E83-10271

HS 230-0019-1679

NASA-CR-170537

SEPT 1982

THEMATIC MAPPER

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Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

CONTRACT NAS 5-24200

FLIGHT MODEL
PRESHIPMENT REVIEW
DATA PACKAGE
VOLUME IV - APPENDIX
PART G - MISCELLANEOUS SYSTEM DATA

Article IV -3A

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Appendix 3.1

Vibration & Acoustic Test Reference Documentation

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HUGHES

INTERDEPARTMENTAL CORRESPONDENCE

TO JL Engel/SG Oxley/
FD McLaughlin/RA Amador

CC Distribution B
Data Bank (2)
File

SUBJECT Thematic Mapper Program; Revisions to Specification GSFC 400.8-D-201

DATE 9 June 1981:227jp
REF. HS236-2154
FROM E. A. Dawson
ORG. 44-03
BLDG. S41 MAIL STA. B353
LOC. SC EXT. 88182

Contract Modification Number 70 incorporates the Change Notices listed below, copies of which are attached for your review. Please forward your comments to me by 15 June 1981 and advise if these Change Notices are acceptable as written, and whether incorporation thereof affects either cost or schedule. Note that NASA/GSFC states in the contract modification that a credit proposal is due. I would appreciate some justification offsetting the need for a credit proposal.

GSFC 400.8-D-201, Revision B

Change Notice No.	Description
14	Deletes the shock test requirements and changes the sinusoidal vibration test requirements.
15	Deletes the contractor choice of performing either acoustic noise or random vibration test, deletes acoustic noise tolerances and changes the acoustic noise test levels.

If you have any questions, please call me.

Appendix 3.2.1

IA01 Test Reference Documentation

SANTA BARBARA RESEARCH CENTER
A Subsidiary of Hughes Aircraft Company

INTERNAL MEMORANDUM

TO: J. B. Young

CC: Distribution
Data Bank (7)
Optics File

DATE: 4 March 1982

REF: 2221-525
HS236-7876

FROM: P. E. Thurlow

BLDG. B11 MAIL STA. 78

EXT. 6267

SUBJECT: Flight Model, Test IA-01:
Coarse Focus/MTF/Shim Requirement

Coarse focus MTF was run vs Z axis location of the reticle wheel in standard IA-01 test configuration and procedure. After test methodology and results were stabilized, two coarse focus runs were made to show repeatability of results.

The attached graphs show MTF along/cross track vs Z axis offset from home position of the reticle wheel, using detector = Band 4, Channel 9, and spatial frequency = 30 meter bar, (107.7 cycles per inch reticle bar frequency).

MTF

Over various trial runs - peak MTF was in the range .49 ± .01 both along track and cross track.

Best Focus Location

From the plotted data, center points of the MTF patterns were found to be:

Cross Track Center = Home - .012" ± .001"
Along Track Center = Home - .024" ± .001"

Best focus location is selected at center of the Cross Track MTF profile (HOME - .012"). From the along track profile it is estimated that along track MTF will be approximately 0.47 ± .01 at the compromise focus.

Shim Thickness Recommendation

From the dial indicator readings tabulated for Home position and collimator focal plane, Home is found to be - .066" on the Z axis relative to the focal plane (i.e., Home lies between the focal plane and folding mirror).

The "best focus location" described in the previous section lies - .012" with respect to Home, or - .078" from collimator focus. In order to move "best focus" to collimator focus, a move of .078" in the + Z direction is required for the TM focal plane image. This requires a move of the focal plane array from its present location toward the secondary mirror. A reduction in shim thickness is therefo[re] indicated.

Flight Model, Test IA-01: Coarse Focus/MTF/Shim Requirement

The shim thickness reduction, based on the above best focus of cross track image is:

$$\Delta T_{shim} = \left(\frac{EFL_{TM}}{EFL_{COLL}}\right)^2 (-.078")$$

$$= \left(\frac{95.995}{109.22}\right)^2 (-.078") = -.0602"$$

The <u>recommended</u> shim thickness reduction is larger, and is based on moving the compromise focus another 2 mils in the -Z direction (to - .014" with respect to Home). This location moves the along-track focus slightly closer to the along-track MTF peak (still about -10 mils away), and slightly further from the steep part of the along-track MTF slope. At the same time, the cross-track focus is still within 1-2 mils of peak MTF location. The resulting shim thickness reduction is:

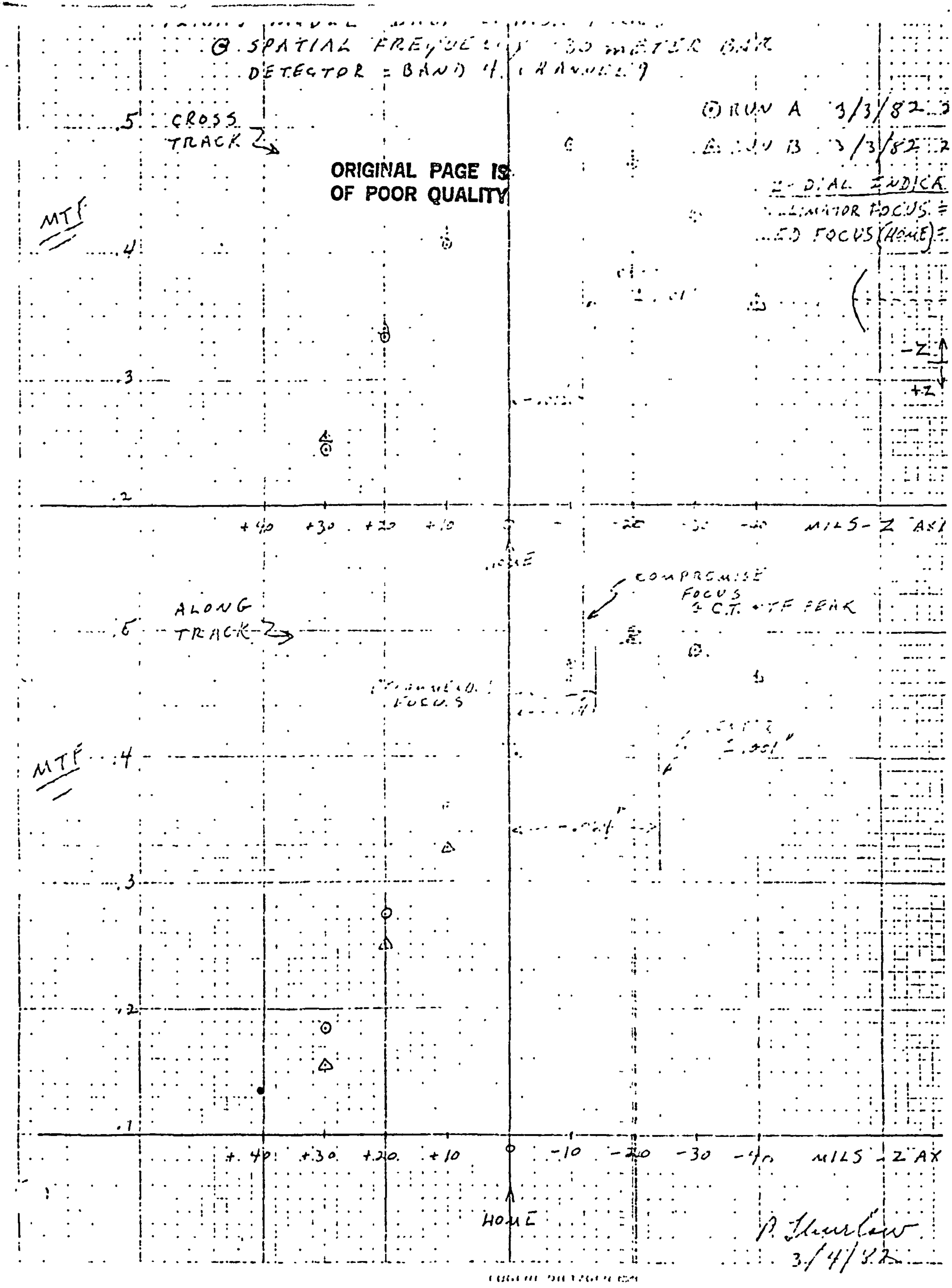
$$\Delta T_{shim} = \left(\frac{95.995}{109.22}\right)^2 (-.080") = \underline{\underline{-.0618"}}$$

P. Thurlow

Paul E. Thurlow

dz

Distribution: W. Balinsky
D. Brandshaft
R. Cline
E. Kelly
L. Long
W. O'Donnell
F. Phillips
G. Plews
T. Sciacca


SPATIAL FREQUENCY 30 METER BAR
DETECTOR = BAND 4
RUN A 3/3/82
RUN B 3/3/82
CROSS TRACK Z
MTF
.5
.4
.3
.2
+40
+30
+20
+10
-20
-30
-40
MILS - Z AXI
-Z
+Z
COMPROMISE FOCUS
ALONG TRACK Z
.6
.4
.3
.2
.1
+40
+30
+20
+10
-10
-20
-30
-40
MILS - Z AX
HOME
B. Thurlow
3/4/82

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SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

TO: J. L. Engel

CC: Data Bank (5)
Optics File
Distribution
L. M. Candell
R. N. Thomsen

DATE: 17 May 1982

REF: HS236-7992
2221-590

FROM: J. B. Young

SUBJECT: Effects on MTF for Flight Model System Due to Variation of Telescope Moisture Content

BLDG. B11 MAIL STA. 78

EXT. 6180

TM Flight Model bands 1-4 FPA were focused in IA01 without compensating for the effects of the graphite epoxy composite structure moisture content. The magnitude of this effect is calculated below.

The equation used to calculate the defocus (ΔF) caused by a change of the primary-secondary mirror spacing (S_{p-s}) is

$$\Delta F = -(M^2+1)\Delta S_{p-s}$$

where $\Delta S_{p-s} = S_{p-s}\,\Delta\alpha$ and

M is secondary mirror magnification
$\Delta\alpha$ is a change in microstrain due to a change in moisture content

Assuming that the FPA was focused during IA01 with a strain of 35×10^{-6} in./in., the defocus in orbit after the graphite epoxy structure has dried out will be

$$\Delta F = -(3^2+1)(22)(0\times10^{-6}-35\times10^{-6})$$
$$= 0.0077 \text{ inch}$$

The associated effect on MTF is obtained by converting this defocus (ΔF) to its equivalent value at the collimator focal plane and then using the MTF vs change of focus data generated in IA01.

$$\Delta F_{COLL} = \left(\frac{EFL_{COLL}}{EFL_{TM}}\right)^2 \Delta F$$
$$= \left(\frac{109.3}{96}\right)^2 0.0077 = 0.010 \text{ inch}$$

For convenience the IA01 MTF focus sensitivity curve is shown as Figure 1. From Figure 1 a change of 0.010 inch of focus changes the MTF from 0.485 to 0.46 for a ratio of 0.46/0.485 = 0.95.

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17 May 1982
HS236-7992
2221-590

Effects on MTF for Flight Model System...

The predicted effect on final flight model SWR is obtained by extrapolating protoflight (PFM) data. SWR for PFM were in the range of 0.41 to 0.46. Applying the flight model moisture defocus effect of 0.95 to these values would result in 0.39 to 0.44.

In conclusion, even though it would have been appropriate to compensate for at least a part of the moisture content effect the above analysis indicates that the effect should not jeopardize meeting the TM SWR specification of 0.35.

J. B. Young

James B. Young

dz

Distribution:	W. D. Adams	B11/39
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	D. G. Brandshaft	B11/40
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	D. Goetze	B11/101
	R. L. Hoelter	B11/101
	K. W. Hubbard	B11/101
	R. L. Julian	SC-S30/P314
	J. C. Lansing	B11/40
	D. L. Morrison	B11/40
	S. G. Oxley	SC-SC1/D335
	P. E. Thurlow	B11/78
	J. A. Walker	B11/73
	R. J. Wengler	B11/40
	E. M. Kelly	B11/101

Appendix 3.2.2

IA03 Test Reference Documentation

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SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

FILE COPY
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DO NOT REMOVE

TO G. Plews

CC. J. Campbell
R. Dick
E. Kelly
F. Nicholas
T. Sciacca
D. Young
Data Bank (6)

DATE 27 May 1982

REF HS236-8005
2221-600

FROM W. J. O'Donnell

BLDG B11 MAIL STA. 78

EXT 6373

SUBJECT IA03R Coarse Focus Determination, Cold Focal Plane

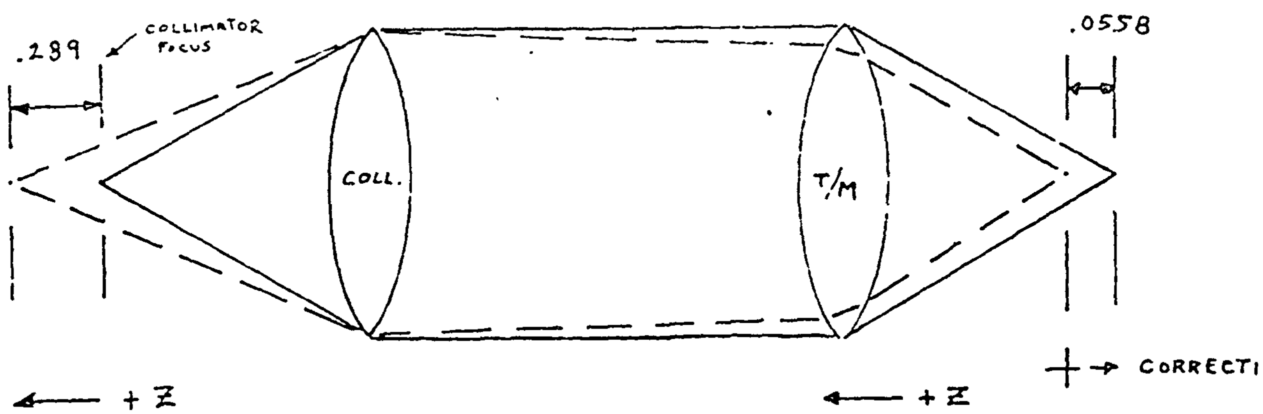
The Thematic Mapper cold focal plane best focus position was found to be .289 + ΔZ from the collimator best focus (long focus), or a .0558 + ΔZ at the T/M cold focal plane (short focus). This dimension was determined by the following formula:

$$\left(\frac{\text{Relay Optics System E.F.L.}}{\text{Collimator E.F.L.}}\right)^2 \times \text{Z Focus Error at Collimator Focus} = \text{Focus Error at Cold Focal Plane, or:}$$

$$\left(\frac{48}{109.225}\right)^2 \times .289 = .0558 + \Delta Z \text{ Focus Error (Short)}$$

Correction: Shim Increase $(-\Delta Z)$

(PARAXIAL LENS THEORY)



W. J. O'Donnell

W. J. O'Donnell

dz

Appendix 3.2.7

AC22 Test Reference Documentation

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SANTA BARBARA RESEARCH CENTER
A Subsidiary of Hughes Aircraft Company

INTERNAL MEMORANDUM

TO: J. B. Young
R. V. Howitt

CC: Optics File
Data Bank (6)

DATE: March 1, 1982

REF: 2221-520
HS236-7873

FROM: M. J. Grady

BLDG. B11 MAIL STA. 78
EXT. 6269

SUBJECT: TM Spectral Matching

In the proposed spectral matching test the Thematic Mapper is first calibrated using the 48" integrating sphere, and is then presented with a scene radiance of different spectral shape using a filtered source at the focal point of Collimator #3. The desired spectral radiance of this scene was determined as follows. On the basis of the spectral radiance curve for the 48" integrating sphere, (figure 1), the derivative of the radiance in each spectral band was computed assuming closest linear fit. Shaping the scene radiance amounts to modeling dL/dλ (where L = spectral radiance). Guidelines for doing this were taken from Table III of the GSFC Specification "Thematic Mapper System and Associated Test Equipment." The criterion taken from this table is the difference in dL/dλ between two scenes for a given band. Figure 2 depicts dL/dλ characteristics for the large sphere and the desired characteristics of the collimator, on the basis of the normalized GSFC spec criterion. Figure 3 shows the resulting spectral radiance.

Figure 4 gives the spectral radiance of Collimator #3, prior to insertion of filters, given the data in figure 5. The table below gives the desired filter characteristics as well as the filters chosen.

Band	λ(μm)	Desired Transmission Ratio Between End Points	Filter Chosen	Actual Transmission Ratio Between End Points
1	.45- .52	1: .83	Corning 4-70	1: .81
2	.52- .60	1: .78	Corning 1-57	1: .80
3	.63- .69	1: .46	Corning 4-69	1: .44
4	.76- .90	1: .41	Schott KG2	1: .39
5	1.55-1.75	1:1.38	Corning 4-67	1:1.32
7	2.08-2.35	1:1.56	Corning [illegible]-59	1:1.57

Figure 6 displays the transmission curves for the above filters.

TM Spectral Matching

It should be noted that the last column above represents nominal catelog values only. One of these filters is presently in-house (Corning 1-57); the rest will need to be ordered.

Figure 7 shows the test layout. The TM is oriented with its optical axis at 30° to the normal of an 18" flat which folds the collimator output. The flat is removed and the 48" integrating sphere placed in position. After calibration, the 18" flat is set back in place and measurements are made using the collimator output. After initial alignment, it will not be necessary to move the TM during the test.

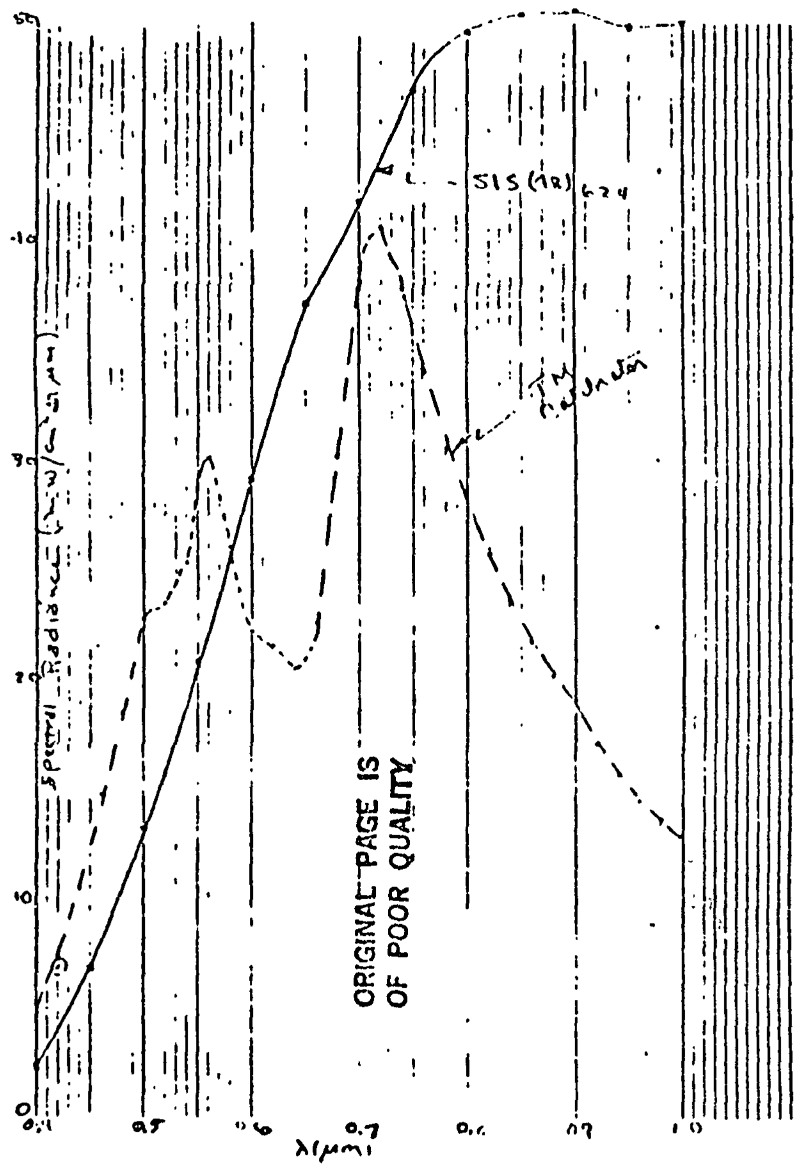
Michael J. Grady

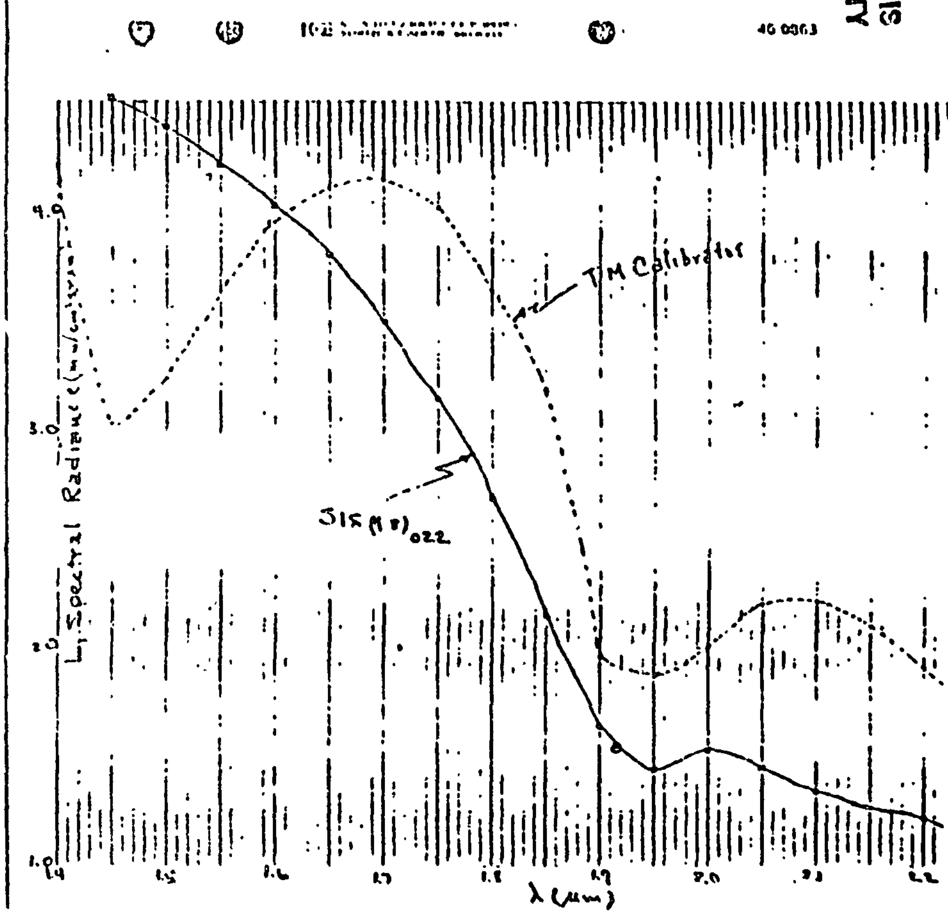
Michael J. Grady

dz

Distribution: D. Brandshaft
J. Engel
J. Kekoanui
C. Kent
J. Lansing
G. Plews
P. Thurlow
J. Walker

