a squint of the phase beam by up to 0.67°. Tests done to find the origin of this squint showed the largest source to be unequal spacing of the polarizer vanes. Without support, the center vanes bow quite badly so that the nominal 0.875" spacing varies from 0.80" to 0.95". These asymmetries result in a maximum difference between the data and model of 8° (10 mils equivalent surface deviation) at the edge of the dish.

Frequency dependence

Without the polarizer there is little if any frequency dependence of the phase pattern from 11.8 to 12 GHz. While no measurements were made over a wider frequency range the agreement with theory is expected to be adequate to predict behavior over a wider frequency range. The polarizer introduces significant frequency dependence over 200 MHz presumably by reflection of the orthogonal linearly polarized TE_{01} mode (which is shorted at the feed transition) back into the feed. The refractive index for the polarizer (E-field aligned with plates) is 0.8 which gives -19dB reflection from each face. The magnitude of the frequency dependence is about 10° peak-peak or an equivalent astigmatism variation of 14 mils p-p.

Linear polarization position angle

Without the polarizer the feed phase patterns are independent of the transmitted linear polarization angle at least for angles within 45° of alignment. When the transmitter is cross-polarized there is little or no signal until the polarizer is inserted to convert the transmitted polarization to circular. With the polarizer in front of the feed some transmitter position angle dependence is measured. The largest effect is that on the total phase for which a rotation of the transmitter produces an almost equal phase change. The phase pattern or equivalent astigmatism also varies with transmitter position angle presumably because of the excitation of the orthogonal polarization mode and the change of propagation mode through the polarizer. The effect is about the same as the frequency dependence and is equivalent to an astigmatism variation of 14 mils p-p.

Comparison with holography data

An attempt has been made to compare the feed phase model with differences in holographic maps taken with different feed configurations.

a) Map 216 (horizontal +30°) - Map 215 (horizontal)
The 10 dB taper weighted rms in the difference map is reduced from 9.5 to 9.1 mils following correction with the feed phase model. When linear, quadratic and tilts are removed the reduction is from 6.6 to 6.2 mils.

b) Map 215 (horizontal) - Map 213 (normal holography)
The 10 dB taper weighted rms in the difference map is reduced from 10.1 to 9.6 mils following correction with feed phase model and removing no other terms (mapcor.big with no options).

Conclusion

The feed measurements without the polarizer are very clean, conform with theory and show little if any asymmetry or rapid frequency dependence. When the feed corrections are applied to the difference between maps 216 and 215 there is a reduction at about the expected level. Therefore it is very unlikely that there is any significant diagonal astigmatism introduced by the feed alone. On the other hand, the feed phases with the polarizer depend on frequency, show considerable asymmetry, and are sensitive to small mechanical variations. In the worst case the 10 mils p-p diagonal astigmation of the model could be increased by asymmetries and frequency dependence as follows:

Model diagonal astigmatism	10 mils p-p
Asymmetry	10 mils p-p
Frequency dependence	14 mils p-p
rss	20 mils p-p

for a worst case rms contribution of about 4 mils. The failure of the model to significantly reduce the difference between maps 215 and 213 is evidence that asymmetries and frequency dependence do have a significant effect. However if we assume that map 215 has no diagonal astigmatism and the diagonal astigmatism in the difference map is all from the polarizer (and now largely rigged into the dish) the amount from the difference is 20 mils p-p.

Therefore we can safely assume that the diagonal astigmatism rigged into the dish is 20 mils p-p or less. More holography measurements are needed to provide additional checks on the differences with and without the polarizer.

Table 1 - Measurements and Model

Plane	Polariz.	Pol	Rot	Measured Phase at 6.7°	Corrected to zero offset	Chart #	Model deg
E	OUT	-	-	27	35	145474	35
E	H	45	45	25	33	145476	41
E	I	45	45	27	35	145476	41
H	OUT	-	-	36	44	145466	43
H	H	45	45	43	51	145466	46
H	I	45	45	42	50	145466	46
45	OUT	-	-	17	25	145472	25
45	H	0	90	15	23	145472	29
45	I	90	0	13	21	145472	22
45	OUT	-	-	18	26	145470	25
45	H	90	90	27	35	145470	34
45	I	0	0	9	17	145470	18
E	H	45	45	38	38	145492	41
E	I	45	45	38	38	145492	41
H	H	45	45	45	45	145493	46
H	I	45	45	48	48	145493	46
45	H	45	90	33	33	145491	32
45	I	45	0	20	20	145491	20

POL = Angle between E vector and polarizer slats
ROT = Angle between rotation vector and slats
H = "holography" position of polarizer
I = "holography" position rotated by 90°