SPECTRAL RADIANCE OF 48" INTEGRATING SPHERE





dL/dλ VALUES FOR 48" INTEGRATING SPHERE AND IDEAL "SECOND SCENE"
(ARROWS POINT FROM SPHERE dL/dλ TO THAT OF "SECOND SCENE")

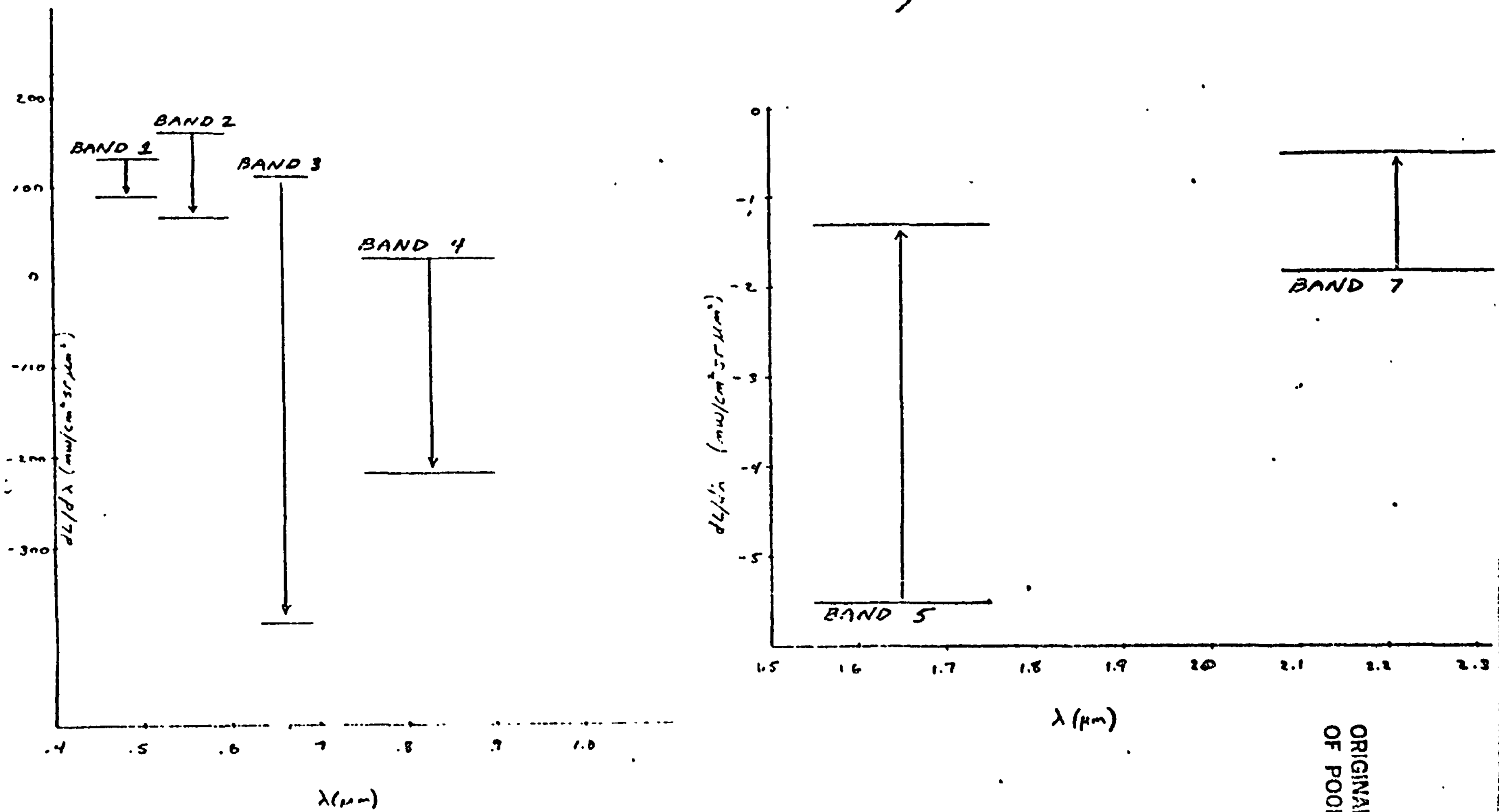


FIGURE 2

IDEAL SPECTRAL RADIANCE
OF "SECOND SOURCE"

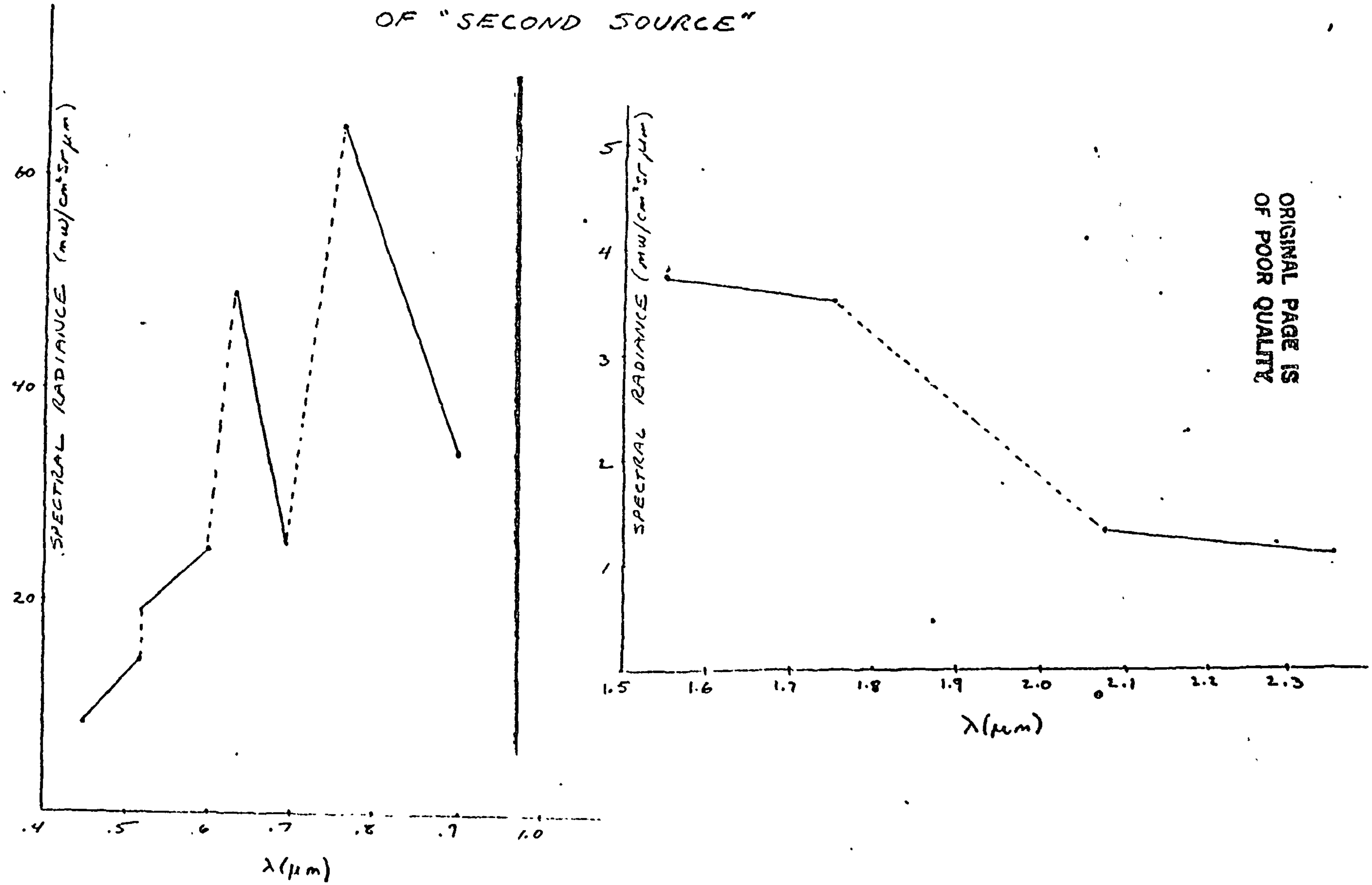


FIGURE 3

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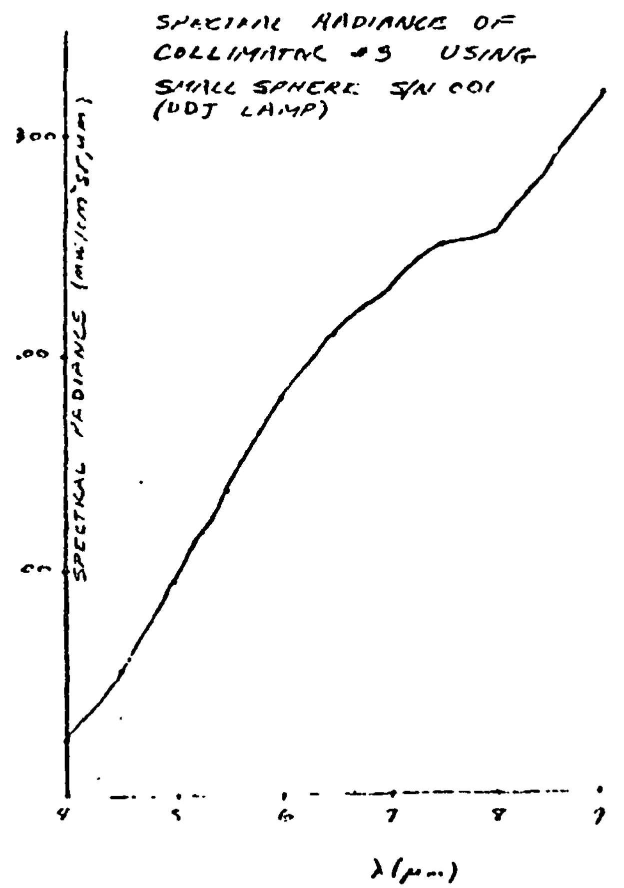
SPECTRAL RADIANCE OF COLLIMATOR #3



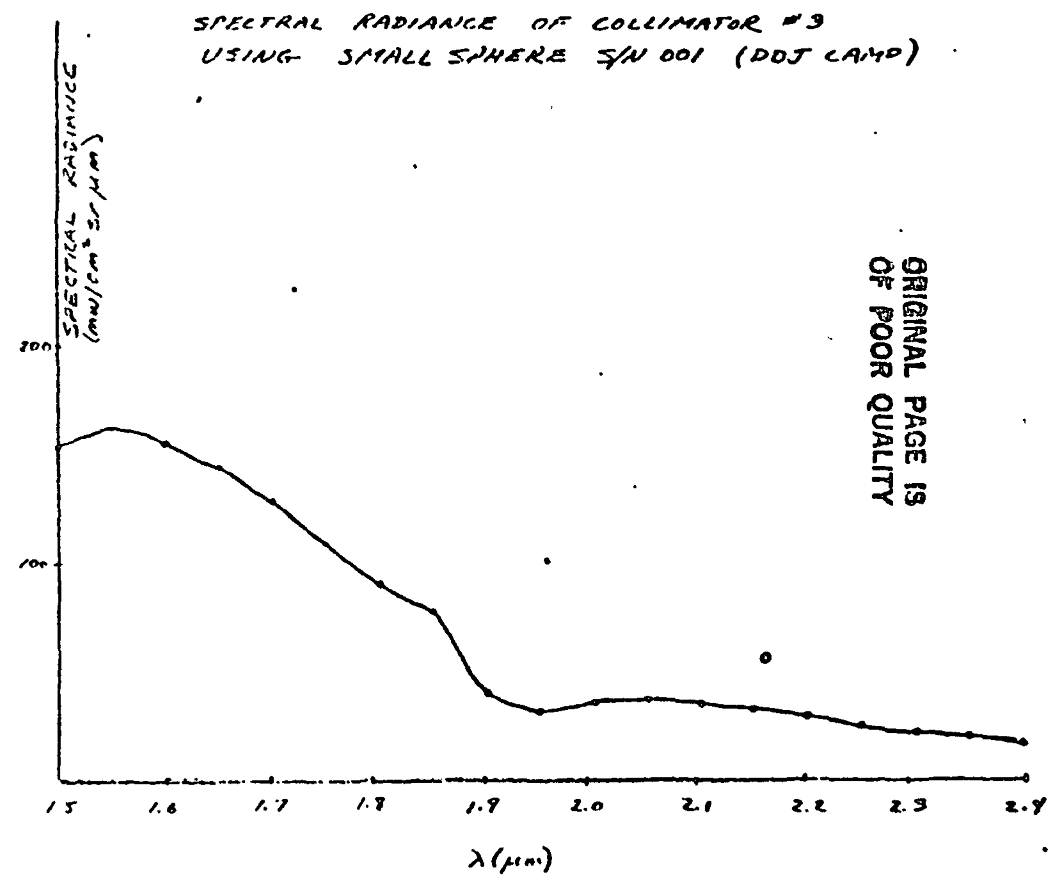
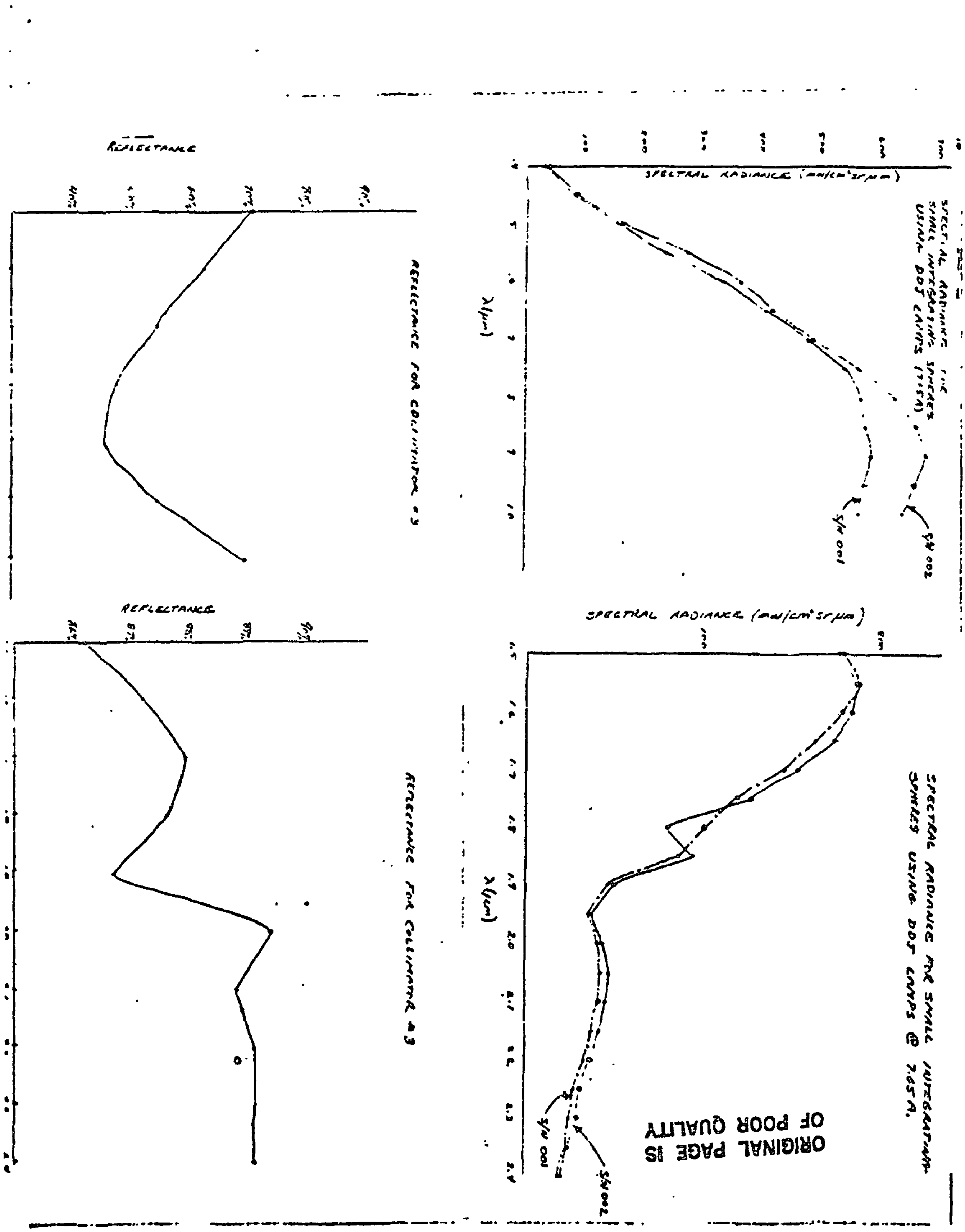


FIGURE 4



SPECTRAL RADIANCE FOR SMALL INTEGRATING SPHERES USING DDS LAMPS @ 7.65A.
SPECTRAL RADIANCE (mw/cm² sr μm)
λ(μm)
S/N 001
S/N 002
REFLECTANCE FOR COLLIMATOR #3
REFLECTANCE
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FIGURE 5

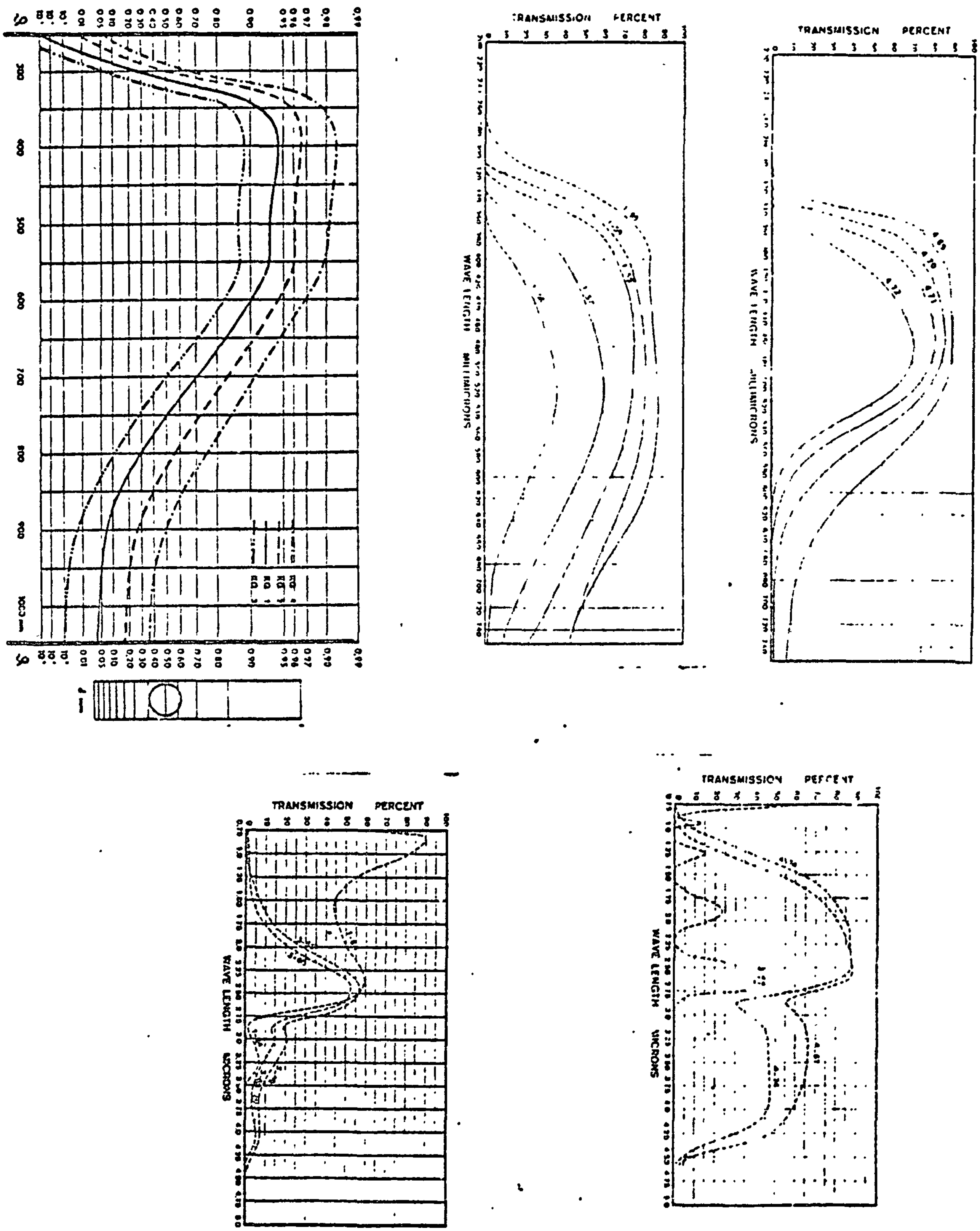
TRANSMISSION PERCENT
WAVE LENGTH MILLIMICRONS
TRANSMISSION PERCENT
WAVE LENGTH MILLIMICRONS
TRANSMISSION PERCENT
WAVE LENGTH MICRONS
TRANSMISSION PERCENT
WAVE LENGTH MICRONS

FIGURE 6

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SPECTRAL MATCHING TEST LAYOUT