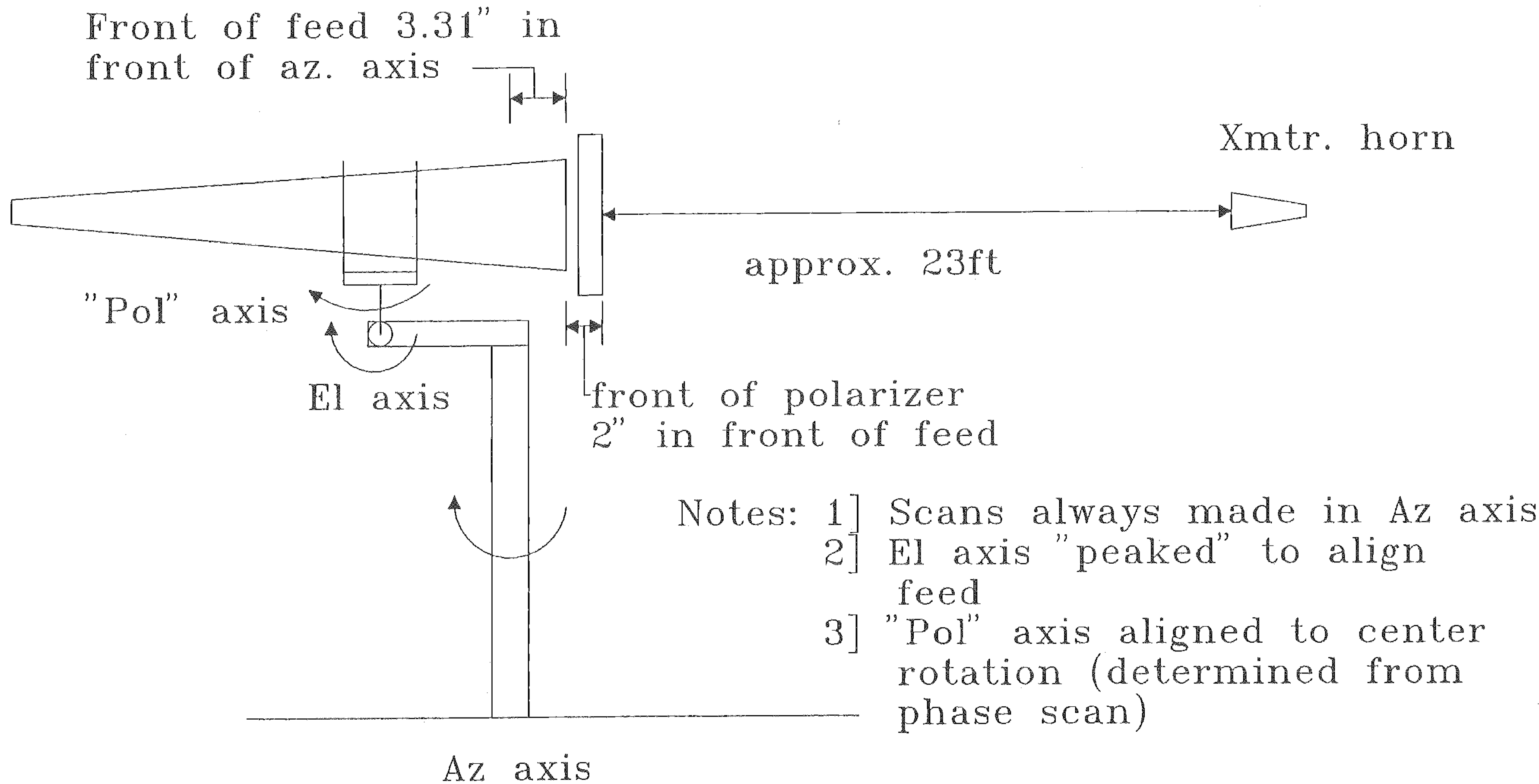


Figure 1. Antenna range set-up