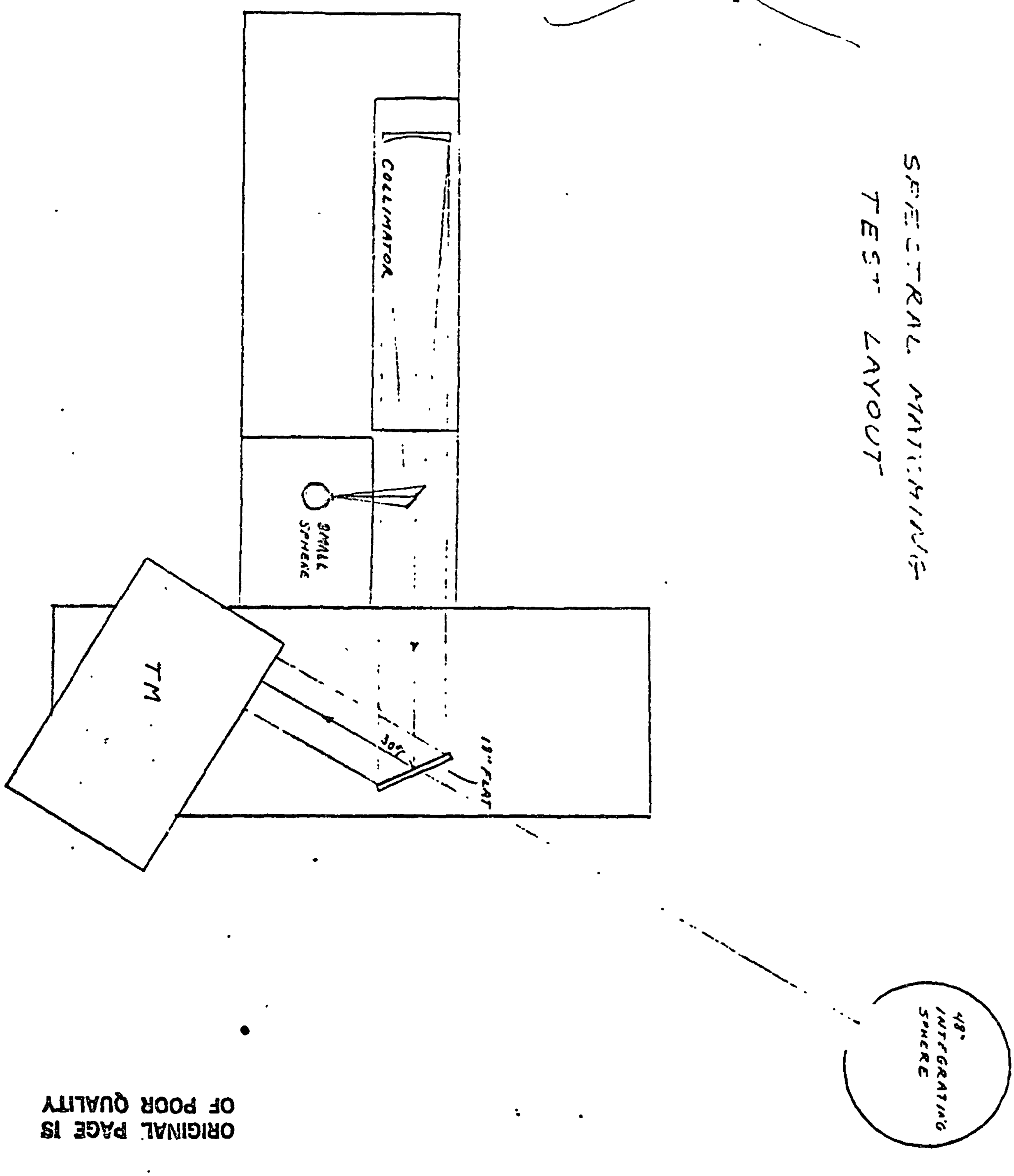

FIGURE 7

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HUGHES

INTERDEPARTMENTAL CORRESPONDENCE

TO: Jack Engel
ORG: SBRC
CC

DATE: 18 January 1980
REF. HS236-1727

SUBJECT: Rationale for Replacing AC01, Spectral Coverage Test

FROM: N. R. Dougherty
ORG. 40-91
BLDG. 373 MAIL STA. A340
LOC. SC EXT. 88865

INTRODUCTION

This IDC examines the potential and the rationale for replacing AC01 with a combination of existing data and analysis. The role of AC01 within the test program is considered in order to show that existing data can be analyzed to meet the program requirements. Representative examples of the proposed analysis are performed and are included.

REQUIREMENTS FOR AC01

From a system test perspective, AC01 meets two objectives. They are

1) Determine compliance with the specification for spectral coverage

2) Provide a data base for AC02 which will verify spectral matching, set the channel gains and calibrate radiometrically for bands 1 through 5 and 7

A prerequisite for both these objectives is obtaining relative spectral response curves for each band and channel of the Thematic Mapper system. AC01 would experimentally obtain this response.

The next section shows how existing spectral data can be used to analytically derive the relative spectral response.

RELATIVE SPECTRAL RESPONSE

The relative system spectral response, $R_b(\lambda)$, of the b band of the system is given by

$$R_b(\lambda) = \tau_{ob}(\lambda)\, \tau_{fb}(\lambda)\, R_b^D(\lambda) \qquad (1)$$

697C CS FEB 72

where

τ_{ob} = spectral transmission of optical system for band b

τ_{fb} = spectral transmission of filter for band b

R_b^D = relative response of detectors for band b

τ_{ob} is simply the product of the spectral reflectances of all the mirrors between the filter and object space. For bands 1 to 4, the mirror surfaces include the scan mirror, the primary, the secondary, and two SLC mirrors. For bands 5 and 7, the surfaces of the two relay mirrors between the ambient and cold focal planes must be also included. τ_{ob} is then

$$\tau_{ob}(\lambda) = \prod_{i=1}^{n} \rho_i(\lambda) \qquad (2)$$

where

ρ_i = average specular reflectance of ith mirror surface

i = mirror surfaces, beginning with the scan mirror

n = number of mirror surfaces: 5 for bands 1 through 4, 7 for bands 5 through 7

To illustrate the process, representative reflectance values from HS 236 — 5843 were substituted into Equation 2. The specific values used were from Table 4, S/N 202, Run 2. Assuming all surfaces have the same total spectral reflectivity function which to a satisfactory approximation is independent of the angle of incidence, the optical transmission was computed from Equation 2. Relative spectral response functions of InSb and HgCdTe detectors were obtained from the SBRC wall chart. Relative response for silicon was obtained from Elements of Infrared Technology: Generation Transmission and Detection by Kruse, McGlauchlin, and McQuistan.

Optical transmission (τ_{ob}), relative detector response (R_b^D), and their product ($\tau_{ob} \times R_b^D$), are graphically presented in Figure 1. Figure 1a covers the spectral range incorporating bands 1 to 4. Figure 1b covers bands 5 and 7. Figure 1c covers band 6. For convenience in interpreting the results, the nominal spectral region for each band is indicated at the top of the appropriate figure.

The significant curve in each figure is the bottom, $\tau_{ob} \times R_b^D$. When multiplied by τ_{fb}, this function becomes the relative spectral response, R_b, of the system.

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To illustrate this method, the system spectral response was calculated for band 2 and is presented in Figure 2. The filter response curve is from HS 236-5905, band 2, sample number 2-1 as measured by OCLI. The combined optics/detector response is from Figure 1 normalized at 650 nm.

From Figure 2, two observations are relevant:

1) The impact of the combined optics/detector response is chiefly to alter the average slope of the final system spectral response and to narrow slightly the half power point measure of bandpass.

2) The fine structure of the spectral response (e.g., the two humps) is contributed completely by the filter transmission function. This is because the combined optics/detector response function is very smooth and very nearly linear within the band.

ACCURACY OF SYSTEM RELATIVE RESPONSE

The procedure leading to the result presented in Figure 2 used data from three sources. The filter transmission curves are from witness samples coated at the same time the flight hardware was coated. These spectral transmission measurements were made using a Cary 14R, a precision dual beam instrument designed for this purpose.

The optical transmission was calculated from surface reflectance measurements performed by SBRC. The smoothness of the spectral reflectance in the spectral regions of interest permits a good estimate of this parameter throughout these regions. Typical detector spectral response curves were used since these detectors are both well understood and smooth in the regions of interest. Because of the smoothness of these functions, their product is well approximated by a straight line within any of the bands 1 through 5 and 7. Figure 1 illustrates this.

From Figure 2 it is clear that the filter response dominates the system spectral response. The combined optics/detector response primarily changes the slope of the top of the system bandpass and the bandwidth. If the combined optics/detector were not very nearly straight lines (within each bandpass), a more complex impact on the system response would result. Much more detailed data would then be required of the optics transmission and detector spectral response functions in order to analytically determine the system response.

In my judgement, the above procedure will produce a fully satisfactory system spectral response for two of the program objectives which would be satisfied by AC01. The result will be quite adequate for verifying compliance with the specification for spectral coverage. It will also provide a satisfactory spectral response function, or data base, for the radiometric calibration procedure of AC02.

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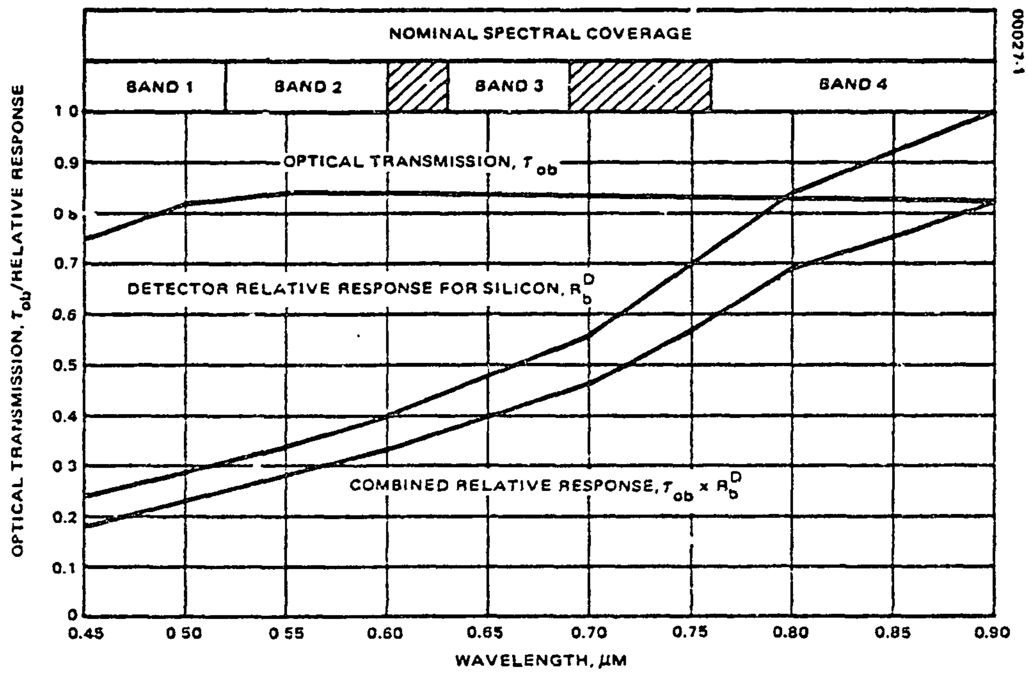

a) BANDS 1 THROUGH 4

FIGURE 1. COMBINED OPTICAL/DETECTOR RELATIVE RESPONSE

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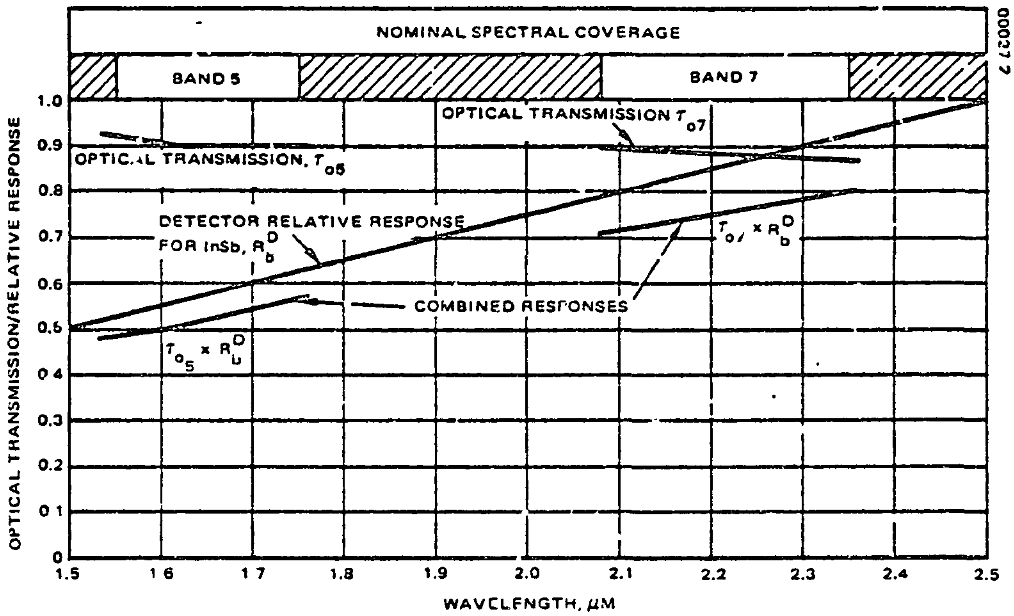
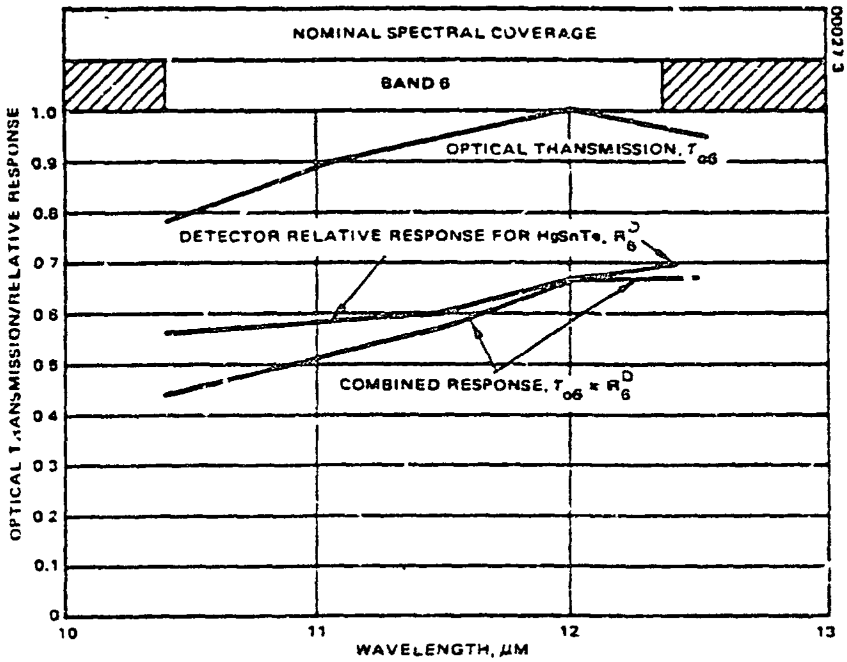


b) BANDS 5 AND 7

FIGURE 1 (CONTINUED). COMBINED OPTICAL/DETECTOR RELATIVE RESPONSE



c) BAND 6

FIGURE 1 (CONCLUDED). COMBINED OPTICAL/DETECTOR RELATIVE RESPONSE

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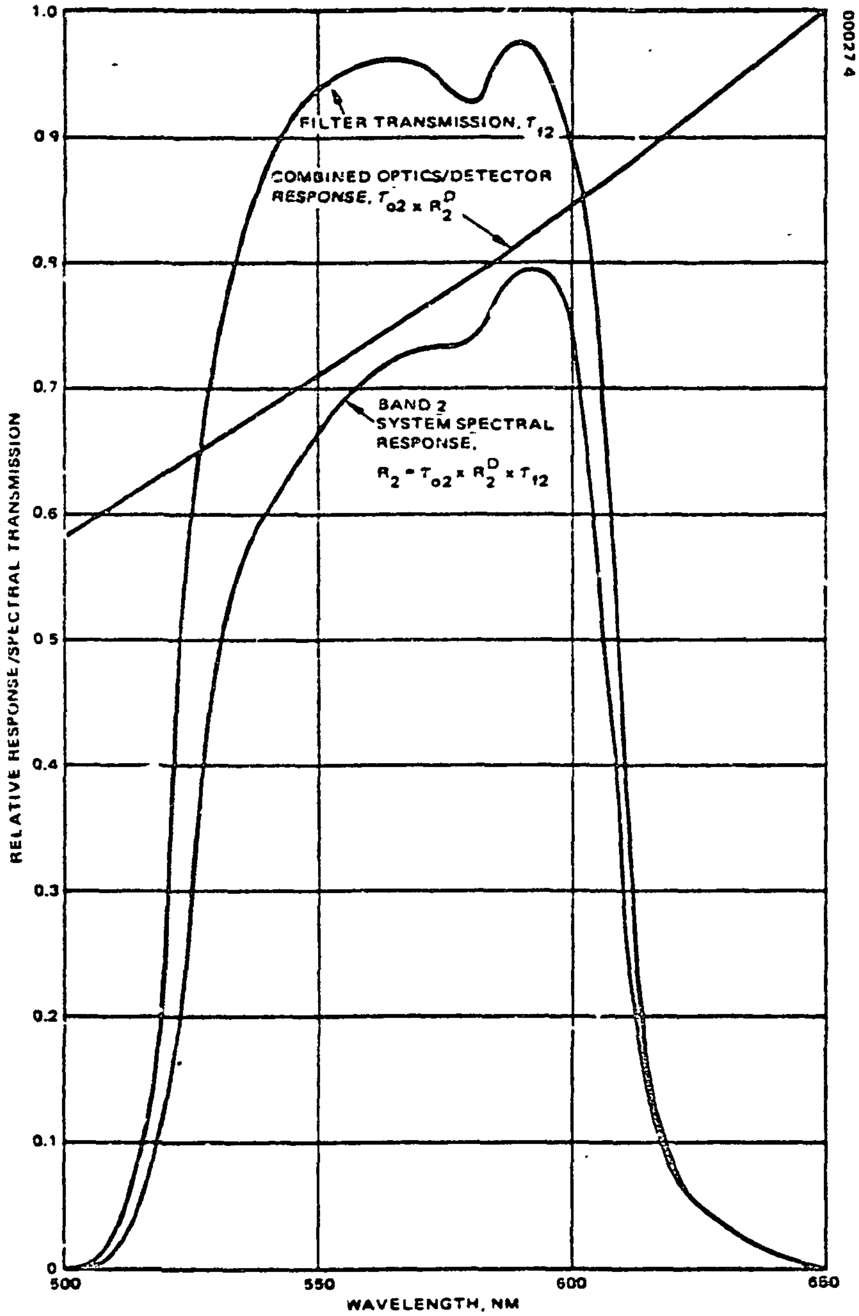

FIGURE 2. BAND 2 SYSTEM SPECTRAL RESPONSE

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Since the above procedure considers spectral response only on a band by band basis, it cannot determine compliance with the spectral matching specification. This issue is addressed in the next section.

SPECTRAL MATCHING COMPLIANCE

Spectral matching is concerned only with the matching of the spectral response of individual channels within a band. Consequently, the optics spectral transmission which effects all channels equally is not a factor. Only the filter response and the detector response are unique to each channel.

The detector spectral response is a property of the material for solid state detectors. The spectral response can be altered by doping, by changes in the device crystal structure, and by thin film coatings on the surface which enhance or retard the entry of specific wavelengths into the detector.

The Thematic Mapper detectors should not have any significant impurity gradient along the channel axes of the bands. The detectors of each band are simultaneously fabricated on a common substrate to produce a uniform crystal structure. An antireflection coating, if applied, would similarly have a negligible differential impact between channels since it would be applied simultaneously to the entire band.

Localized differences in the spectral transmission of the interference filter could cause variations of the spectral response between channels of a band. This is because the filter is placed very near the detector array so that each channel looks through a different part of the filter.

Localized variations in the spectral transmission function could occur in two ways. A lateral gradient in the thickness of the multilayer dielectric films will cause a lateral gradient in the spectral transmission function. However, when a filter is coated, it is mounted in a vacuum chamber position which minimizes any lateral thickness gradients. Purely statistical fluctuations in the coating thicknesses could also cause local variation in the spectral transmission function. The coatings are, after all, very thin, especially bands 1 through 4.

Spatial uniformity of the spectral transmission function was experimentally investigated using the witness samples for bands 1, 2, and 3. These three, of course, have the thinest film layers and would be the most susceptible to random layer thickness fluctuations. A description of the testing and the analysis is presented in the Appendix.

The experimental design described in the Appendix is tailored to produce a very conservative estimate of the probability of meeting the spectral matching specification. The most conservative estimate is that there is a 80 percent probability that all 96 channels will meet the specification. Less conservative, but readily defensible assumptions, lead to a

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97 percent probability that all channels will meet specification. For various reasons discussed in the Appendix, both estimates are conservative and the actual probability is most likely higher than 97 percent. However, hard data to support a higher value do not exist.

Finally, it is worth noting that if the allowed mismatch were 1 percent rather than 1/2 percent of the minimum saturation radiance, the probability of meeting the specification becomes virtually 100 percent. This is true even with the most conservative set of assumptions.

USER PERSPECTIVE

Users of the Thematic Mapper imagery will have a variety of unique interests and perspectives. However, they will share some common features of the Thematic Mapper radiometric imaging system. The more significant are discussed below.

Spectral Resolution. The spectral resolution of the Mapper is essentially determined by the bandpass filters. Fine structure of the earth's spectral radiance will not be observable below the resolution limits set by the filter bandpasses. Similarly, fine structure of the filter spectral transmission function or, more generally, the actual channel spectral response, will not significantly increase or reduce the information content.

Hypothetical cases can be constructed in which the information content would be effected. For example, if a user were trying to discriminate a feature such as a narrow spike in the earth's spectral radiance function, and the band within which the spike fell contained a coincident narrow but deep dip in the spectral response function, then the ability of the Thematic Mapper to reliably discriminate and measure the presence of the spike would be impaired. For this hypothetical case, the information content of the Mapper imagery would be clearly reduced.

However, the broad spectral bands specified for the Mapper were not intended to detect and discriminate narrow spikes. The bands were carefully selected based upon previous emperical data, to detect features which are characterized by broader spectral differences and which are also of interest to the user community.

Fortunately, the spectral filters which OCLI was able to supply do not have any deep dips within the nominal bandpass. The filters produce spectral response functions which will serve very well in characterizing the broad spectral radiance features of the earth.

Spectral Coverage. Since the fine structure of the Mapper band spectral responses will not significantly effect the ability of the instrument to characterize the broad spectral radiance features of the terrain, these questions arise: why is a tightly controlled specification of spectral coverage necessary and how important is it that the specification be met?

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To address these questions, it is necessary to recognize that the Thematic Mapper is part of an historical series of instruments. The immediate predecessor the Thematic Mapper is the MSS series. Other instruments, perhaps a more advanced Thematic Mapper, will surely follow.

If the imagery from an instrument were never compared to that produced by its predecessor and if that imagery would never be used as a reference for the imagery of future instruments, there would be little need to specify in detail the spectral response of the bands. Given two instruments with matching spectral responses between coresponding bands and appropriate radiometric calibration, an arbitrary terrain spectral radiance will produce the same set of measured values from each instrument. The ratio of the output between two bands in one will equal the corresponding ratio in the other.

If the corresponding bands in the two instruments do not have the same spectral response, an arbitrary spectral radiance will not generally produce the same results. The degree of difference in result depends in a complex way on the degree of difference in the two spectral responses.

The spectral response of the corresponding MSS bands do not match those of the Mapper either by design or specification. Thus, the empirical data b[illegible] developed by the MSS series to characterize, say, the growth and matu[illegible] of a wheat crop cannot be used without qualification as a Thematic Mapper data base. This is not to suggest that the MSS data will not be used to estimate the response of the Thematic Mapper, but only that the band ratios and radiance values will be different.

A correlation between the MSS and Thematic Mapper responses to various ground truth and atmospneric conditions will be developed as the Thematic Mapper and MSS are flown together on the same satellite. However, because of the bandpass differences, the useful data base for the Thematic Mapper will be developed by the Thematic Mapper.

From this discussion two conclusions are reached

1) If the Thematic Mapper should fail by a small margin to meet some part of the spectral coverage specification, the utility of the first instrument will not be effected in any way.

2) If the Thematic Mapper fails by a small margin to meet some part of the specification, the specification should be waived. However, the specifications for any future instruments should be modified to match that of the flight instrument. This modification will ensure that the data base developed by the initial Thematic Mapper will be valid for the future instruments.

Radiometric Calibration. A user perspective of radiometric calibration should reflect an appreciation of how the Thematic Mapper data will be used and how the atmosphere will effect the orbital radiometric performance. Consider first the atmospheric effects.

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All other things (season, latitude, etc.) being equal, the atmosphere will effect the apparent spectral radiance of a point on the earth's surface. For the solar reflection bands (1 through 5 and 7), atmosphere's absorption and scatter will alter the following:

1) The spectral irradiance of the scene on the ground and the geometry of the irradiance. Depending on the atmospheric aerosol content and structure, the dominant irradiance of the scene can range from direct sunlight (on a cloudless, high visibility day) to pure diffuse (when the scene is in a cloud shadow).

2) The atmospheric path spectral radiance. Single and multiple scattered light from aerosol (Mies) and molecular (Rayleigh) scatter will be superimposed upon image forming light reflected from the scene.

3) The image forming light from the scene will be attenuated by atmospheric spectral transmission.

The Thematic Mapper will have very limited ability to destinguish between the scene and the atmospheric path spectral radiance. Consequently, atmospheric conditions can significantly alter the spectral data collected by the Thematic Mapper. Moreover, the atmosheric phenomona which can cause these effects are often highly localized.

All this is simply to point out that the atmosphere can significantly alter the accuracy with which scene spectral radiance can be obtained from Thematic Mapper data. If sufficient information is available about the atmospheric aerosol structure, the Thematic Mapper data can be much improved by atmospheric modeling. However, unless the spectral path radiance and transmission are considered, accurate scene spectral reflectance estimates will only be available when the atmosphere is clear.

The atmospheric path radiance and transmission will be dealt with in one of two ways. If the local aerosol structure of atmosphere is available from other Landsat D instrumentation, then modeling of the atmosphere can be used to correct the data for scene spectral reflectance. Otherwise, empirically developed measures and/or ground observations will be used to establish when the atmosphere is sufficiently clear and to make small corrections for the atmospheric effects.

At this point, it is helpful to again recall that the data base which will permit a quantitative interpretation of the Thematic Mapper's imagery also will be empirically derived. Measurements obtained from previous instruments will provide a useful first estimate, but the ultimate data base must be derived from the Thematic Mapper itself.

With this background, it is possible to rank in order of importance those radiometric properties which will most concern a user of Thematic Mapper imagery. In my judgement, the following sequence is appropriate.

Radiometric Stability and Predictability. Since the data base for Thematic Mapper imagery will be empirically derived over considerable time, the radiometric performance of the Thematic Mapper must be highly stable and predictable. The requirement here is that the Thematic Mapper radiometric response at a particular point in the orbit be known with respect to its response at all previous times. This can be achieved by built-in stability, by correcting for such variables as focal plane temperature, by inflight calibration, or by some combination. Provisions for all of these, of course, are incorporated into the Thematic Mapper specifications and design.

Inflight calibration here implies only that the radiometric response can be a corrected to match that of a previous time. No level of accuracy, either absolute or relative between bands, is implied. The historical value of empirically derived data will be preserved if this correction can be made.

Dynamic Range. It is essential that the scene radiance plus the atmospheric path radiance fall within the dynamic range for each band and channel. This condition must be met for all scene and atmospheric conditions of serious interest to users. On the other hand, too much dynamic range will not make optimum use of the digitizer. A compromise which meets this requirement is specified as the minimum saturation radiance.

Signal-to Noise. The analog signal-to-noise plus the quantization noise associated with the digitizing process determine the accuracy, with which a particular pixel's spectral radiance can be determined. This should be as high as current detector technology permits.

Relative Band-toBand Calibration Accuracy. If the relative calibration accuracy between bands is high and two instruments have well matched spectral response functions, then the data base band ratios developed by one instrument can be applied with minimal correction to the other. However, even without a high relative accuracy, surface features of known spectral reflectance (e.g., fresh snow on a clear day) can be used to quickly relate two instruments.

In the case of the first Thematic Mapper, the previous instruments (MSS series) did not have the same spectral responses in the comparable channels. Thus, the MSS data base will not be directly applicable.

Absolute Calibration Accuracy. Absolute calibration needs to be accurate enough to permit the dynamic ranges of the channels to be correctly set. A high accuracy should be helpful in quickly relating the imagery of a new instrument to the data base produced by a previous instrument. However, as noted above, a scene of known reflectance can also be used to quickly relate the responses of the two instruments.

Absolute calibration is necessary if the atmospheric aerosol structure is available and atmospheric modeling is used to correct the flight imagery.

<u>Fine Structure of Spectral Coverage.</u> It is only important that future instruments which will use the Thematic Mapper data base match the spectral coverage of the first instrument.

Of these six radiometric properties, the first three are clearly more essential to the Thematic Mapper user than the last three. If the instrument is stable, the dynamic ranges are correct and the signal-to-noise ratio is adequate, a valid data base can be developed to quantitatively interpret the Thematic Mapper imagery. Precise relative (i.e., between bands) and absolute radiometric calibration, while useful and desirable, are much less critical to the user. This is true because the data base will be empirical and because a resonably good correlation between instruments can be developed from a combination of ground based measurements and orbital data.

The above discussion is not intended to suggest that the specifications for relative and absolute radiometric calibration be relaxed nor that the radiometric calibration test (AC02) be changed in any significant way. It does intend, however, to point out that small improvements in the accuracy with which radiometric calibration is performed are of very limited value to a user. It follows, then, that significant commitments of program resources would not be justified to achieve small improvements in radiometric calibration i.e., improvements in the order of 1 to 3 percent.

It is quite possible that the relative spectral response generated in AC01 would be more precise than that obtained from existing data using the procedure illustrated in the section Relative Spectral Response. However, this is not necessarily the case. While conceptually sound, AC01 is a complex test which will require a lot of time to perform. In any case, it is unlikely that the few resulting differences in relative spectral response would alter the relative or absolute radiometric calibration by as much as 3 percent. An uncertain improvement in the radiometric calibration accuracy would provide little justification for performing AC01.

SPECTRAL MATCHING TEST

This section describes a simple modification of AC02 which would permit spectral matching to be verified. The test is similar in concept to the test described in the Appendix, but is designed to test the entire instrument.

The modification consists of including a minimum of one additional radiometric data collect at an appropriate integrating sphere radiance level for each band. The additional data collects would be performed with spectral filters covering the aperture of the Mapper. The spectral filters would, on a band by band basis, conservatively approximate the slope differences between the flat and sloping spectra of Dr. Vincent Salomonson's 26 March 1979 Memo.

For bands 1 through 4, Wratten Filters 66, 40, 34A, and 102, respectively, are suggested. Each of these filters exaggerates the slope difference specified in Dr. Salomonson's memo. Meeting the specification with these filters would therefore mean that the actual specification would be exceeded.

The Wratten filters are available in 250 mm by 250 mm format on a special order, 60 day delivery basis. Four such filters, taped together, provide a 500 mm by 500 mm filter which will cover the Thematic Mapper aperture. The tape should be narrow and opaque or the filters should overlap slightly to avoid leakage.

The spectral data which Kodak normally provides on Wratten filters is not sufficient to select appropriate filters for bands 5 and 7. With more spectral data, suitable Wratten filters can probably be selected. Alternative filters are also available from a variety of sources, e.g., Corning, Jena, Schott, etc.

It should be noted that bands 5 and 7 are significantly less likely to have spectral matching problems. The filter dielectric layers are much thicker and thus less subject to small local statical variations in thickness. Also, the bands are well removed from the wavelength at which the detector (In-Sb) cuts off. Thus, if bands 1 through 4 were tested and passed, bands 5 and 7 would be unlikely to fail.

The integrating sphere radiance which should be used with each filter needs to be carefully selected to place the resulting in band radiance (i.e., sphere plus filter) at 80 to 90 percent of the minimum saturation radiance for the band. This will minimize the impact of quantizing and of analog channel noise on the measurement. Choosing the correct integrating sphere radiance is simply a matter of multiplying the average in band filter transmission times the candidate in band integrating sphere radiances and selecting the one immediately below 90 percent of minimum saturation radiance. To ensure that at least one radiance level is suitably placed at the upper end of the dynamic range, it would be prudent to obtain a filtered radiance on each side of the chosen valve.

An analytical procedure similar to that outlined in the Appendix could be followed to analyze the data. However, the following procedure would be simpler:

Assume V''_{bc} is the mean value of the Mapper digital output of band b, channel c when the appropriate Wratten filter is placed in front of the aperture. V''_{bc} would then be corrected using the calibration constants (gain and offset as functions of focal plane temperature) to produce the corrected value, V_{bc}

Dr. Salomonson's memo expressed a preference that the gains be corrected to exactly match with the sloping spectra and the spectral matching criteria be applied to the flat spectra condition. The V'_{bc} should therefore be further corrected to V_{bc} which has the same average value as the flat band radiance, V_{bf}. This is accomplished by

$$V_{bc} = \frac{16\ V_{bf}}{\sum_{c=1}^{16} V'_{bc}}\ V'_{bc} \qquad (1)$$

The spectral matching criteria can then be applied as

$$\left[V_{bc}\ \text{Maximum} - V_{bc}\ \text{Minimum}\right]_{c=1}^{16} \leq \frac{256}{200} \qquad (2)$$

for bands b = 1 through 5 and 7.

CONCLUSIONS

From a program systems test view point, AC01 accomplishes two objectives:

1) It verifies compliance with the spectral coverage specification

2) It provides the data base for radiometric calibration, gain set, and verification of the spectral matching specification which will be performed in AC02.

Except for spectral matching, these program requirements can be adequately met by analytically determining the system spectral response for each band using existing data. The procedure for doing this is illustrated in the section on Relative Spectral Response.

Spectral matching is influenced by variations in the spectral response between detectors in a band and by localized variations in the spectral transmission of the band filter. For the Thematic Mapper, the filters were the most likely cause of spectral matching errors.

To establish the contribution of the filters to spectral mismatch, the witness sample filters for bands 1, 2, and 3 were investigated using a microdensitometer and appropriate Wratten filters. Details of this investigation are included in the Appendix.

The witness sample investigation concluded that the probability of meeting the spectral matching specification on all 96 channels ranged from a very conservative 80 percent to a conservative 97.4 percent. In fact, the actual probability is likely to be higher, but the data to support a higher value can not be obtained from the witness samples because of their physical condition.

If a system level confirmation of compliance with the spectral matching specification is required, a simple addition to the AC02 procedure and analysis would suffice. The addition, described in the section Spectral Matching Test, would approximate the slope differences of the specification with readily available filters.

In short, the program objectives which AC01 is intended to meet can be easily met by an analysis of existing data and, if it is considered necessary, a minor addition to the AC02 data collect and analysis.

A qualitative analysis of the needs of Thematic Mapper imagery users concluded that the most important radiometric properties were high stability/correctability, good signal-to-noise, and proper setting of the dynamic range (or minimum saturation radiance). Of much less importance were absolute and relative (between bands) radiometric calibration accuracy and fine structure deviations from the spectral coverage specification. Relative calibration between channels within a band must, of course, be very precise.

The principal benefit of precise spectral coverage control is that future Thematic Mapper-like instruments can use the data base developed by the first instrument. To achieve this benefit, corresponding channels of the future instruments should match the spectral coverages of the first.

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RECOMMENDATIONS

The following recommendations are made

1) The currently planned AC01 test should be dropped. The test is soundly conceived, but costly in terms of schedule and program resources.

2) The system spectral response on a band-by-band basis should be obtained using the analytical procedure presented in section Relative Spectral Response. This will provide the necessary data base for determining compliance with the spectral coverage specification and for AC02 (radiometric calibration and gain set).

3) A careful review should be conducted of the results of the spectral matching investigation (filter microdensitometer tests) reported in the appendix. I feel that the remote chance (< 3 percent probability) of failing to meet the spectral matching specification will not justify further testing. If a system level test is required, the simple addition outlined in the section Spectral Matching Test should be incorporated into AC02.

4) In designing and interpreting the radiometric/spectroradiometric test program, emphasis should be placed on four properties of key importance to users.

   a) A highly stable radiometric performance. This property may be achieved through software correction, for example, for the focal plane temperature.

   b) A high signal-to-noise, per specification.

   c) Accurate gain sets to achieve the proper dynamic range and minimum saturation radiance.

   d) Precise relative calibration between channels within a band.

5) If the Thematic Mapper should fail by some small margin to satisfy all of the spectral coverage specifications, we should recommend to NASA that the requirement be waived while the specifications for future instruments (i.e., those which will rely on the data base of the first instrument) should be written to match the first instrument.

ACKNOWLEDGEMENT

The author wishes to thank Dr. L. J. Richter for her assistance in reducing the microdensitometer digital data. The data are stored on magnetic tape for further processing should the need arise.

APPENDIX

FILTER – MICRODENSITOMETER TESTS

INTRODUCTION

These tests were performed to quantify the impact of the interference filters on the ability of the Thematic Mapper system to meet the spectral matching* requirement. Witness samples for bands 1, 2, and 3 were used as representative of the flight hardware in these tests. Bands 4 to 7 fell outside the spectral range of the microdensitometer photomultiplier and, therefore, witness samples for these bands were not included.

The basic approach was to simulate the way the filters will function within the Mapper system. This simulation was performed twice for each filter: once representing the flat spectra of the spectral matching specification* and once representing the sloping spectra requirement.

The resulting data were analyzed to determine whether statistically significant variations in the spectral transmission function occurred.

SIMULATION

The basic instrument used to simulate the function of the filter in the Mapper was a Perkin Elmer PDS microdensitometer. For those unfamiliar with the instrument, it is briefly described in an extraction from Perkin Elmer's advertising literature included at the end of this Appendix.

The simulation was accomplished by setting up the microdensitometer to sample and digitize the optical transmission through a 0.004 inch by 0.004 inch square aperture projected on the surface of the witness sample. The 4 mil dimension is the same as the detector dimensions for bands 1 to 4, thus simulating a detector immediately behind the filter surface irradiated by an f/6 cone of light.

To simulate the difference between the two spectra specified in Dr. Salomonson's memorandum. Kodak Wratten filters were selected for each band. Table A-1 summarizes the relevant data from his memorandum.

*GSFC 400.8-D-210, Paragraph 3.2.8.1, modified by Salomonson's memo.

TABLE A-1. SPECTRAL MATCHING SPECIFICATION

Band	Spectral Radiance at Lower Band edge, mw/cm^2 -sr - μm	Spectral Radiance at Upper Band lodge, mw/cm^2 -sr - μm	In Band Flat Radiance, mw/cm^2 -sr	Minimum Saturation Levels, mw/cm^2 -sr
1	5.7	10.0	0.45	1.00
2	9.9	9.1	0.77	2.33
3	3.2	7.8	0.25	1.33
4	13.2	14.1	1.93	3.00
5	2.3	1.7	0.4	0.6
7	0.47	0.41	0.12	0.43

For bands 1 and 3, filters were chosen which exaggerate, the relative slopes specified in columns 2 and 3 of Table A-1. The spectral transmission and the specified relative spectral radiance of columns 2 and 3 are presented in Figure A-1. Note that the relative spectral radiance was normalized to match the peak filter transmission value within each band.

The filter for band 2 was chosen to greatly exaggerate the Salomonson slope. To do otherwise would not have provided a sensitive measure of localized variations of the spectral transmission function.

The transmission of each sample point on a witness sample was measured twice, once without any filter in the optical path and once with the Wratten filter appropriate to the particular witness sample inserted into the path. The clear path transmission represents the flat spectrum (column 4 of Table A-1) while the Wratten filter transmission represents the sloping spectrum (columns 2 and 3 of Table A-1).

It should be recognized that this is a less than perfect simulation of the conditions reflected in Table A-1. An ideal simulation would take into account the source, sensor, and optical transmission spectral character of the microdensitometer, as well as the detector and optics transmission spectral character of the Thematic Mapper. The complexity of a more precise simulation was avoided by choosing filters which in each case exaggerated the in band slope specified in Table A-1. The test is therefore more sensitive to localized variations in spectral transmission than a more precise simulation would be.

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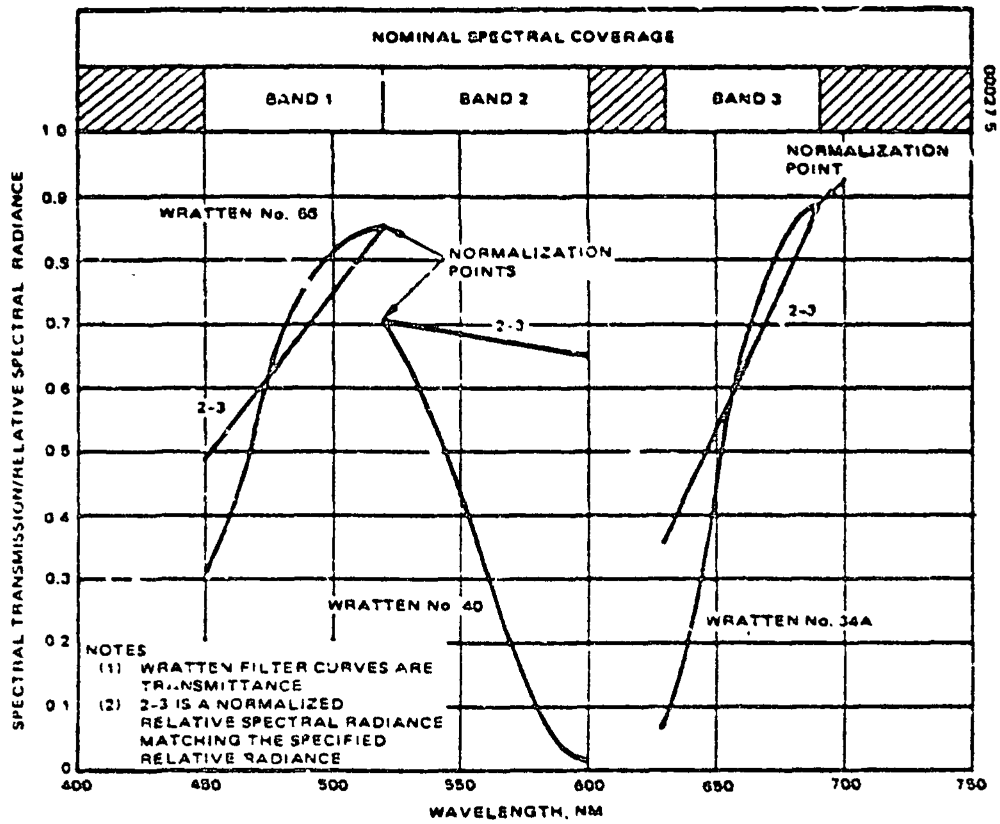

FIGURE A-1. FILTER TRANSMISSION VERSUS SPECTRAL MATCHING SPECIFICATION

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Five separate raster scans were performed on each witness sample to produce five 20 by 20 sample arrays. The arrangement of these arrays on the witness sample is illustrated in Figure A-2.

The sample points of the arrays are on 4 mil (100 μm) centers with a positional accuracy of 40 microinches (1 μm) (The projected aperture is also 4 mils square as noted above.) The arrays then simulate the approximate dimensions of both the detector apertures and the individual Mapper band arrays which are 16 elements long.

For each witness sample, this procedure produced 2000 discrete, orthogonal transmission values without a filter in the optical path of the micro densitometer. A second set of 2000 transmission values were produced with the appropriate Wratten filter in the optical path. The second set of values correspond on a one-to-one basis with the first; each pair represents the transmissions at the same location on the witness sample.

Finally, the gain of the photometric channel was adjusted for each setup (combination of witness sample and filter or no filter) to produce the same average digital value of transmission. The advantage of this adjustment will be discussed later.