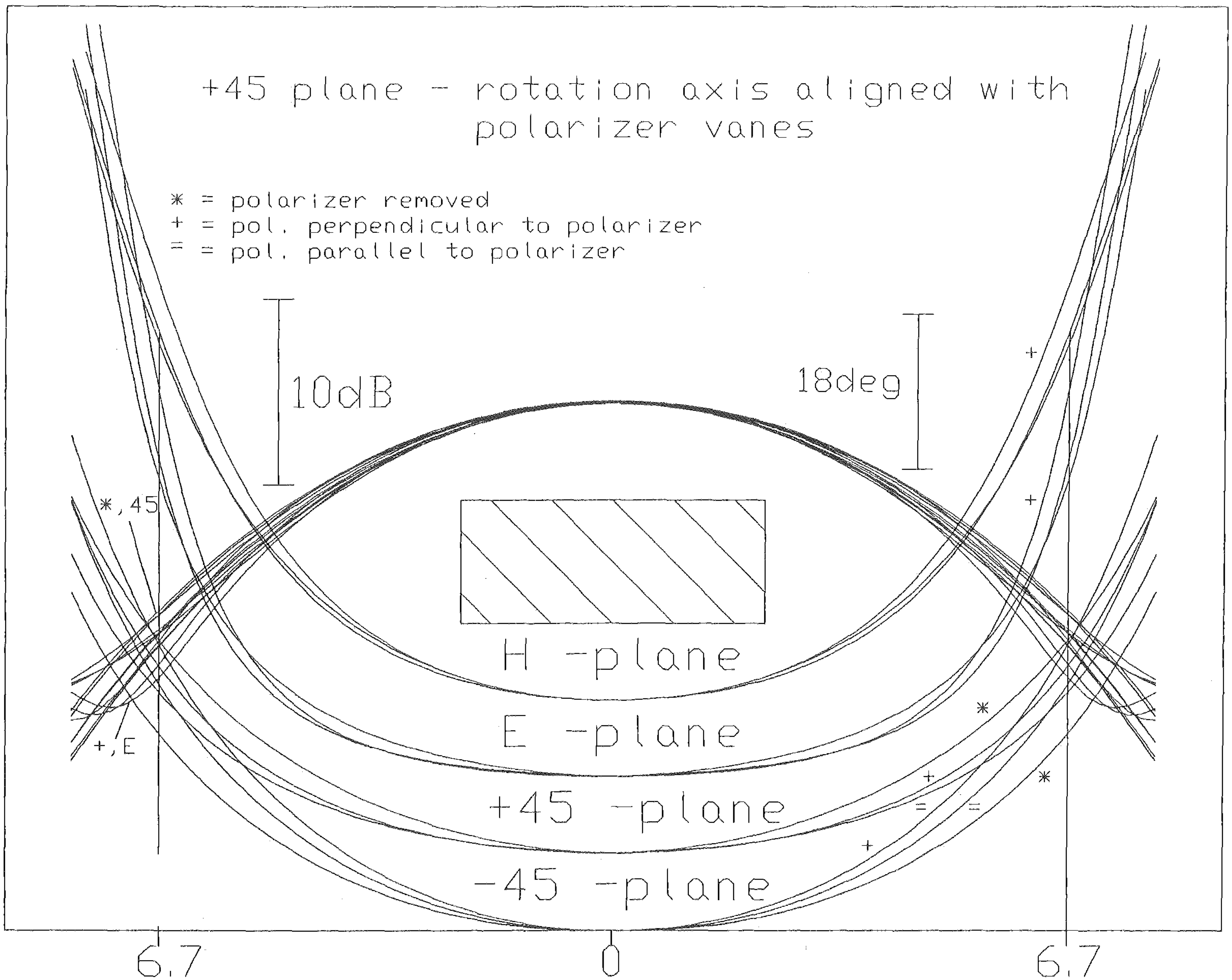
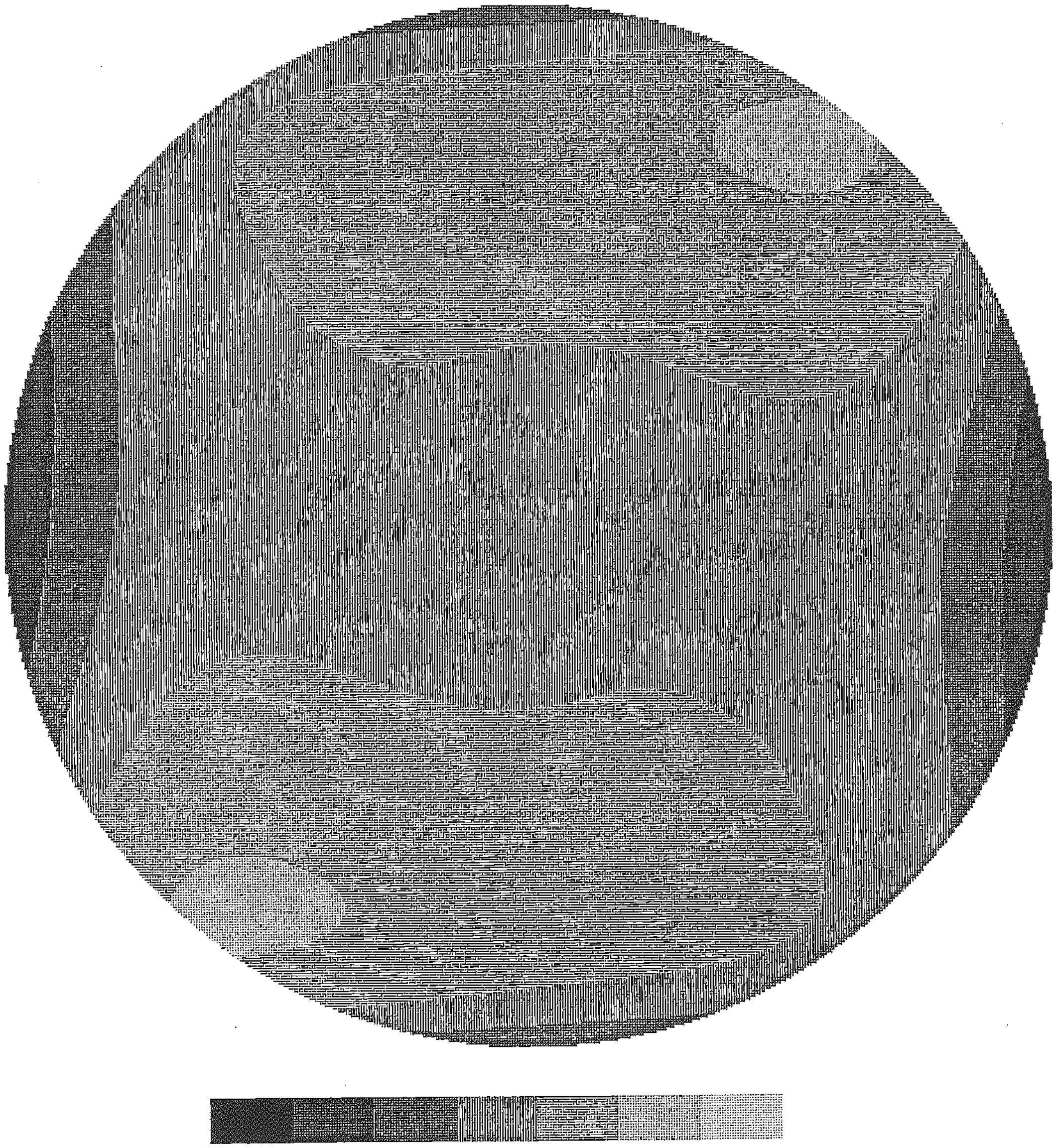