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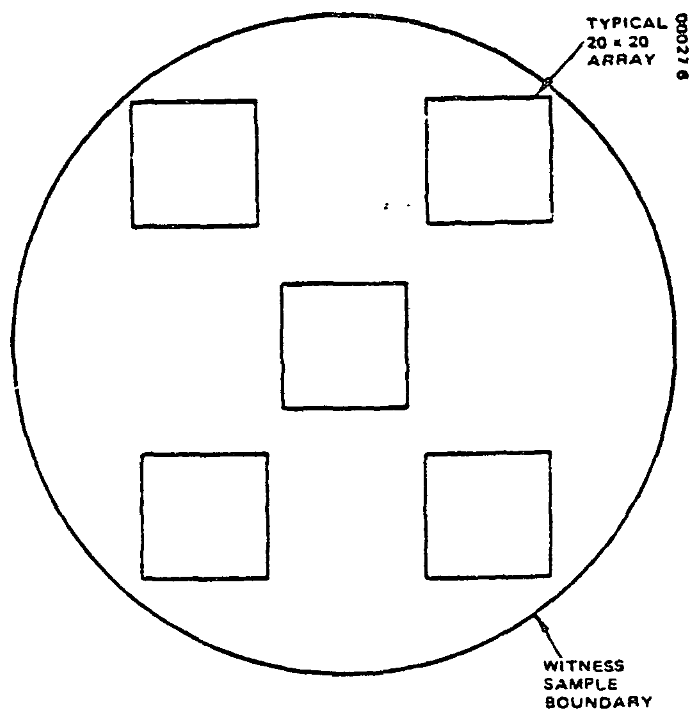

FIGURE A-2. ARRAY PATTERN

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ANALYSIS

The probability of meeting the spectral matching specification can be obtained by examining the statistics of the function p, where p is defined as

$$p_i^b = A_i^b - kB_i^b \tag{A-1}$$

where

A_i^b = i^{th} transmission value of b^{th} band witness sample taken without Wratten filter in optical path

B_i^b = corresponding transmission value to A_i^b taken with appropriate Wratten filter in path

k = constant

If there were no localized variation in the spectral transmission function and no noise in the microdensitometer photometric function, then there would exist a constant k such that

$$p_i^b = A_i^b - kB_i^b \equiv 0. \tag{A-2}$$

The gain of the photometric channel of the microdensitometer was adjusted so that Equation A-2 is statistically satisfied with k equal to one. However, since both noise in the photometric channel and localized variation in the spectral transmission function are present, the actual value of p_i^b is seldom zero.

The measured values of A_i^b and B_i^b and the calculated value of p_i^b always contain the effects of microdensitometer channel noise. What is needed for this analysis is an accurate estimate of the variance of p with the effect of photometric channel noise removed. To obtain this estimate, a distinction is made between the measured variances of p, A, and B and the actual variances which would be obtained without channel noise. Then the following definitions apply

σ_{pM}^2 = variance of p calculated from measured A and B, including channel noise

σ_p^2 = variances of p which would be obtained if no channel noise were present

σ_{AM}^2 = variance of A including channel noise

σ_A^2 = variance of A without channel noise

σ_{BM}^2 = variance of B including channel noise

σ_B^2 = variance of B without channel noise

σ_N^2 = variance of the channel noise.

Since k is equal to 1, Equation A-2 leads to the following relationships between the variance

$$\sigma_{pM}^2 = \sigma_{AM}^2 - \sigma_{BM}^2 \qquad \text{(A-3)}$$

$$\sigma_p^2 = \sigma_A^2 - \sigma_B^2 \qquad \text{(A-4)}$$

and since the noise is additive and noncorrelated

$$\sigma_{AM}^2 = \sigma_A^2 - \sigma_N^2 \qquad \text{(A-5)}$$

$$\sigma_{BM}^2 = \sigma_B^2 + \sigma_N^2 \qquad \text{(A-6)}$$

Substituting Equations A-5 and A-6 into Equation A-3 obtains

$$\sigma_{pM}^2 = \sigma_A^2 + \sigma_B^2 + 2\sigma_N^2 \qquad \text{(A-7)}$$

and substituting A-4 into A-7

$$\sigma_{pM}^2 = \sigma_p^2 + 2\sigma_N^2 \qquad \text{(A-8)}$$

which solved for σ_p yields

$$\sigma_p = \sqrt{\sigma_{pM}^2 - 2\sigma_N^2} \qquad \text{(A-9)}$$

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The actual error which results from localized variations in spectral transmission is proportional to the signal level. For this reason, a more useful form is a fractional standard deviation, σ'_p, where σ'_p is defined as

$$\sigma'_p = \frac{\sigma_p}{\langle A \rangle} \tag{A-10}$$

where

$\langle A \rangle$ = average of A_i^b

It is now necessary to calculate the number of standard deviations, y, which would produce an error equal to the limit specified in paragraph 3.2.3.1 of GSFC 400.3-D-210. This limit was 0.5 percent of the minimum saturation level. If Dr Salomonson's suggestion is followed that the calibration be performed on the sloping spectra (columns 2 and 3 of Table A-1), and the criteria be applied to the flat spectra, then y is obtained from

$$y = \frac{0.005\ N_{MS}}{\sigma_p\ \ N_{IBF}} \tag{A-11}$$

where

N_{MS} = minimum saturation radiance (column 5 of Table A-1)

N_{IBF} = in band flat radiance (column 4)

Substituting Equations A-9 and A-10 into A-11 produces

$$y = \frac{0.005 \langle A \rangle\ N_{MS}}{N_{IBF}\sqrt{\sigma_{pM}^2 - 2\sigma_N^2}} \tag{A-12}$$

All of the parameters Equation in A-12 are either specified by NASA or obtainable from the microdensitometer array data.

For a single channel of a particular band, the probability $P_b(<y)$ of exceeding the NASA specification can be readily obtained from normal

disbribution tables. Since the channels are independent, the probability, $P_b^{'}(<y)$, of all sixteen channels simultaneously meeting the specification is

$$P_b^{'}(<y) = \left[P_b(<y)\right]^{16} \tag{A-13}$$

for bands 1 through 5 and 7 and

$$P_b^{'}(<y) = \left[P_b(<y)\right]^{4} \tag{A-14}$$

for band 6.

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COMPUTATIONS

From the digital data generated by the microdensitometer raster scans, values were calculated for <A> and σ_{pM}. For bands 1, 2, and 3, the values were calculated directly from the data. For bands 4, 5, and 7, the average values from the band 1 to 3 calculations were used as representative.

A noise value, σ_N, was calculated from a histogram of microdensitometer values taken when the instrument was not scanning. A normal distribution curve was fitted to the histogram in order to obtain an accurate value of σ_N. The minimum saturation radiance, N_{ms}, and the in band flat radiance, N_{IBF}, were obtained from Table A-1.

The above values were substituted into Equation A-12 to obtain the appropriate y values. From these y values, corresponding single channel probabilities, P_b, were obtained from normal distribution tables. These values were, in turn, substituted into A-13 to obtain the probability, P_b', that all channels of the band will meet the specification.

The results of this process for bands 1 through 5 and 7 are summarized in Table A-2. The probability that all channels in a band, P_b', will meet the specification is indicated in the right hand column.

An additional parameter of interest is the probability, P_T, that all channels of bands 1 through 5 and 7 will meet the specification. This probability is 0.80. It is obtained by multiplying together the P_b' values for these bands, i.e.,

$$P_T = \prod_{b=1-5,7} P_b'$$

The microdensitometer signal-to-noise ratio is readily obatined by

$$S/N = \langle A \rangle / \sigma_N$$

TABLE A-2. SUMMARY OF COMPLIANCE PROBABILITY COMPUTATION

Band	<A>	N_{ms}	N_{ibf}	σ_{pm}	σ_n	y	P_b	P_b'
1	1604	1.00	0.45	6.856	3.011	3.317	0.9991	0.985
2	1600	2.33	0.77	5.595	3.011	6.670	1 000	1.000
3	1607	1.35	0.25	6.128	3.011	9.848	1.000	1.000
4	1604	3.00	1.93	6.193	3.011	2.77	0.9944	0.914
5	1604	0.6	0.4	6.193	3.011	2.675	0.9925	0.887
7	1604	0.43	0.12	6.193	3.011	6.391	1.000	1 000

Substituting from Table A-2, one obtains an average S/N of 259. This average compares with a specified Thematic Mapper S/N ranging from 45 for channel 7 to 240 for channel 4 (GSFC 400.8-D-210), Rev B, April 1978). For an equal sample size, the microdensitometer accuracy are comparable to the best which would be obtained from the Mapper digitized data.

ASSUMPTIONS

There are two key assumptions in this analysis:

1) The witness sample filters for channels 1 through 3 are conservatively representative of the flight hardware for all bands.

2) The relative spectral response of detectors within a band are essentially the same.

The first assumption is supported by several factors. First, the witness samples showed some evidence of abrasion (especially channels 1 and 3) which could very well cause localized variations in the spectral transmission function. If these abrasions had not been present, the values of σ_{PM} would have been lower and the P_b' values would have all been nearer 1.

Channels 1 through 3, of course, have the thinnest layers in their dielectric stack. As a result, small localized variations in the thickness of a particular layer would result in larger fractional changes in the spectral transmission function than would a similar variation in a layer of channels 4 through 7. Thus the choice of channels 1 through 3, a choice dictated by the spectral response of the microdensitometer PMT, is conservative.

Finally, the simulated sloping spectra of channel 2 is much more severe than is specified for any of the channels. This adds another conservative element to the data acquisition and analysis.

As an example of how these factors cause a more conservative estimate of the probability of meeting the specification, assume that the channel 2 witness sample which showed the least abrasion was more representative. Then the σ_{PM} for all channels would be 5.595 and the probabilities that bands 1, 4, and 5 will meet specification are 1.000, 0.990 and 0.984. The probability that all channels will meet the specification is 0.974. Noting that the in band spectral radiance slope for channel 2 was greatly exaggerated (see Figure A-1), it is certain that a more representative slope would further improve these probabilities.

The relative spectral response of the detectors is determined primarily by the material (Si, In-Sb, and HgCdTe) and only secondarily by the structure. Since the channel detector of a band is formed on a single chip, structural differences between channels of a band are minor and will have a negligible effect on their spectral responses.

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SUMMARY

Based on very conservative assumptions, there is an 80 percent chance that all channels will satisfy the system spectral matching specification. If conservative assumptions are made, the probability that all channels will meet the specification is 97 percent.

Actually, because of the condition of the witness samples, the exaggerated spectral slopes of the filters, and the short wavelength bands being the most critical, both of the above estimates are probably low. Data do not exist, however, to support a higher value.

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Photodigitizing

You can think of any photographic image as a unique pattern of density variations. Some images contain a large range of densities, from white to black with many different grays. Others such as line work may contain only white (transparent) and black (opaque). With modern photodigitizing equipment, the information contained in any image can be scanned and converted to digital form ready for manipulation by computers.

In order to do this, the image area is divided into a large number of discrete picture elements called pixels. A numerical value is assigned to the density observed in each pixel. A pixel size is chosen which is small enough to resolve the finest detail required.

The photograph is divided into pixels by sampling the amount of light that passes through an appropriately sized aperture as the aperture scans back and forth to cover the entire area of interest. Each density sample is given a digital value, and all of the values are stored on magnetic tape for subsequent computer processing. The result is a "numerical image" which can be used instead of the original visual image for a wide variety of computational purposes. A few of the applications are discussed in this brochure.

PDS Microdensitometer

The Applied Optics Division of Perkin-Elmer manufactures the PDS Model 1010A Micro-D, a flatbed optical scanning digitizer. This instrument will scan a 10 x 10-inch area at speeds up to 50 mm per second. Pixels can be as small as 5μ. Output consists of pixel density or transmittance measurements that cover a range from 0 to 4D and pixel position information with a resolution of 1μ. All the scanning parameters can be selected by the operator under computer control.

Systems

The Perkin-Elmer PDS Micro-D is available in various configurations to suit individual needs:

- PDS Micro-D alone, as a computer peripheral
- Microprocessor-controlled PDS Micro-D for stand-alone operation
- Microprocessor-controlled PDS Micro-D for real-time data handling by minicomputer. The microprocessor control of the Micro-D frees the computer for computational tasks.
- Complete Photometric Data System. Such a system might include 16-bit minicomputer, 9-track magtape drive and keyboard terminal.

The applications of photodigitizing are of three general kinds. (1) Encoding, (2) Transforming, and (3) Information Extracting.

Analog, that is, continuous tone photo images may simply be digitized, or encoded for storage, display, transmission, data-base establishment, or direct transfer to digital equipment.

Transformation converts an image into a better looking or more useful form. It may use such techniques as contrast enhancement, deblurring, image restoration, noise reduction, edge sharpening, color enhancement, density slicing, and spatial filtering.

Extraction of the informational content of a photograph can take one or more of three forms, detection, mensuration and identification. Detection refers to the determination of the existence, size, shape and location of a feature. Mensuration is concerned with the spatial relationships between such features, as in the examination of star plates and spectrograms.

Identification involves the recognition of the photometric "signature", the particular pattern of density variations associated with a feature, such as in pattern recognition. In fact, the uses to which the capabilities of photodigitizing can be turned are as far-ranging as the imagination allows. Let us show you how they can be suited to your needs in such fields as

- Aerial Reconnaissance
- Aerospace
- Astronomy
- Earth Resources
- Electronics
- Graphics Reproduction
- Mapping and Photogrammetry
- Materials Research
- Medicine
- Photographic Science
- Textile Production

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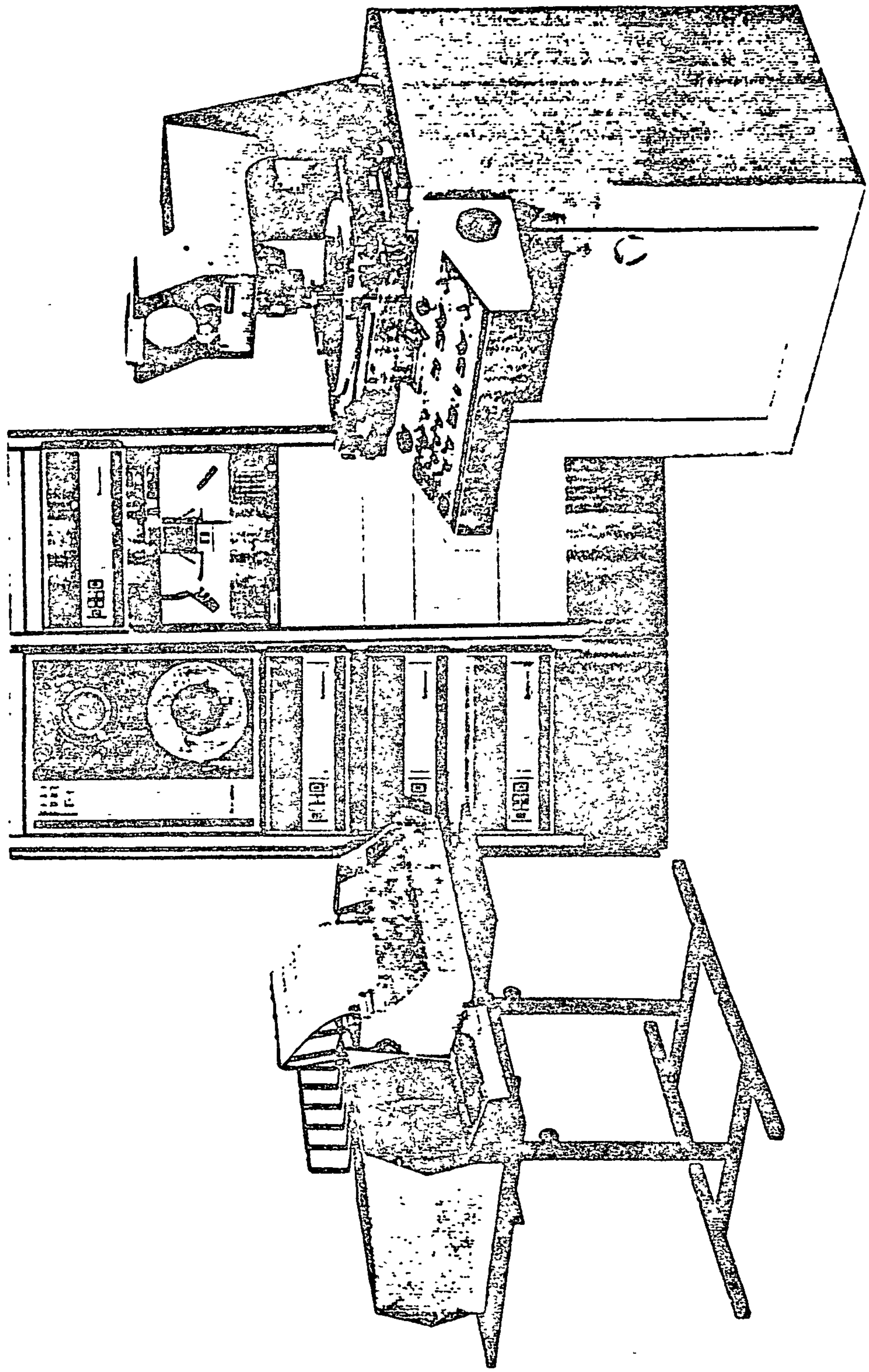

Appendix 3.2.8

AC07 Test Reference Documentation

SANTA BARBARA RESEARCH CENTER

A [illegible]

INTERNAL MEMORANDUM

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TO: Marshall Sheinblatt CC:
CA: 40-92

DATE: 30 January 1978

HS236-50[illegible]

SUBJECT: Thematic Mapper Spatial Coverage Test Description

FROM: G. R. Hyde

BLDG. MAIL STA.
EXT.

This test is performed on the Thematic Mapper with the scan mirror stationary to determine the size and location of the 64 detectors in 6 separate bands. (16 more detectors may be added if band 7 option is exercised.)

The Thematic Mapper is mounted on a precision table. However, the position of the TM is determined by autocollimating a a theodolite on the locked scan mirror to measure to the required precision. The source is projected towards the TM through a collimator which has a computer driven X-Y stepping stage to position the entrance slit. However, the collimator has a narrow field of view range, so it is necessary to move the TM four times during the test.

The software procedure for controlling the test is specified in the following steps. These steps in turn call procedures which are detailed in subsequent sections. The procedures perform the following functions.

Procedure A

The data for one band of 16 detectors are taken in X and Y and stored for reduction. Bands 1, 2, 3, 4, 5 and 7 use this procedure.

Procedure B

The data i[illegible] one band are reduced to give normalized data, and the detector width is determined in X and Y.

Procedure C

The detector size and location for the band are checked against specifications, and the size, location, and condition relative to specifications are printed on a priority basis to keep the test operator abreast of progress.

Procedure D

The field of view data are converted to radian measure relative to the optical axis of TM, and the data are sent to a plot file to be plotted as time is available, but with low priority.

Procedure E

The movement of TM is controlled and monitored, including all interaction with the optical technician operating the theodolite.

Procedures F, G, H, and I

These procedures are analogous to A, B, C, and D, but they apply to band 6 only, which has 4 detectors.

VPEAK Subroutine

The data on any given detector are sampled and processed to determine the peak-to-peak output.

Sequence No. 1

This sequence is called by Procedures A and F to take data on a sequence of detectors over a specified slit step range. Data are taken, then the entrance slit is stepped in X.

Sequence No. 2

Analogous to No. 1, but it uses Y coordinates.

Sequence No. 3

Similar to No. 1, but the slit step occurs before data are taken.

Sequence No. 4

Similar to No. 2, but the slit step occurs before data are taken.

The Test Procedure Follows

1. Instruct the operator to set the scan mirror to the center of scan and lock it in place.

2. Verify that the scan line corrector is off; if not, command it off, and verify.

3. Instruct the operator to align the collimator with TM.

4. Perform Procedure E with IBAND=1 to initialize all counters and position on the LED.

5. Instruct the operater to connect the auxiliary detector plane cooling equipment, but do not turn it on at this point in time.

6. Command all bands to "off."

7. Select the ADAU A/D in the SIU.

8. Select the 39 KHz sampling rate in the ADAU (the divide by 16 function).

9. Switch in the 100 Hz filter with a 10 Hz bandpass in the ADAU.

10. Drive the aperture table in the -X direction toward band 4 for the following IFOV distances

LED to axis	7.988 IFOV units
Axis to Band 4 center	10.394 IFOV units
Band 4 center to even detector center	1.250 IFOV units
total	19.632 IFOV units

NOTE: The number of steps to use must be calculated from the collimator focal length FLC as follows

$$\text{STEP ANGLE} = \frac{0.0001 \text{ inch/step}}{\text{FLC inches}}$$

$$\text{NO. STEPS/IFOV} = \frac{42.5\times10^{-6} \text{ radians}}{\text{STEP ANGLE}}$$

Currently there are 2 possible collimators which may be used. They have FLC of 108 inches and 111 inches corresponding to 45.9 and 47.175 steps/IFOV, respectively.

11. Command Bands 1 to 4 to "ON," and instruct the operator to turn on the auxiliary cooling for Bands 5 and 6.

12. Instruct the operator to turn on the chopper motor and adjust the source current until the peak-to-peak signal is 18.8 volts (±1920 DN). While the operator is adjusting the current, continually monitor and display the peak-to-peak signal of detector 2 of Band 4 using the VPEAK procedure until the operator signals that the voltage is correct. Switch to detector 16 of Band 4 and verify that the voltage is within 1 volt of the detector 2 value. If not, write a message to the operator to give him a chance to abort the test. If he chooses to continue, go the next step.

13. Step to the center of the band in preparation for execution of the Procedure A which takes a full set of field of view data by stepping as follows. (The narrow slit is at the center of the even detectors.) Step in the +X direction by 1.25 IFOV units (53.125 microradians).

14. Perform Procedure A on Band 4.

15. Reduce the Band 4 data by performing Procedure B.

16. Print the Band 4 data using Procedure C which also checks the parameters against specification.

17. Plot the Band 4 data by performing Procedure D.

18. Save the Band 4 data on a 9 track mag tape for future reference including the associated parameters REFX, REFY, TMANGX, TMANGY, XOFFST, YOFFST, and RSTEP.

19. The narrow vertical slit is now at the center of Band 4. Step it to the center of Band 5 by moving in the +X direction by

Band 4 to axis	10.394 IFOV units
Axis to Band 5	60.606 IFOV units
total	71.000 IFOV units

20. Command Band 5 to "ON."

21. Perform Procedures A, B, C, and D on Band 5.

22. Save the Band 5 data and associated parameters on 9 track mag tape.

23. Move the narrow vertical slit to the center of the collimator field by stepping in the -X direction by

Band 5 center to axis	-60.606 IFOV units
Axis to collimator center	+ 7.988 IFOV units
Anti-backlach overtravel	- 0.2
total	-52.818 IFOV units

Move in the +X direction 0.2 IFOV units.

24. Move the Thematic Mapper to the center of Band 3 by exercising Procedure E with IBAND=2. This will generate a new TMANGX and TMANGY which give the location of TM as measured by the theodolite. This Procedure E also moves the collimator slit as a fine adjustment to the center of Band 3.

25. Perform Procedures A, B, C, and D on Band 3.

26. Save the Band 3 data on magnetic tape as above.

27. Step the narrow vertical slit to the center of Band 4 by stepping in the +X direction by

Band 3 to axis	35.392 IFOV units
Axis to Band 4	-10.394
total	24.998 IFOV units

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No anti-backlash movement is needed since the movement is in the +X direction, only.

28. Perform Procedures A, B, and C to check registration. No plot will be performed since the data were previously measured.

29. Save the Band 4 data on magnetic tape as above. Step the narrow slit in the -X direction to the center of Band 2 by stepping by

Axis to Band 2	-60.392
+axis to Band 4	+10.394
Anti-backlash	- 0.2
total	-50.198 IFOV units

Step in +X direction by 0.2 IFOV units.

30. Perform Procedures A, B, C, and D on Band 2.

31. Save Band 2 data on magnetic tape, as above.

32. Step the narrow vertical slit to the center of Band 3 again to center the collimator travel by stepping in the +X direction by

Band 2 to axis	+60.392
Axis to Band 3	-35.392
total	+25.0 IFOV units

33. Move the Thematic Mapper to the center of Band 2 by performing Procedure E with IBAND=3.

34. Perform Procedures A, B, and C on Band 2 (no plot is needed again).

35. Save Band 2 data on magnetic tape as above.

36. Setp to the center of Band 3 by stepping in the +X direction by +25.0 IFOV units.

37. Perform Procedures A, B, and C on Band 3 (no plot is needed again).

38. Save Band 3 data on magnetic tape as above.

39. Step in the -X direction to Band 1 by stepping

Axis to Band 1	-85.390
Band 3 to axis	+35.392
Anti-backlash	- 0.2
Total	-50.198 IFOV units

Step in the +X direction by 0.2 IFOV units.

40. Perform Procedures A, B, C, and D on Band 1.

41. Save the Band 1 data on magnetic tape, as above.

42. Step in the +X direction to Band 2 center to return the collimator to center of travel by stepping.

Band 1 to axis	+85.390
Axis to Band 2	-60.392
Total	+24.998 IFOV units

43. Move the TM to Band 5 by performing Procedure E with IBAND=4.

44. Perform Procedures A, B, and C on Band 5 (no plot is needed again). Then store data on magnetic tape.

45. Instruct the operator to install the blackbody source for Band 6, then command Band 6 "ON."

46. Step to the center of the even detectors by stepping in the +X direction by

Axis to band 6 center	+95.603 IFOV units
Band 5 to axis	-60.606
Band 6 to center to even detector	- 5.0
total	+29.997 IFOV units.

47. Step the slit wheel CCW 180 degrees to position the Band 6 vertical slit into place.

48. Instruct the operator to increase the source current until the peak-to-peak signal is 18.8 volts (±1920 DN) as measured by VPEAK subroutine, and the blackbody controller is stable.

49. Step in the +X direction to the center of Band 6 by stepping +5.0 IFOV units.

50. Perform Procedure F to acquire the data, Procedure G to reduce it, Procedure H to print and check against specifications, and Procedure I to plot it.

51. Save the Band 6 data on magnetic tape as above.

52. Step the slit wheel CW 180 degrees to move the small vertical slit into place.

53. Drive the slit back to the LED to close the traverse by performin Procedure E with IBAND=5.

54. Instruct the operator to switch the X, Y controller to local mode, then position the vertical slit onto the LED by stepping in from the - to + direction in the final approach to remove backlash. Instruct the operator to select the narrow horizontal slit, then center the middle LED by stepping from -Y to +Y direction on the final approach.

55. Instruct the operator to switch the X, Y controller to remote.

56. Read the X and Y encoders, then calculate

    XERR = (X-XOFFST) RSTEP radians
    YERR = (Y-YOFFST) RSTEP radians

57. Command Bands 1, 2, 3, 4, 5, and 6 to "OFF."

58. Instruct the operator to turn off the auxiliary detector plane cooling.

59. Instruct the operator to turn off the blackbody and visible detector sources.

60. Command the SIU back to internal MUX usage.

61. Print the message

    "END OF SPATIAL COVERAGE TEST,
    X closure error = (XERR value) radians,
    Y closure error = (YERR value) radians."

G. R. Hyde

/mr
Attachments
<u>Distribution</u>:
TM project office (14)
J. Young

PROCEDURE A

This procedure is used to acquire the data from the field of view measurements for one detector band in a form suitable for reduction by Procedure B, and for print and plot by Procedures C and D.

This procedure assumes that the narrow vertical slit is in the center of the band in the X direction, and the narrow horizontal slit may be centered in the Y direction by a 90-degree rotation of the slit wheel.

Data Storage Description

Data are described as though 0.05 IFOV (2.125 microradians) steps were possible. The data step size and count must be adjusted here and in Procedure B to accommodate practical step size as determined by the collimator focal lengths. This adjustment must respect IFOV boundary locations, but may allow more incremental steps within boundaries. For example, it takes 20 positions of 0.05 IFOV units (2.125 microradians each) to cover one IFOV. However, if the 111-inch focal length collimator were to be used each step is 0.9009 microradians, so each data point would require either two steps (1.8018 microradians) or three steps (2.727 microradians). In the case where a movement of 1 IFOV is required, 42.5 microradians/.9009 microradians indicates 47 of the .9009 microradians steps are required. Thus, 13 positions of 2 steps each plus 7 positions of 3 steps each will be equivalent to the desired 20 positions of 0.05 IFOV.

Figure 1 illustrates the testing procedure to be followed in taking data in the X direction, and Figures 2 and 3 illustrate the procedure used in the Y direction. Figure 4 illustrates the distribution between narrow slit data and wide slit data in the Y direction.

In the X direction, the wide slit is positioned -12.25 IFOV units from the center line (see Figure 1), then the slit is stepped in units of 1 IFOV to take the far field data. The wide slit is not used on the detectors since the signal level is 10 times saturation, so stepping stops at -2.25 IFOV. Narrow slit data is then taken after backing the narrow slit to X = -3.75 IFOV units. The narrow slit data is taken until X = +3.75 IFOV units. The slit location is moved to X = +2.25, the wide slit inserted, and the remaining data are taken. See Table I for the data storage sequence.

The Y direction data acquisition proceeds in a similar fashion. The slit is moved to Y = -17.5 IFOV units, then the wide slit is moved into place. At that position only detector 1 is within 10 IFOV of the slit, so only detector 1 is used. After the slit has been stepped to -16.5 IFOV units, detectors 1 and 2 are within 10 IFOV units. Finally, when the sl't is at -8.5 IFOV,

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detectors 1 through 10 are within 10 IFOV units of the slit. Since the power through the slit is 10 times saturation, the wide slit is not stepped across the detectors.

The slit is changed to the narrow size, then backed up to the position illustrated in Figure 2. For the first IFOV, only detector No. 1 is within 2 IFOV units of the slit. When the slit is 1 IFOV unit from detector 1, data can also be taken on detector 2 since it is then 2 IFOV units away. As the slit is stepped further, more detectors come within the +/-2 IFOV data range. The data storage is listed in Table II, and the range of data are illustrated in Figure 4. In the figure, the narrow slit range is illustrated by a T-shaped line on each side of the detector, and the wide slit data points are illustrated by an X.

The data acquisition steps will now be described.

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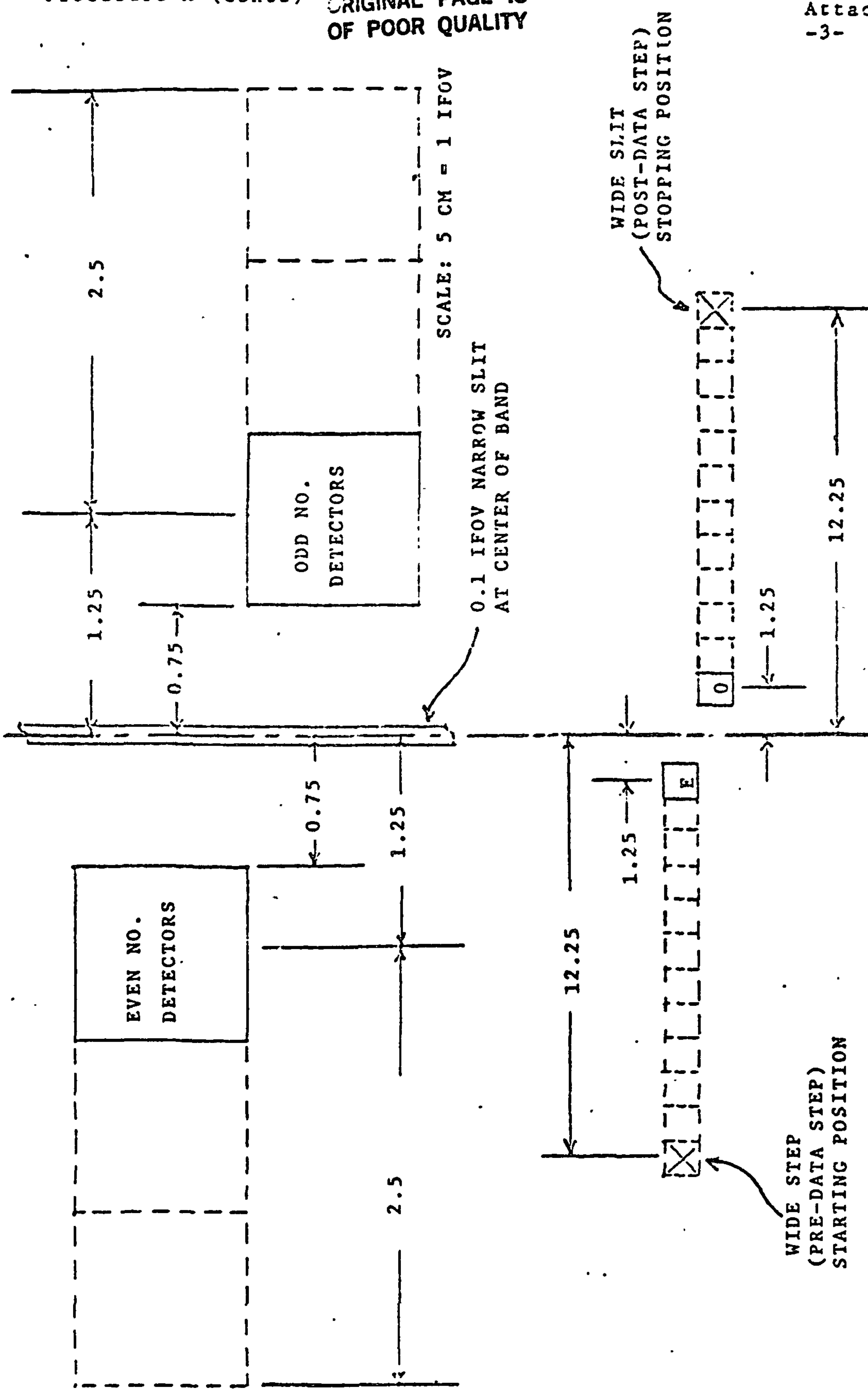
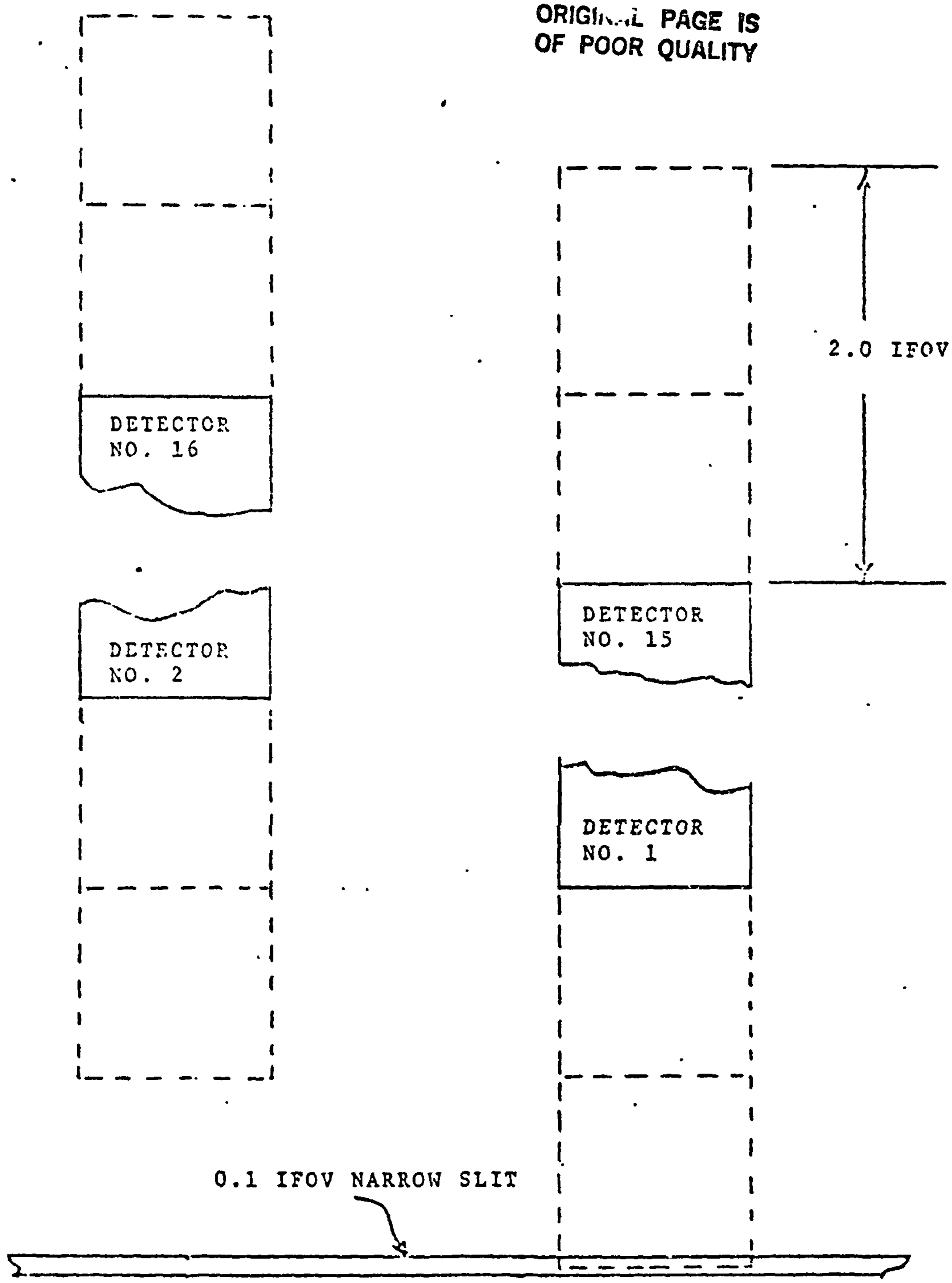
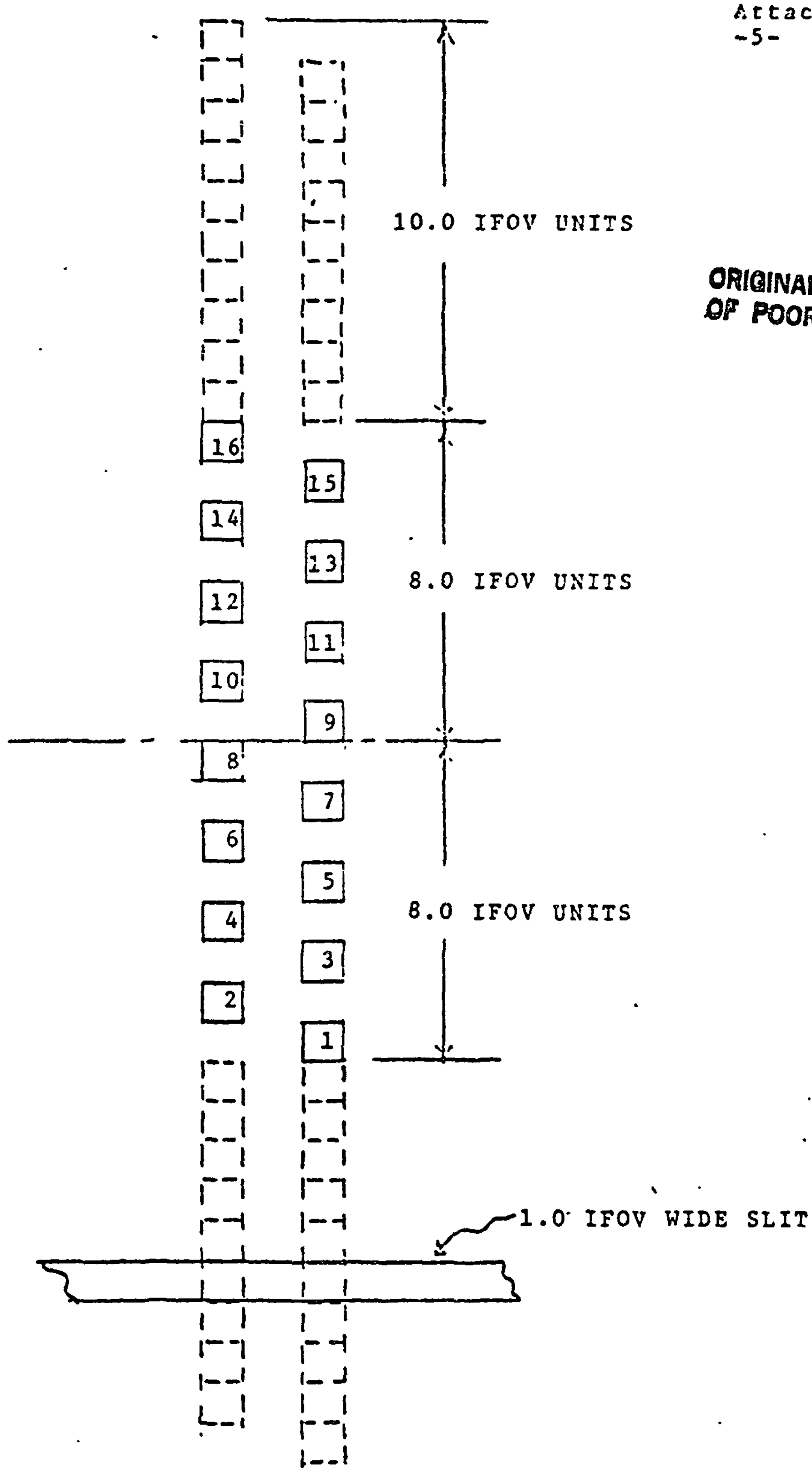


X DIRECTION MEASUREMENT PARAMETERS
FIGURE 1



Y DIRECTION NARROW SLIT MEASUREMENT
FIGURE 2



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Y DIRECTION WIDE SLIT MEASUREMENT
FIGURE 3

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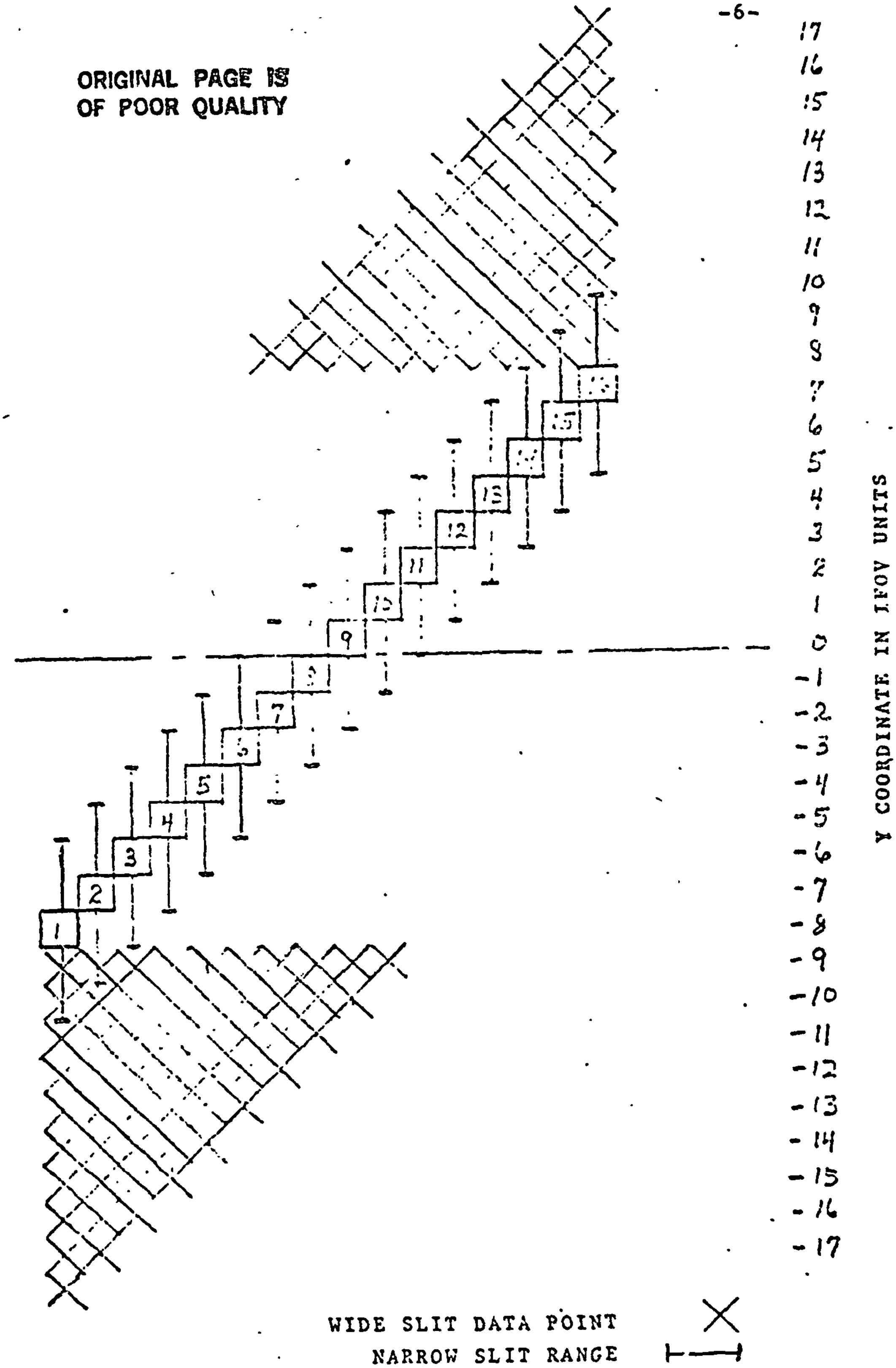

RANGE OF DATA POINTS IN Y COORDINATE
FIGURE 4

TABLE I
X DATA STORAGE ORDER
(ALL UNITS ARE IFOV UNITS)

X POSITION	NO. POINTS	DETECTORS USED	SLIT SIZE	RECORD COUNT
-11.25	8	2-16, STEP BY 2	W	
-10.25	8		W	
- 9.25	16	1-16	W	
- 8.25	16	1-16	W	
- 7.25	16	1-16	W	
- 6.25	16	1-16	W	
- 5.25	16	1-16	W	
- 4.25	16	1-16	W	
- 3.25	16	1-16	W	
- 2.25	16	1-16	W	
				144
- 3.75	8	2-15, STEP BY 2	N	
- 3.70	8	2-16, STEP BY 2	N	
⋮	⋮	⋮	⋮	
- 1.80	8	2-16, STEP BY 2	N	320
- 1.75	16	1-16	N	
- 1.70	16	1-16	N	
⋮	⋮	⋮	⋮	
+ 1.75	16	1-16		1136
+ 1.80	8	1-15, STEP BY 2	N	
+ 1.85	8	1-15, STEP BY 2	N	
⋮	⋮	⋮	⋮	
+ 3.70	8	1-15, STEP BY 2	N	
+ 3.75	8	1-15, STEP BY 2	N	320
+ 2.25	16	1-16	W	
+ 3.25	16	1-16	W	
⋮	⋮	⋮	⋮	
+ 9.25	16	1-16	W	
+10.25	8	1-15, STEP BY 2	W	
+11.25	8	1-15, STEP BY 2	W	144
		TOTAL RECORDS		2064

NOTE: IF THE STEP SIZE IS VARIED FROM 0.05 IFOV, THE RECORD COUNT MUST BE ADJUSTED ACCORDINGLY.