Figure 2. Holography feed phase and amplitude



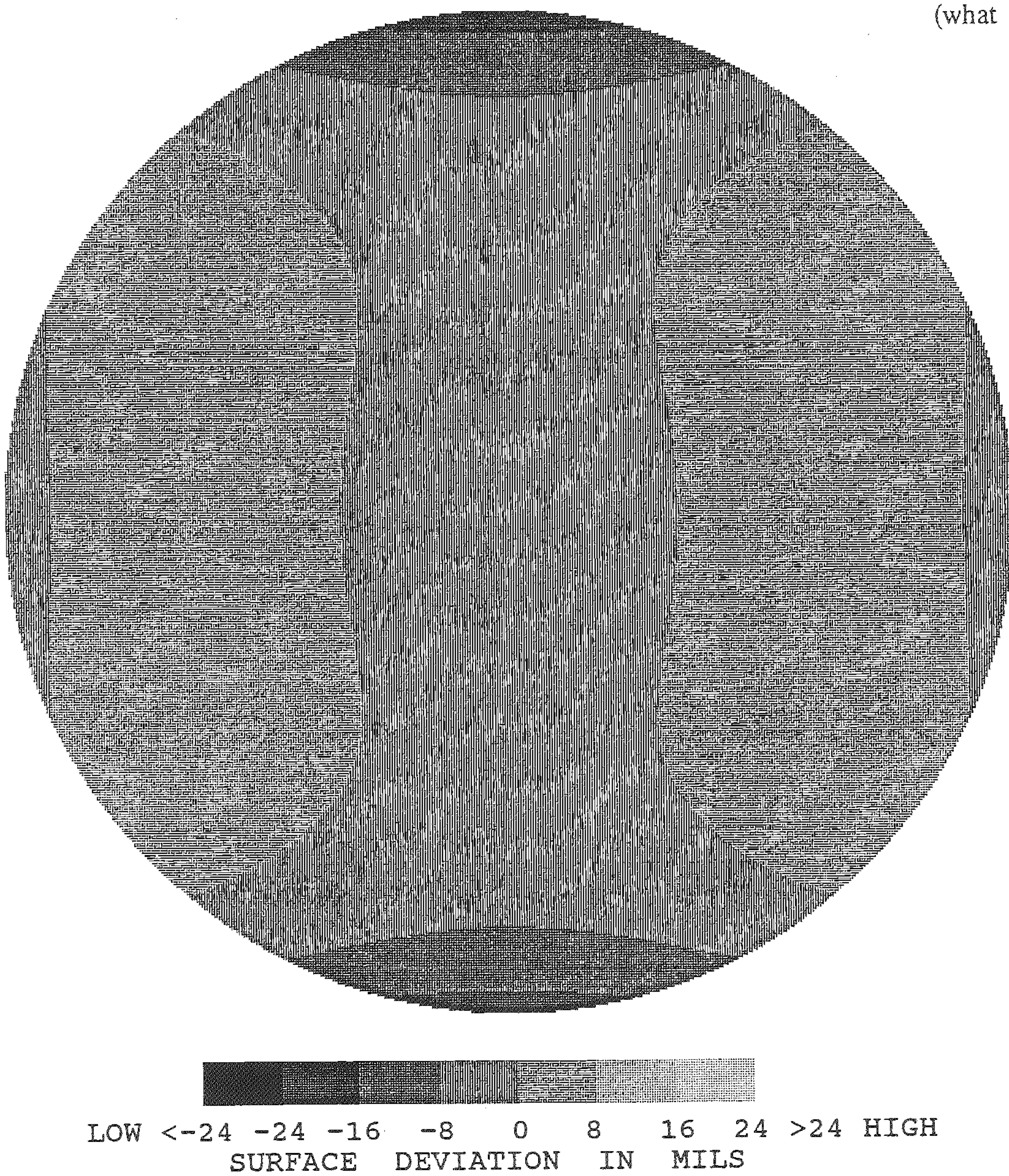
Delta_Tilt_Az = 0.0 (mdeg)
Delta_Tilt_El = -4.1 (mdeg)
Delta_Focus = -0.01 (cm)