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TABLE II
Y DATA STORAGE ORDER
(ALL UNITS ARE IFOV UNITS)

Y POSITION	NO. POINTS	DETECTORS USED	SLIT SIZE	RECORD COUNT
-17.5	1	1	W	
-16.5	2	1-2	W	
-15.5	3	1-3	W	
-14.5	4	1-4	W	
-13.5	5	1-5	W	
-12.5	6	1-6	W	
-11.5	7	1-7	W	
-10.5	8	1-8	W	
- 9.5	9	1-9	W	
- 8.5	10	1-10	W	
				55
-10.0 to -9.05, STEP 0.05	20	1	N	
- 9.0 to -8.05, STEP 0.05	40	1-2 EACH Y	N	
- 8.0 to -7.05, STEP 0.05	60	1-3 EACH Y	N	
- 7.0 to -6.05, STEP 0.05	80	1-4 EACH Y	N	
- 6.0 to -5.05, STEP 0.05	100	1-5 EACH Y	N	
- 5.0 to -4.05, STEP 0.05	100	2-6 EACH Y	N	
- 4.0 to -3.05, STEP 0.05	100	3-7 EACH Y	N	
⋮	⋮	⋮		
+ 5.0 to 5.95, STEP 0.05	100	12-16 EACH Y	N	
+ 6.0 to 6.95, STEP 0.05	80	13-16	N	
+ 7.0 to 7.95, STEP 0.05	60	14-16	N	
+ 8.0 to 8.95, STEP 0.05	40	15-16	N	
+ 9.0 to 9.95, STEP 0.05	20	16	N	
+10.0	1	16	N	1601
+ 8.5	10	7-16	W	
+ 9.5	9	8-16	W	
+10.5	8	9-16	W	
+11.5	7	10-16	W	
+12.5	6	11-16	W	
+13.5	5	12-16	W	
+14.5	4	13-16	W	
+15.5	3	14-16	W	
+16.5	2	15-16	W	
+17.5	1	16	W	55
		TOTAL RECORDS		1711

NOTE: IF STEP SIZE IS VARIED FROM 0.05 IFOV,
THE RECORD COUNT MUST BE ADJUSTED ACCORDINGLY

1. Field of View Stepping in X Direction (along scan)

   a. Step in the -X direction to a position which is 12.25 IFOV units from the band center line. Step 0.2 IFOV units further in -X direction, then step 0.2 IFOV units in the +X direction to minimize backlash.

   b. Rotate the slit wheel 45 degrees CCW to position the wide vertical slit over the source. This signal level is 10 times saturation, so should not be stepped across the detectors.

   c. Take data for 10 IFOV positions on the -X side of the even detectors as follows (using a pre-data step to avoid the detector at the end).

      (1) Set NDSTRT = 2 NDSTOP = 16
          DSTEP = 2 FSTEP = 1.0 NSTEP = 2

      (2) Perform Sequence No. 3.

      (3) Set NDSTRT = 1 DSTEP = 1 NSTEP = 8

      (4) Perform Sequence No. 3.

   d. Rotate the slit wheel 45 degrees CW to position the narrow vertical slit over the sourve. This signal level is set for saturation level. The narrow slit data will be taken from 2 IFOV units on the -X side of the even detectors to 2 IFOV units on the +X side of the odd detectors.

   e. Move the slit 1.7 IFOV units in the -X direction, then move it 0.2 IFOV units in the +X direction to minimize backlash.

   f. Take data for 7.5 IFOV units in steps of 0.05 IFOV units as follows.

      (1) Set NSDTRT = 2 NDSTOP = 16 DSTEP = 2
          FSTEP = 0.05 NSTEP = 40

      (2) Perform Sequence No. 1.

      (3) Set NDSTRT = 1 DSTEP = 1 NSTEP = 71

      (4) Perform Sequence No. 1.

      (5) Set NDSTRT = 1 NDSTOP = 15 DSTEP = 2
          NSTEP = 40

      (6) Perform Sequence No. 1.

g. Step back to the center of the first IFOV on the +X side of the odd detettors by stepping in the -X direction by 1.8 IFOV units, then stepping by 0.2 IFOV units to remove backlash.

h. Rotate the slit wheel 45 degrees CCW to position the wide vertical slit over the source. This signal level is 10 times saturation, so should not be stepped across the detectors.

i. Take data for 10 IFOV positions on the +X side of the odd detectors as follows (use post-data step to avoid the detectors).

(1) Set NDSTRT = 1 NDSTOP = 16 DSTEP = 1
FSTEP = 1.0 NSTEP = 8

(2) Perform Sequence No. 1.

(3) Set NDSTOP = 15 DSTEP = 2 NSTEP = 2

j. This completes the acquisition of data in the X direction for this band. The slit will be set on the small size horizontal slit and the slit will be moved back to the center of the band. The center of the slit is currently 10.5 IFOV on the +X side from the odd numbered detectors. Rotate the slit wheel CCW by 45 degrees. Step the slit in the -X direction 12.45 IFOV units, then step 0.2 IFOV units in the +X direction to remove backlash.

2. Field of View for Band 4, Stepping in the Y Direction (across scan)

The narrow horizontal slit is now positioned between detectors 8 and 9 of the array.

a. Step the slit 18.7 IFOV units in the -Y direction, then step 0.2 IFOV in +Y to remove backlash. This leaves the center of the slit 10.5 IFOV units below detector No. 1.

b. Rotate the slit wheel CCW by 45 degrees to position the wide horizontal slit into place. Since the radiance level is 10 times the saturation level, this slit should not be stepped across the detectors.

c. Take signal data on detector 1 which is 10 IFOV away at this position, then step 1 IFOV and take data on detectors 1 and 2 which are 9 and 10 IFOV from the source, and continue a similar procedure until the slit is 1 IFOV from detector 1 at which time data will be taken on detectors 1 through 10. The data acquisition is accomplished as follows.

(1) Set NDSTRT = 1 NDSTOP = 0 DSTEP = 1
FSTEP = 1.0 NSTEP = 1

(2) NDSTOP=NDSTOP+1

(3) Perform Sequence No. 4 (pre-data stepping to avoid the detector).

(4) Repeat steps (2) and (3) until 10 cycles have been completed.

d. Step to a position 2.5 IFOV below detector No. 1, in preparation for fine slit measurements. The wide slit is currently centered 0.5 IFOV below detector 1. Proceed as follows. Step in the -Y position 2.7 IFOV units, then step in the +Y direction 0.2 units.

e. Rotate the small horizontal slit into place by stepping CW by 45 degrees.

f. Take data on all detectors which are within two IFOV of the slit. Thus, for the first IFOV located 2 IFOV units below detector 1, only detector 1 will be used. For the next IFOV, detectors 1 and 2 are used. After stepping through 5 IFOV units, detectors 1 through 5 will be used. However, stepping through the 6th IFOV unit, detector 1 is no longer within 2 IFOV units, so it is not used. A similar procedure is followed until the small slit is 2 IFOV units above detector 16. The procedure is as follows.

(1) Set NDSTRT=1 NDSTOP=0 DSTEP=1
FSTEP=0.05 NSTEP=20

(2) NDSTOP=NDSTOP+1

(3) Perform Sequence No. 2 (post-data stepping).

(4) Repeat (2) and (3) until 4 cycles have been completed.

(5) NDSTRT=1

(6) NDSTOP=NDSTRT+4

(7) Perform Sequence No. 2

(8) NDSTRT=NDSTRT+1

(9) Repeat (6) through (8) until 12 cycles have been completed.

(10) Set NDSTRT=12 NDSTOP=16

(11) NDSTRT=NDSTRT+1

(12) Perform Sequence No. 2

(13) Repeat (11) and (12) until 4 cycles have been completed.

(14) NDSTRT=16

(15) Perform Sequence No. 2

g. Step back to center the slit 0.5 IFOV above detector 16 by stepping in the -Y direction by 1.8 IFOV, then stepping in +Y by 0.2 IFOV to remove backlash.

h. Rotate the large horizontal slit into place by moving CCW 45 degrees.

j. Set NDSTRT=6 NDSTOP=16 DSTEP=1
FSTEP=1.0 NSTEP=1

(1) NDSTRT=NDSTRT+1

(2) Perform Sequence No. 2

(3) Repeat (1) and (2) until the cycle has been done 10 times.

k. The center of the slit is now located 10.5 IFOV above detector 16. Return the slit center to the band center reference between detectors 8 and 9 as follows.

(1) Rotate the slit wheel CW by 135 degrees to move the small vertical slit into place.

(2) Step in the -Y direction 18.7 IFOV units, then step 0.2 IFOV units in the +Y direction to remove backlash.

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PROCEDURE B

This procedure reduces the field of view data for one band, only. The 50 percent signal point is determined in X and Y for each detector, then the detector center coordinate is calculated. The narrow slit data taken 1. to 2. IFOV from a detector is used to compare with the wide slit data.

I Data Storage Description

NOTE: Data are described as though 0.05 IFOV (2.125 microradian) steps were possible. The data step size and count must be adjusted here and in procedure A to accommodate practical step size as determined by the collimator focal length.

A. Input Data

See Procedure A.

B. Output Data

1. The X data output consists of 16 data records each with the following data items.

a. Detector No.

Records 1-8 will be for detector numbers 1,3,...15. Records 9-16 will use detector numbers 2,4,...16.

b. PEAKV

PEAKV is largest voltage for this detector which is used for normalization of the data samples.

c. Normalized Narrow Slit Data

This data set consists of nominally 151 sets of X, Y, and the normalized voltage VPN. The set will probably not be exactly 151 values since the step size will vary from position to position to accommodate the collimator focal length. However, since X, Y are both stored, the coordinate variation will not cause a problem as long as the field of view boundary is respected (see discussion in Procedure A).

d. X1, X2, XC

X1 is the X coordinate (obtained by interpolation) of the signal which is 0.5 of the peak of the normalized data. X1 is the value on the -X side of the detector, X2 is the value on the +X side. XC is the average of X1 and X2.

e. Normalized Wide Slit Data

This data set consists of 18 sets of X, Y, and the normalized voltage VPN. Items 8 and 9 of this set (X= -2.25 and +2.25 IFOV units) will not be plotted since they are adjacent to the detector and may show cross talk since the wide slit has a power density which is 10 times saturation. These two points will be printed for diagnostic interest, only.

f. VNAVE, VWAVE

VNAVE is the integrated and averaged value of the signals which together combine to make up the second IFOV away from the detector. This value is compared with VWAVE which is the normalized wide slit response at X= -3.25 for the even detectors or X= +3.25 for the odd detectors. VWAVE is also divided by 10 to allow for its higher signal level.

g. NBAND

The band no. of the data taken.

2. The Y data output consists of 16 data records, each with the following data items.

a. Detector No.

Records 1-16 will increase sequentially in detector number.

b. PEAKV

This is the same as X, except the Y data are used.

c. Normalized Narrow Slit Data

This data is similar to the X data, except there are nominally 100 points covering 5 IFOV worth of data with the detector centered in the array.

d. Y1, Y2, YC

These are analogous with X1, X2, and XC, above.

e. NW and Normalized Wide Slit Data

There will be a variable number of wide slit data points for each detector. The data record should save space for a point counter NW and up to 10 sets of X, Y, and VPN as follows.

Detector No.	NW
1 and 16	10
2 and 15	9
3 and 14	8
4 and 13	7
5 and 12	6
6 to 11	5

f. VNAVE and VWAVE

These are analogous to the X data, <u>except</u> only detectors 1 and 16 have data entries.

g. NBAND

The band no. of the data taken.

II X Data Reduction

A. Repeat the following for the odd no. detectors 1,3,...15.

1. Field of View in X (Scan) Direction

Extend the small step data VPP from the file for X= -1.75, -1.70, ..., +3.70, +3.75 for 151 points. The peak value will be nominally at X= +1.25 but search the array for the peak; call this PEAKV, save it. Normalize the data by dividing by PEAKV to get VPN. Save this data. Search the normalized data on both sides of the peak for the two values which are less than 0.5. These will be nominally at X=0.70 and X=1.80. Take the two adjacent normalized data values which are just larger than 0.5 (nominally at X=0.75 and X=1.75) and by linear interpolation determine the two X values for VPN=0.5 as follows.

For the lower X value edge,

Let X_i be the coordinate for VPN_i (VPN<0.5)

X_{i+1} be the coordinate for VPN_{i+1} (VPN>0.5)

where $X_{i+1}>X_i$. Then the half width coordinate is given by

$$XHW = \frac{(X_{i+1}-X_i)(1.0-VPN_i)}{VPN_{i+1}-VPN_i} + X_i \qquad (1)$$

Let X1=XHW for this coordinate on the -X side of center. Similarly, the coordinate for the higher X value edge (nominally at X=1.75) is given by (1) where

X_i is the coordinate for VPN_i (VPN>0.5)

X_{i+1} is the coordinate for VPN_{i+1} (VPN<0.5)

Let X2=XHW for this coordinate on the +X side of center. Calculate the coordinate of the center of the detector. XC from the two half width coordinates X1 and X2 is calculated as follows.

$$XC = \frac{X1+X2}{2} \qquad (2)$$

Save the X1, X2, XC for future use.

Extract the wide slit data for this detector by retrieving the data for the 8 settings of X= -9.25 to X= -2.25 in steps of 1 IFOV, and the 10 settings for
X= +2.25 to X=11.25 in steps of 1 IFOV.
The X= +2.25 value is adjacent to the detector and may have cross talk obscuring its value since the wide slit has 10 times the detector saturation power. This value is not plotted with the field of view data, but is printed out for diagnostic value. The X= -2.25 value may be used for these odd no. detectors.

Normalize the 18 wide slit data values as follows.

$$VPN = \frac{VPP}{PEAKV*10.} \qquad (3)$$

and save these values.

2. Small Slit and Wide Slit Data Match

Using the normalized values above, get the 21 VPN values for X=2.75 to 3.75 in steps of 0.05 and integrate these values using the trapezoidal rule. However, the end points must be divided by 2 to allow for overlap at the ends by 0.05 IFOV, and the whole result divided by 2 due to 0.1 IFOV slit size. Thus, the integral end point division is given by

$$VN = \left[\frac{VPN(1)+VPN(21)}{4} + \sum_{I=2}^{I=20} VPN(I)\right] \times \frac{0.05}{2} \qquad (4)$$

Average VN over the IFOV, then use this as a comparison with the wide slit VW after it has been reduced by a factor of 10 to account for the power difference between wide and narrow slits.

$$VNAVE = VN/10. \qquad (5)$$

Obtain the normalized wide slit VPN at X=3.25; call it VWAVE. Save VNAVE, VWAVE. These numbers are the match between small slit data and the wide slit data at 2 IFOV from the detector.

B. Repeat the following for the even no. detectors 2,4,...16.

1. Field of View in the X (Scan) Direction

Extract the small step data VPP from the file for X= -3.75, -3.70,...,+1.70, +1.75 for 151 points.

The peak value will be norminally at X= -1.25, but search the array for the peak; call this PEAKV, save it. Normalize the data by dividing by PEAKV to get VPN. Save this array. Search the normalized data on both sides of the peak for the two values which are less than VPN=0.5, nominally at X= -0.70 and X= -1.80. Using the two adjacent data values which are just larger than 0.5 (nominally at X= -0.75 and X= -1.75), use linear interpolation to determine the X values for VPN=0.5 as follows.

For the most negative X value edge (nominally X= -1.75)
Let X_i be the coordinate for VPN_i (VPN<0.5)

X_{i+1} be the coordinate for VPN_{i+1} (VPN>0.5)
where $X_{i+1}>X_i$.

Then the half width coordinate is given by equation (1).

Let X1=XHW for this coordinate on the most negative X side.

Similarly, the coordinate for the less negative X side (nominally X= -0.75) is given by (1) where

X_i is the coordinate for VPN_i (VPN>0.5)
X_{i+1} is the coordinate for VPN_{i+1} (VPN<0.5)

Let X2=XHW for this coordinate on the less negative X side of the detector center.

Calculate the coordinate of the detector center XC using equation (2). Save X1, X2, XC.

Extract the wide slit data for this detector by retrieving the 10 settings of X= -11.25 to X= -2.25 in steps of 1.0 IFOV, and the 8 setting of X= +2.25 to X= +9.25 in steps of 1.0 IFOV. The X= -2.25 value is adjacent to the detector and may have cross talk obscuring its value since the wide slit has 10 times the detector saturation power. This value is not plotted with the field of view data, but it is printed for diagnostic value. The X= +2.25 value may be used for these even no. detectors.

Normalize the 18 wide slit data values using equation (3), and save them for subsequent use.

2. Small Slit and Wide Slit Data Match

Using the normalized values above, get the 21 VPN values for X= -2.75 to -3.75 IFOV in steps of 0.05 and integrate these using equation (4). Get the wide slit VPN at X= -3.25, call it VWAVE, calculate equation (5) and save VNAVE, VWAVE.

III Y Data Reduction

Repeat the following for all detectors 1, 2,...16.

A. Field of View in Direction Normal to Scan (Y)

Extract the 100 narrow slit VPP data values for the detector from the file. The starting Y value is given by YS=NDET-11, and the ending Y value is YE=NDET-6.05 where the data steps assumed are 0.05 IFOV.

The nominal center of the detector is given by

$$YC = \frac{YS+YE+.05}{2}, \text{ nominal}$$

Search the data array for the peak value; call this PEAKV; save it. Normalize the data by dividing by PEAKV to get VPN; save this array. Search the normalized data on both sides of the peak for the two values which are less than VPN=0.5. These will be nominally at

YC nominal ±0.5 IFOV.

Using these 2 values and the 2 adjacent values just larger than VPN=0.5, linearly interpolate for the Y values corresponding to VPN=0.5.

Let Y_i be the coordinate for VPN_i (VPN>0.5)

Y_{i+1} be the coordinate for VPN_{i+1} (VPN<0.5)

where $Y_{i+1} > Y_i$. Then the half width coordinate is given by

$$YHW = \frac{(Y_{i+1}-Y_i)(1.0-VPN_i)}{VPN_{i+1}-VPN_i} + Y_i \qquad (7)$$

Let Y1=YHW for this coordinate on the -Y side of center.

Similarly, the coordinate for the higher Y half width is found by letting

Y_i be the coordinate of VPN_i (VPN>0.5)

Y_{i+1} be the coordinate of VPN_{i+1} (VPN<0.5)

Let Y2=YHW for this coordinate on the +Y side of the detector center.

Calculate the detecter center coordinate YC by

$$YC = \frac{Y1+Y2}{2} \qquad (8)$$

Save Y1, Y2 and YC for future use.

The wide slit data is variable by detector number. The starting Y value on the minus side of the detector YSM is given by

$$YSM = NDET-18.5 \text{ IFOV} \qquad (9)$$

The ending value on the minus side YEM is

$$YEM = -8.5 \qquad (10)$$

Thus, detector 10 is the last detector which has a wide slit data point on the misus side.

The starting Y value on the positive Y side of the detector YSP is given by

$$YSP = +8.5 \qquad (11)$$

The ending value on the positive side YEP is

$$YEP = NDET+1.5 \qquad (12)$$

Thus, detector 7 is the first detector which has a wide slit data point on the positive side.

Retrieve the wide slit data between YSM and YEM and also between YSP and YEP as defined in equations (9) through (11) for all entries where YEM is greater than or equal to YSM and where YEP is greater than or equal to YSP. Normalize each value by using equation (3). Store the VPN value, the Y coordinate, and the number of data points NW.

B. Small Slit and Wide Slit Data Match

Calculate the following for the odd detector No. 1, only.

Using the normalized values above, get the 21 VPN value for Y= -10.0 to -9.0 IFOV units in steps of 0.05 IFOV units. Also retrieve the normalized wide slit data covering this same off detector region which is stored by Y= -9.5 IFOV units. Integrate the 21 values using equation (4). Note that the end points are divided by 2 in the equation to allow for the excess of 1/2 of the small slit width on each end, when compared with the wide slit result. The integration result is VN, and the average is VNAVE and given by (5). The wide slit value is VWAVE. Save VNAVE and VWAVE.

Calculate the following for detector 16 only.

Using the normalized values above, get the 21 VPN values for Y=9.0 to 10.0 IFOV in steps of 0.05 IFOV units. Also retrieve the normalized wide slit data covering the same off detector region which is stored for Y=9.5 IFOV units. Integrate the 21 values using equation (4). The integration result is VN, and the average is VNAVE, given by (5). The wide slit value is VWAVE.

Save VNAVE and VWAVE.