Amp_cos(2*theta) = 10.87 mils
Phi_cos(2*theta) = -12.86 degrees

		VERTICAL ASTIG. REMOVED
Phase rms, weighted by 1-0.94(r/60)**2	= 3.14	2.00
Phase rms, weighted by 1-0.68(r/60)**2	= 3.92	2.62
Phase rms, inner, weighted by amplitudes	= 1.72	1.33

Figure 3. Feed Phase with Polarizer in "Holography" Position

Linear Feed
horizontal pol -
- correction
(what would be rigged in?)

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Delta_Tilt_Az  =     -6.4 (mdeg)
Delta_Tilt_El  =      0.0 (mdeg)
Delta_Focus    =   -0.01 (cm)

Amp_cos(2*theta) =    7.87 mils
Phi_cos(2*theta) =   90.01 degrees
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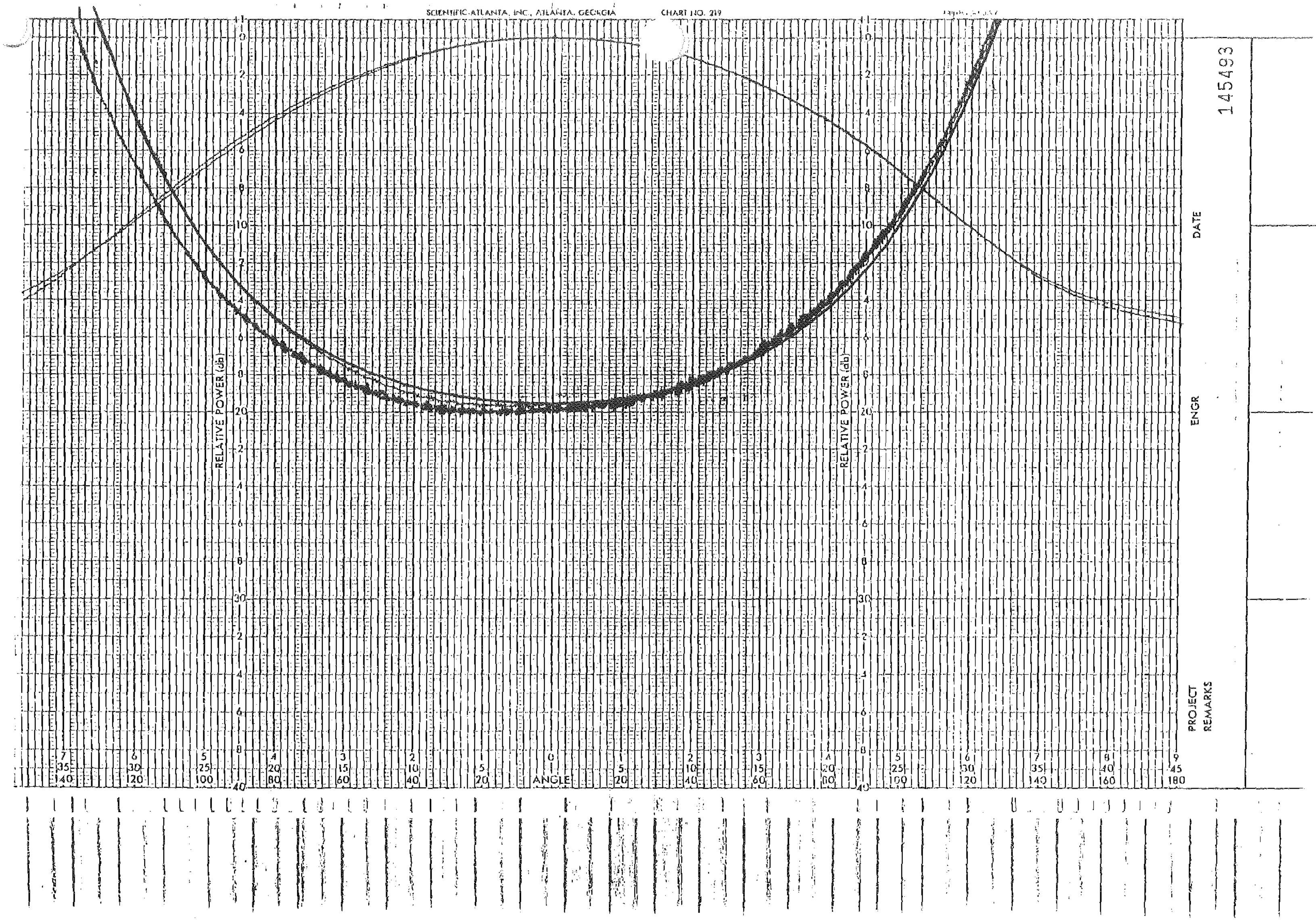
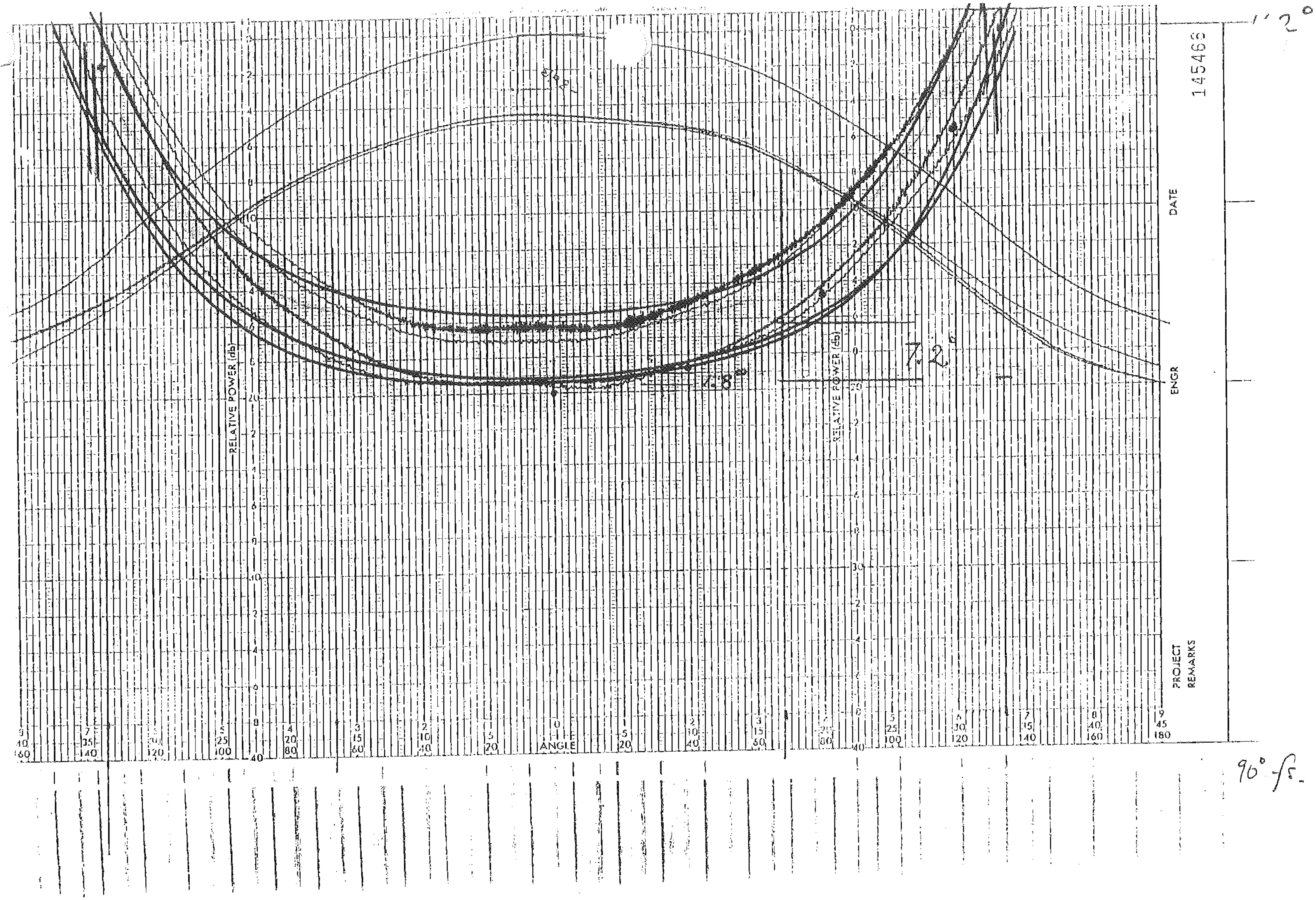
		VERTICAL ASTIG. REMOVED
Phase rms, weighted by 1-0.94(r/60)**2	= 2.31	1.26
Phase rms, weighted by 1-0.68(r/60)**2	= 2.89	1.66
Phase rms, inner, weighted by amplitudes	= 1.25	0.90

Figure 4. Feed Phase for Horizontal Polarization (Polarizer Removed)


SCIENTIFIC-ATLANTA, INC., ATLANTA, GEORGIA
CHART NO. 219
145493
DATE
ENGR
PROJECT
REMARKS
RELATIVE POWER (db)
RELATIVE POWER (db)
ANGLE

H - plane X - pol

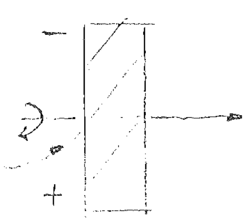


6.7° half angle

fit $a\theta^2$ ... 29°

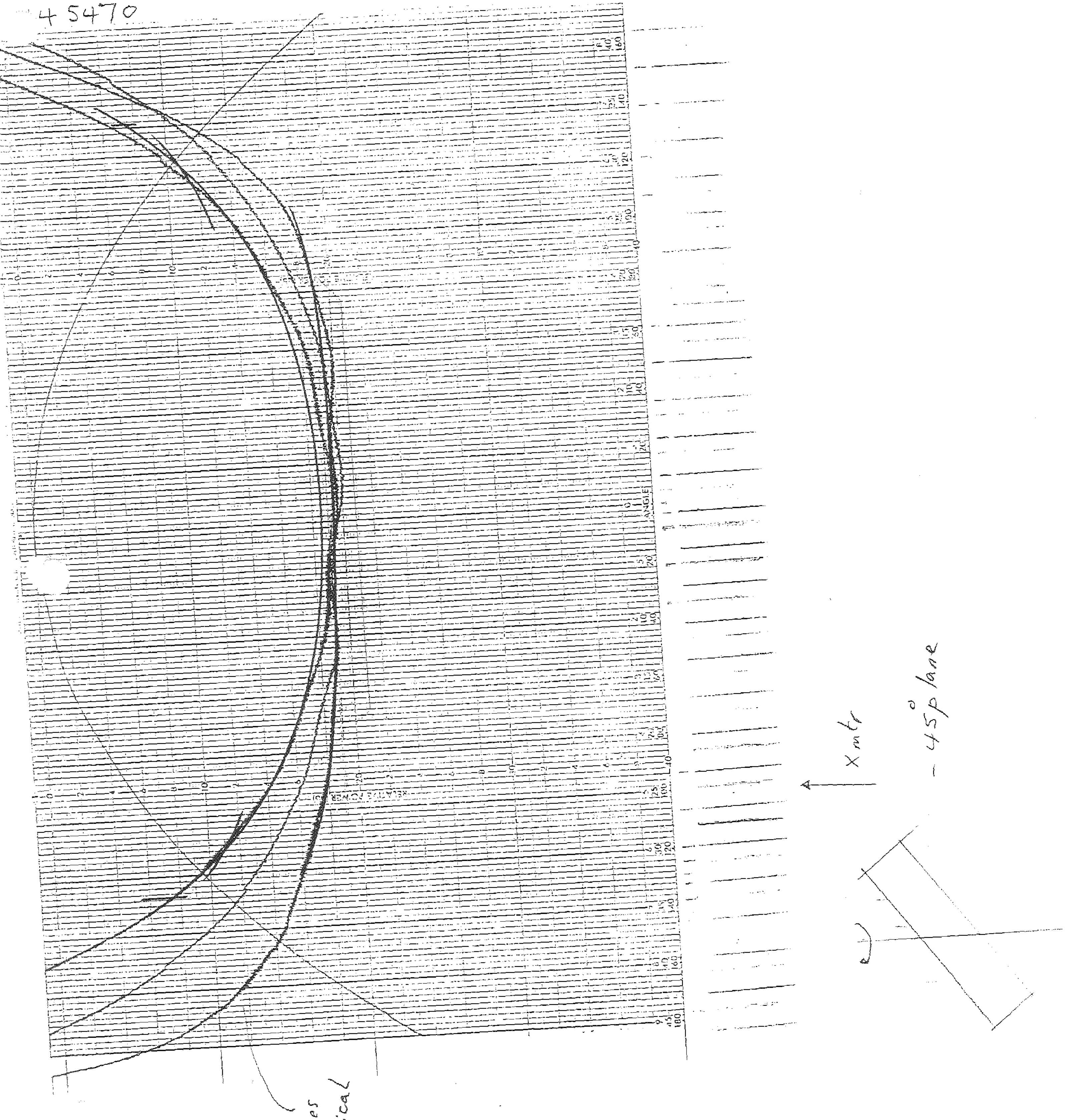
$+ b\theta^4$ 13°

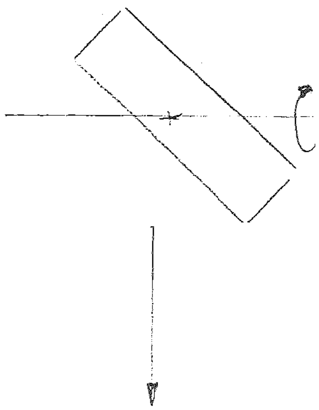
Looking into feed



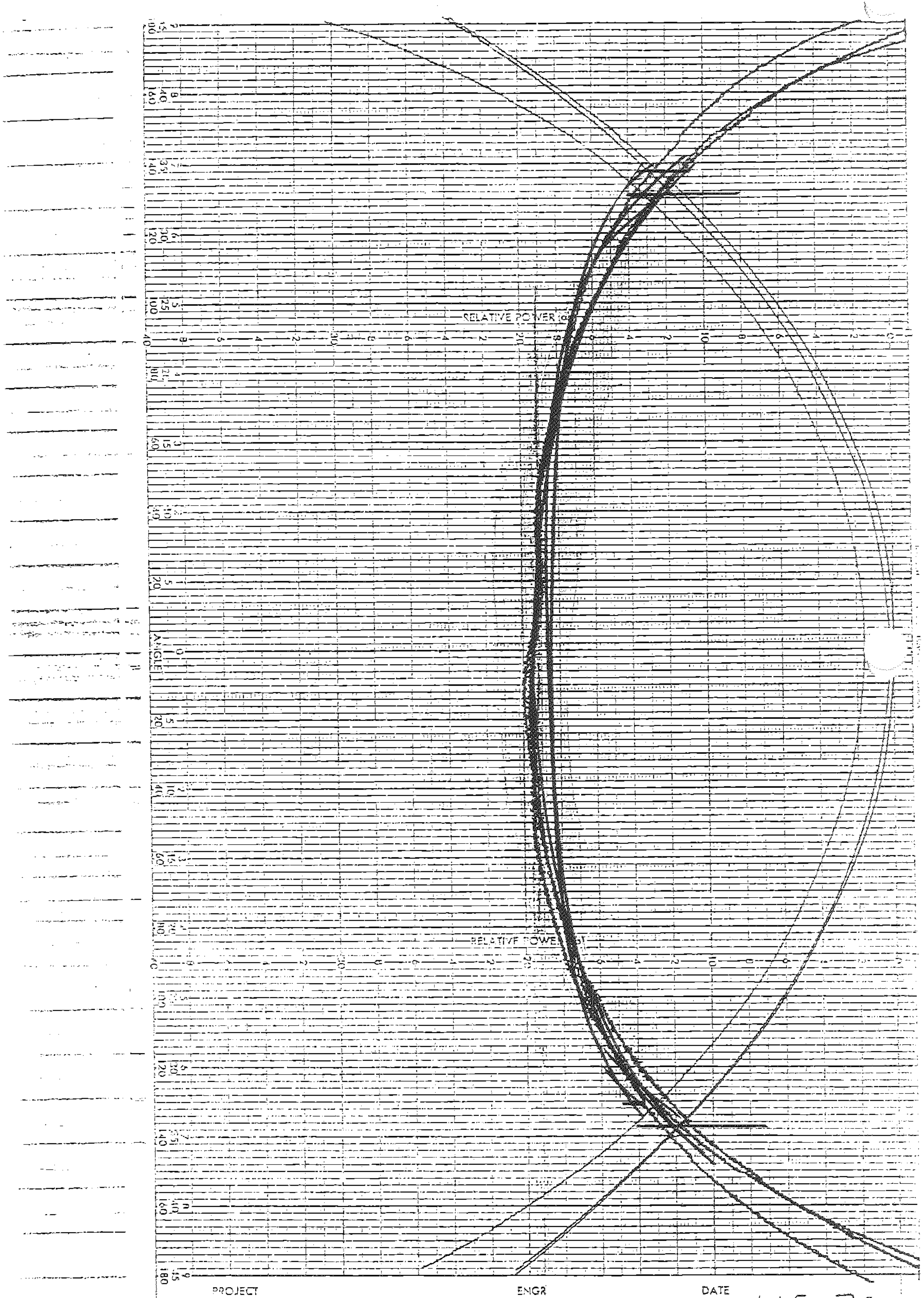
H-plane

45470

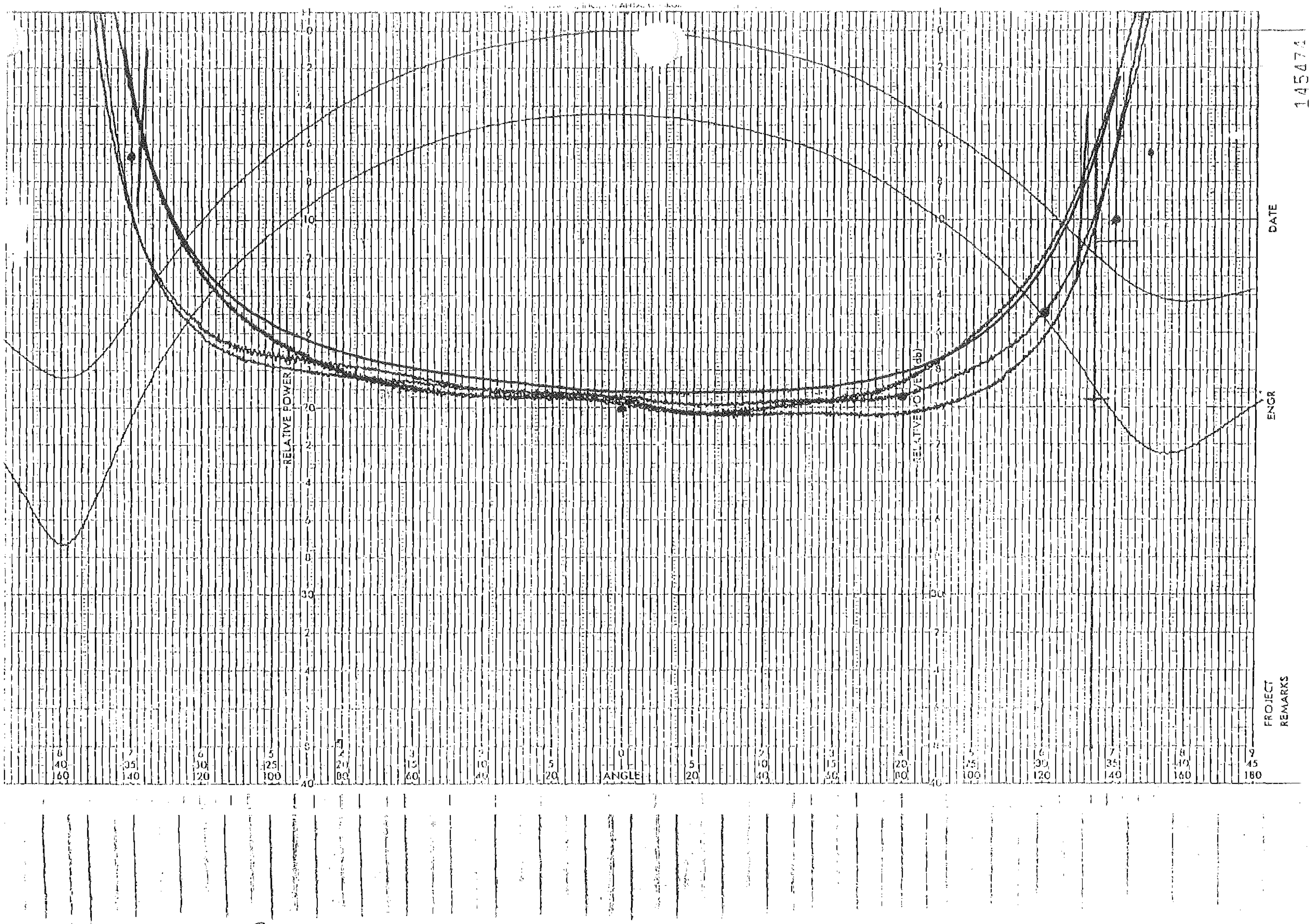




45° plane



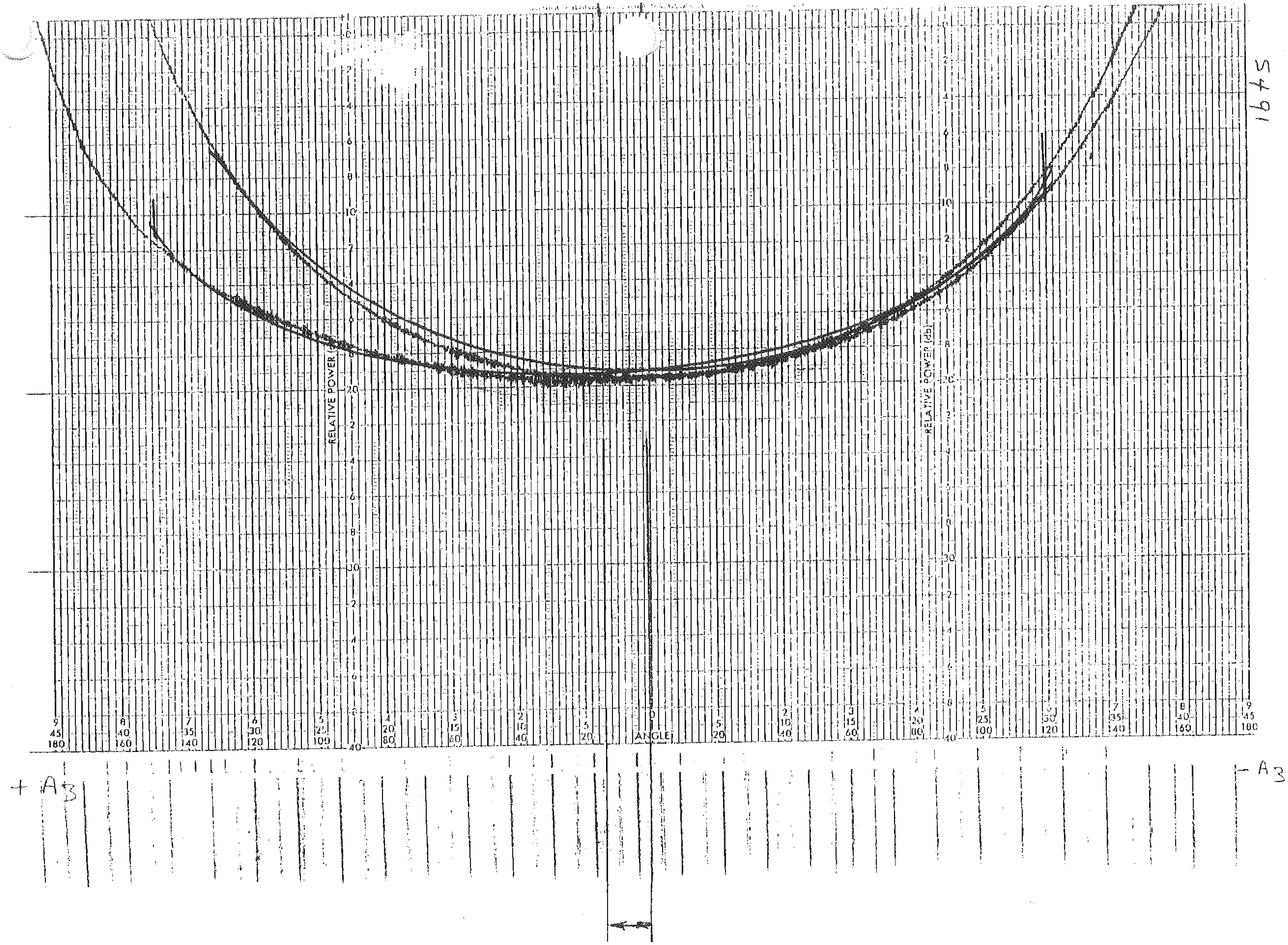
145472



$a\theta^2$

$+ b\theta^4$ 18°

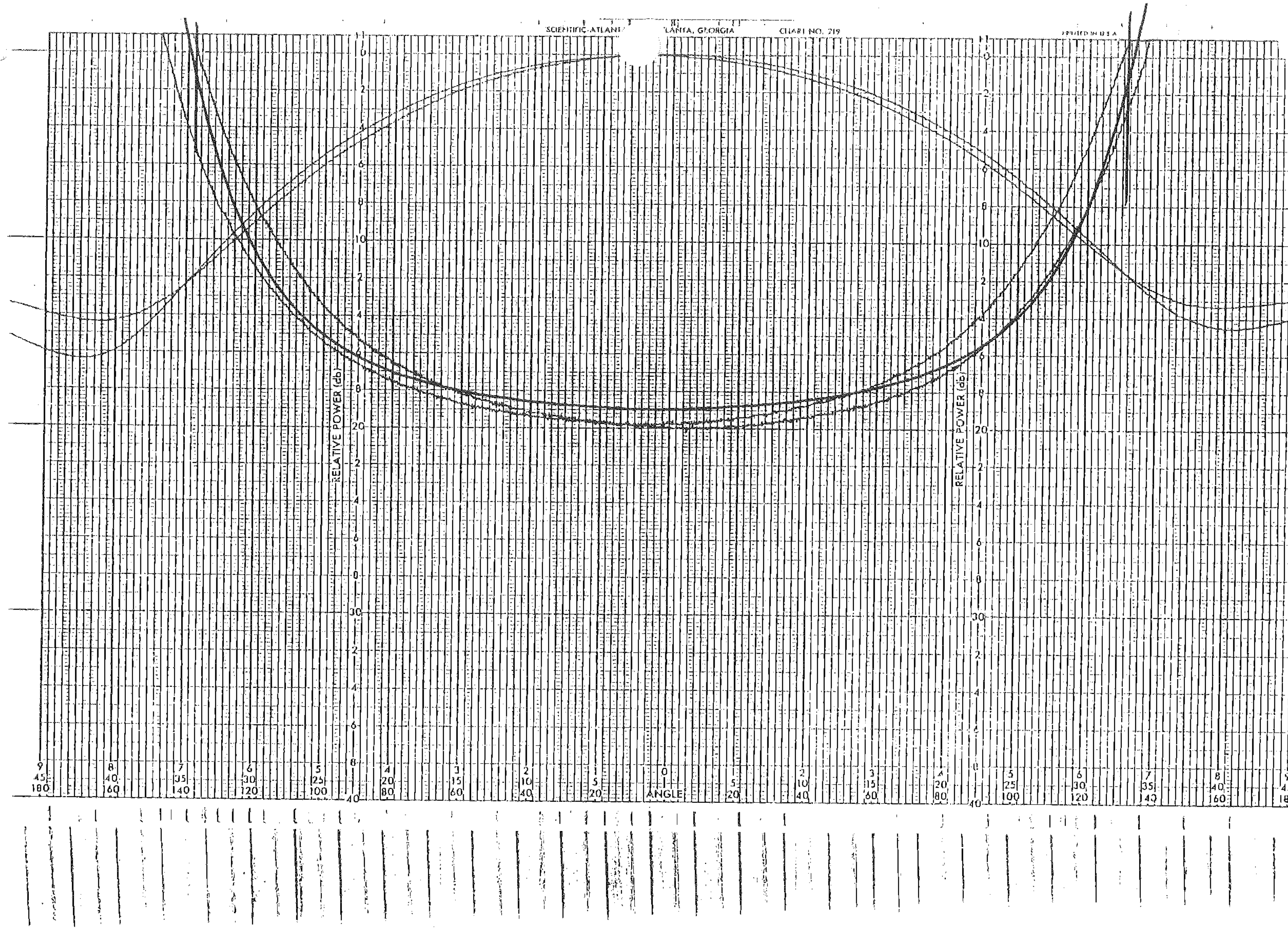
E-plane



45 plane X-pol

0.67° phase beam squint

145492



E - plane X - pol