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PROCEDURE C

This procedure retrieves data stored by Procedures B and E which allow conversion of X and Y from steps to radians. The field of view data for the band is then checked against the specified parameters, and the results printed.

Input Data

The data from Procedure E includes REFX, REFY, TMANGX, TMANGY, XOFFST, YOFFST, and RSTEP. See Procedure E for definitions.

The data from Procedure B includes NBAND, Detector No., PEAKV, narrow slit array data in sets of X, Y, VPN where X, Y are in step count units, X1, X2, XC, Y1, Y2, YC all in step count units, wide slit data in sets of X, Y, and VPN, VNAVE, and VWAVE.

Conversion from Step to Radians

The conversion equations are described in Procedure E and are reproduced here.

ANGLEX=X*RSTEP+TMANGX-REFX+0.01945π/180. (1)

ANGLY=Y*RSTEP+TMANGY-REFY (2)

Specified Values for Each Band

A. Band Centers (in milliradians), BC relative to the optic axis

BAND	XBC	YBC
1	-3.6291	0.
2	-2.5667	0.
3	-1.5041	0.
4	-0.44174	0.
5	+2.5758	0.
6	+1.4708	0.
7	+4.0631	0.
LED	+0.33947	0.

B. Detector Center (in milliradians) for Bands 1-5, 7

1. X Coordinate Relative to Band Center

XDC = 1.25*.0425(-1+2*MODULO(NDET,2)) (3)

Where NDET is the detector No.

2. Y Coordinate Relative to Band Center

YDC = (-8.5+NDET)*.0425 (4)

C. Optimum Detector EDGES X1P, Y1P, X2P, Y2P

The ideal location for the detector edges is given by

X1P= XDC+XBC-.02125 milliradians (5)

X2P= XDC+XBC+.02125 (6)

Y1P= YDC+YBC-.02125 (7)

Y2P= YDC+YBC+.02125 (8)

D. Detector Width, (X2-X1) OR (Y2-Y1) Specified

BAND	MINIMUM DIFFERENCE	MAXIMUM DIFFERENCE
1	.0419 milliradians	.0431 milliradians
2	.0419	.0431
3	.0419	.0431
4	.0419	.0431
5	.04115	.04635
7	--	--
6	.1656	.1744

E. Detector Location and Size Printout

Perform the following 16 times.

1. Input X and Y data records for this detector.
2. Convert all coordinates to radians.
3. Store the converted data in the plot file.
4. Calculate DX=X2-X1
   DY=Y2-Y1
5. Print the following
   a. Detector No.
   b. XDC+XBC
   c. XC
   d. X1P
   e. X1
   f. X2P
   g. X2

h. DX

i. "in spec" or "out spec", see D above

j. error amount if out spec, 0. if in spec

k. YDC+YBC

l. YC

m. Y1P

n. Y1

o. Y2P

p. Y2

q. DY

r. "in spec" or "out spec", see D above

s. err amount if out spec, 0. if in spec

F. Tabulate Curve Data for Small and Large Slits

Print the following data in compact form.

1. Narrow Slit Data

a. X direction

This data consists nominally of 151 sets of X, Y, VPN with X, Y expressed in radian measure from the axis and VPN is the normalized voltage.

b. Y direction

This data consists nominally of 100 sets of X, Y, and VPN data as above.

2. Wide Slit Data

a. X direction

This data consists of 18 sets of X, Y, and VPN, plus VNAVE and VWAVE.

b. Y direction

This data consists of NW sets of X, Y, and VPN where NW is a function of detector No. Detectors 6 to 11 have 5 points, 5 and 12 have 6 points, 4 and 13 have 7 points, etc. until 1 and 16 have 10 points. Only detectors 1 and 16 have VNAVE and VWAVE values.

PROCEDURE D

This procedure takes data stored in the plot file by Procedure C for each band and forms two types of plot. The first plot is the detector location plot. This consists of the outline of the 16 detectors in the band for ideal conditions with the X1, X2, XC and Y1, Y2, and YC measured points plotted on the outline.

The second plot consists of a presentation of the narrow and wide slit data for each axis on a 3 cycle semi-log paper. This will require 32 plots for each band.

I Detector Location Plot

The ideal location of each detector edge is given by equation (5) through (8) of Procedure C. The ideal detector size for bands 1 through 5 is 42.5 microradians square. The plot scale should be chosen to give the best resolution possible. Since the 16 detector array is 3.5 IFOV wide (148.75 microradians), a scale of 5.0 IFOV in 10 inches would seem reasonable. This would produce a plot 3 feet in length with legend, but only one such plot will be made per band.

On this scale of 2 inches/IFOV unit, the edge tolerance will be ±0.03 inches for bands 1-4 and ±0.12 inch in band 5. Since the function of the plot is the illustration of any gross errors andsystematic errors, this resolution should be adequate.

II Detector Field of View Plot

Each axis of a given detector is the subject for this plot. Thus, 32 plots will be required. The plot will be made on 3 cycle, semi-log paper. Both the narrow slit and wide slit data are to be included on the same plot. This requires an abscissa dimension of 23.5 IFOV units. An appropriate scale to use is 2 inches/IFOV for the central ±3.75 IFOV, then, on the same plot, use a scale of 0.5 inches/IFOV for points outside these limits (wide slit data) for X plots.

The Y plots may use a scale of 2 inches/IFOV units for the central ±2.5 IFOV units, then a scale of 0.5 inch/IFOV unit outside this range.

III Plot Priority

The plotting should not be allowed to slow up the test. The information is stored in a plot file, and plotted during theodolite setting after the Procedure C print is complete as time is available.

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PROCEDURE E

This procedure is called when it is desired to move the Thematic Mapper instrument relative to the collimator in the field of view tests. The movement is monitored by manually autocollimating a theodolite on the TM scan mirror.

The TM will be located at the following points.

1. At the LED reference point.
2. At the center of Band 3.
3. At the center of Band 2.
4. At the center of Band 5.
5. Returned to LED at close of tests.

The procedure should be called with a switch parameter IBAND which will specify which of the 5 settings above is desired.

The following parameters must be kept in a programming COMMON, or on disk in a fashion which allows access by this procedure.

REFX, the theodolite reading (converted to radians) when the narrow vertical slit is aligned with the LED.

REFY, the theodolite reading converted to radians when the narrow horizontal slit is aligned with the center of the 3 LED.

TMANGX, the theodolite reading converted to radians when the TM is positioned with the center of the collimator projected <u>near to</u> Bands 3, 2, or 5 specified by switch IBAND.

XOFFST, the number of steps in X required to bring the collimator axis on the center of the band specified.

TMANGY, analogous to TMANX, but in Y.

YOFFST, analogous to XOFFST, but in Y.

RSTEP, the number of radians/step in either X or Y axis. This must be calculated and stored when the collimator focal length is input.

I Set at LED Reference Point (IBAND=1)

A. Slit Setting

1. Instruct the operator to manually drive the X slit table to center of scan.
2. Repeat for Y.

3. Instruct the operator to move the narrow vertical slit into position.

4. Instruct the operator to step in Z until the slit is at the previously determined focal position.

5. Instruct the operator to set the X, Y, Z, and slit wheel controller in the remote positions.

6. Zero X, Y, Z, and slit wheel controller.

7. Ask the operator to input the readings for X, Y, Z, slit wheel.

8. If readings in 7. are not all 0, repeat 5. to 7.

B. LED Alignment

1. Instruct the operator to align the slit on the LED by moving TM.

2. Step the slit wheel CCW 90° to position the narrow horizontal slit into place.

3. Instruct the operator to center the middle LED in the slit.

4. Set the slit wheel CW 90° to position the narrow vertical slit into place.

NOTE: It is assumed that the equipment registration has been previously perfected so recheck is unnecessary between X, Y in steps 1. to 4., otherwise, repetitive operator interaction is required.

5. Verify X, Y are still zero by reading their output. If not, re-zero them.

C. Set Reference Position

1. Instruct the operator to autocollimate the theodolite on the scan mirror--avoiding angles greater than 350 degrees or less than 10 degrees.

2. Request the operator to input the theodolite azimuth readings. Store it as

RXDEG, RXMIN, RXSEC

Convert to radian measure by

ANGX= (RXDEG+RXMIN/60.+RXSEC/3600.)π/180. (1)
REFX=ANGX

If REFX is greater than 350 degrees or less than 10 degrees, repeat 1.

3. Request the operator to input the theodolite elevation angle. Store it as

RYDEG, RYMIN, RYSEC

Convert to radian measure by

ANGY=(RYDEG+RYMIN/60.+RYSEC/3600.)π/180. (2)
REFY=ANGY

NOTE: If RYDEG is negative, assume that RYMIN and RYSEC are also negative. That is, set

RYMIN= -ABS(RYMIN)
RYSEC= -ABS(RYSEC)
IF RYDEG IS -

NOTE: Standard theodolite procedure consists of taking a reading, then flipping the telescope for a second reading. However, since theodolites differ in their use, it is assumed that the operator does the averaging before input. This may be revised, if desired, when the exact theodolite is chosen.

4. Set the Current Angle Indicators

TMANGX=REFX (3)
TMANGY=REFY (4)

5. Set the Offset

Since this is the reference position no steps will be required to move into the center position, so set

XOFFST=0. (5)

YOFFST=0. (6)

II Set at Band 3 Center (IBAND=2)

Band 3 center is specified to be the following angular distance from the LED:

LED to Axis	-0.01945 degrees
Axis to Band 3 center	-0.08618
Total	-0.10563 degrees

Set DELTAX= -0.10563
DELTAY= 0.

then follow the common procedure at V.

III Set at Band 2 Center (IBAND=3)

Band 2 center is specified to be the following angular distance from the LED:

LED to axis	-0.01945 degrees
Axis to Band 2	-0.14706
Total	-0.16651 degrees

Set DELTAX = -0.16651
DELTAY = 0.

then follow the common procedure at V.

IV Set at Bard 5 Center (IBAND=4)

Band 5 center is specified to be the following angular distance from the LED:

LED to axis	-0.01945 degrees
Axis to Band 5	+0.14758
Total	+0.12813 degrees

Set DELTAX = +0.12813
DELTAY = 0.

then follow the common procedure at V.

V Common Procedure for Bands 3, 2, 5

A. Remove previous offset by

1. Step in the X direction by -XOFFST steps. Remove backlash by overtravel and return if "XOFFST" is -.

2. Step in the Y direction by -YOFFST steps. Remove backlash by overtravel and return if "-YOFFST" is -.

B. Calculate New Theodolite Setting

1. Convert reference to degrees

RXD=REFX*180./π (7)

RYD=REFY*180./π (8)

2. Add Step to New Band

XD=RXD+DELTAX (9)

YD=RYD+DELTAY (10)

3. Convert to theodolite coordinates

This procedure is most easily described in FORTRAN as follows:

```
IDEG=XD
RXMIN=(XD-IDEG)*60.
IMIN=RXMIN
RXSEC=(RXMIN-IMIN)*60.
RXMIN=IMIN
RXDEG=IDEG
```

where IDEG and IMIN are integers.

RYDEG, RYMIN, and RYSEC are determined in a similar fashion. However, if YD is negative, it is easier to convert the absolute value, then apply the sign.

C. Move the Thematic Mapper

1. Instruct the operator to move the TM so the theodolite autocollimated on the scan mirror will be "approximately RXDEG, RXMIN, RXSEC in azimuth and RYDEG, RYMIN, RYSEC in elevation." Emphasize in the message that the exact value is not essential because it will be "trimmed" by the X-Y table.

2. Ask the operator to input the azimuth and elevation angles. Store them as RXDEG, RXMIN, RXSEC, RYDEG, RYMIN, RYSEC.

3. Calculate the current angle in radians using equations (1) and (2). Then

TMANGX=ANGX (11)

TMANGY=ANGY (12)

4. Calculate Offset needed

$$XOFFST=(XD*\pi/180.-TMANGX)/RSTEP \tag{13}$$

$$YOFFST=(YD*\pi/180.-TMANGY)/RSTEP \tag{14}$$

NOTE: Round these to nearest step.

5. Step off the Offset

   a. Step in the X direction XOFFST Steps. If XOFFST is -, add in -10 steps, then return +10 steps to remove backlash. If XOFFST is +, no backlash compensation is needed.

   b. Step in the Y direction YOFFST steps, and remove backlash as in a.

NOTE: The slit center should now be at band center. The calculation of angles from the axis TM axis using the present settings are given by

$$ANGLX=X*RSTEP+TMANGX-REFX+0.01945*\pi/180. \tag{15}$$

$$ANGLY = Y*RSTEP+TMANGY-REFY \tag{16}$$

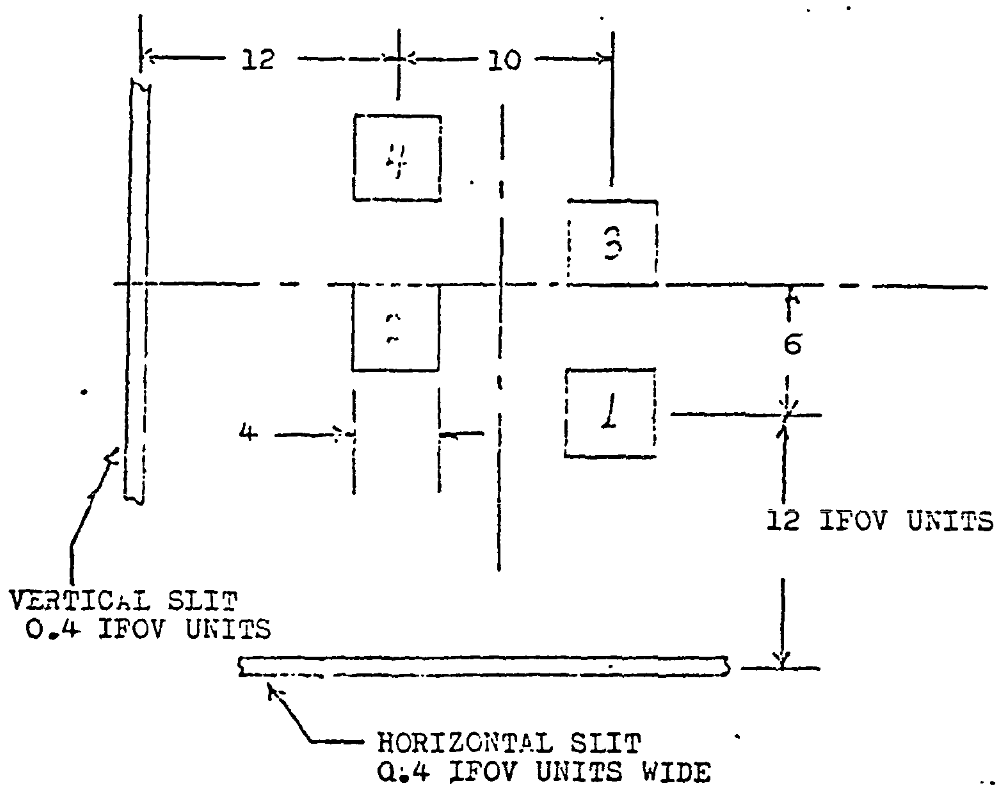
since X Y counters contain the offset between TMANGX AND XD as well as between TMANGY AND YD

VI Return to LED at End of Test (IBAND=5)

LED center is specified by

DELTAX=0.
DELTAY=0.

then follow the common procedure of V.



X AND Y DIRECTION MEASUREMENT PARAMETERS FOR BAND 6

FIGURE 1

c. Rotate the slit wheel 45 degrees CCW to position the horizontal Band 6 slit into place.

d. Return X to band center by stepping in the -X direction by 17.2 IFOV units +0.2 units for overtravel for a total of 17.4 IFOV units, then step in the +X direction by 0.2 units to remove the backlash.

e. Step in the -Y direction 18.2 IFOV units, then step in the +Y direction by 0.2 units to remove the backlash.

f. Take data on all four detectors from Y= -18.0 to +18.0 IFOV units as follows.

   1) Set NDSTRT = 1   NSTOP = 4   DSTEP = 1
      FSTEP = 0.2   NSTEP = 181

   2) Perform Sequence No. 2.

g. Rotate the slit wheel 45 degrees CW to position the vertical slit into place for Band 6.

h. Return Y to band center by stepping in the -Y direction by 18.2 IFOV units +0.2 units for overtravel for a total of 18.4 IFOV units, then step in the +Y direction by 0.2 units to remove the backlash.

PROCEDURE G

This procedure reduces the field of view data for Band 6, only. The 50 percent signal point is determined in X and Y for each detector, then the center coordinate is calculated.

I Data Storage Description

NOTE: Data are described as though 0.20 IFOV (8.5 microradians) steps were possible. The data step size and count must be adjusted here and in Procedure F to accommodate <u>practical</u> step size as determined by the collimator focal length.

A. Input Data

See Procedure F.

B. Output Data

The X data output consists of 4 data records, each with the following data items.

1. Detector No.

   Records 1-4 correspond to detector 1-4, respectively.

2. PEAKV

   PEAKV is the largest voltage for this detector which is used for normalization of the data samples.

3. Normalized Data

   This set consists of nominally 171 sets of X, Y, and the normalized voltage VPN. This set will probably not be exactly 171 values since the step size will vary from position to position to accommodate the collimator focal length. However, since X, Y are both stored, the coordinate variation will not cause a problem as long as the field of view boundary is respected (see discussion in Procedure F).

4. X1, X2, XC

   X1 is the X coordinate (obtained by interpolation) of the signal which is 0.5 of the peak of the normalized data. X1 is the value on the -X side of the detector, X2 is the value on the +X side. XC is the average of X1 and X2.

The Y data output is similar to the X data except in 3. the nominal number is 181 sets.

II X Data Reduction

Repeat the following for detectors 1 through 4
Field of View in X direction

Extract the X data from the file, consisting of nominally 171 sets of X, Y, and VPP data. Search the array for the peak value which will be found nominally at XC listed below.

Detector No.	Nominal X1	Nominal XC	Nominal X2
1	+3.	+5.	+7.
2	-7.	-5.	-3.
3	+3.	+5.	+7.
4	-7.	-5.	-3.

Call this peak value PEAKV, and save it. Normalize the data by dividing by PEAKV to get VPN. Save this data.

Search the normalized data on both sides of the peak for the two values which are less than 0.5. These will be nominally at X1 and X2 above. In addition to these two values, use the two adjacent values which are just larger than 0.5 and by linear interpolation, determine the two X values for VPS = 0.5 as follows.

For the lower X value edge,

Let X_i be the coordinate for VPN_i (VPN<0.5)
X_{i+1} be the coordinate for VPN_{i+1} (VPN>0.5)
where $X_{i+1} > X_i$.

The half width coordinate XHW is given by

$$XHW = \frac{(X_{i+1}-X_i)(1.0-VPN_i)}{VPN_{i+1}-VPN_i} + X_i \qquad (1)$$

Let X1=XHW for this coordinate on the -X side of center.

Similarly, the coordinate for the higher X value edge is given by (1) where

X_i is the coordinate for VPN_i (VPN<0.5)
X_{i+1} is the coordinate for VPN_{i+1} (VPN>0.5)

Let X2=XHW for this coordinate on the +X side of center. The coordinate of the center of the detector XC is then given by

$$XHW = \frac{X1+X2}{2} \qquad (2)$$

Save X1, X2, and XC for future use.

III Y Data Reduction

Repeat the following for detectors 1 through 4 Field of View in the Y direction

Extract the Y data from the file, consisting of nominally 181 sets of X, Y, and VPP data. Search the array for the peak value which will be found nominally at YC listed below.

Detector No.	Nominal Y1	Nominal YC	Nominal Y2
1	-8.	-6.	-4.
2	-4.	-2.	0
3	0.	+2.	+4.
4	+4.	+6.	+8

Call this peak value PEAKV, and save it. Normalize the data by dividing by PEAKV to get VPN. Save this data.

Search the array and determine Y1, Y2, and YC in an analogous fashion to the procedure used for X in II, above.

Save Y1, Y2, and YC for future use.

PROCEDURE H

This procedure retrieves data stored by Procedures G and E which allow conversion of X and Y from steps to radians. The field of view data for Band 6 is then checked against specified parameters, and the results printed.

Input Data

The data from Procedure E includes REFX, REFY, TMANGX, TMANGY, XOFFST, YOFFST, and RSTEP. See Procedure E for definitions.

The data from Procedure G includes NBAND, Detector No., PEAKV, slit array data in sets of X, Y, and VPN where X, Y are in step count units, X1, X2, X6, Y1, Y2, YC all in step count units.

Conversion from Step to Radians

The conversion equations are described in Procedure E and are reproduced here.

$$ANGLX=X*RSTEP+TMANGX-REFX+0.01945\pi/180. \quad (1)$$

$$ANGLY=Y*RSTEP+TMANGY-REFY \quad (2)$$

Specified Values for Band 6

A. Band Center (in milliradians), BC relative to the optic axis.

XBC= +4.0631
YBC= 0.

B. Detector Center (in milliradians) for Band 6

1. X Coordinate Relative to Band Center, BC

$$XDC=5.0*.0425(-1+2*MODULO(NDET,2)) \quad (3)$$

where NDET is the detector No.

2. Y Coordinate Relative to Band Center

$$YDC= -10+4*NDET \quad (4)$$

C. Optimum Detector Edges X1P, Y1P, X2P, Y2P

The ideal location for the detector edges is given by

$$X1P= XDC+XBC-0.085 \text{ milliradians} \quad (5)$$

$$X2P= XDC+XBC+0.085 \quad (6)$$

$$Y1P= YDC+YBC-0.085 \quad (7)$$

$$Y2P= YDC+YBC+0.085 \quad (8)$$

D. Detector Width, (X2-X1) on (Y2-Y1) specified

Minimum Difference = 0.1656
Maximum Difference = 0.1744

E. Detector Location and Size Printout

Perform the following 4 times

1. Input the X and Y data records for this detector.

2. Convert all coordinates to radians.

3. Store the converted data in the plot file.

4. Calculate

DX=X2-X1
DY=Y2-Y1

5. Print the following

a. Detector No.
b. XDC+XBC
c. XC
d. X1P
e. X1
f. X2P
g. X2
h. DX
i. "IN SPEC" or "OUT OF SPEC," see D above
j. error amount, if out of spec, or 0. if in spec.
k. YDC+YBC
l. YC
m. Y1P
n. Y1
o. Y2P
p. Y2
q. DY
r. "IN SPEC" or "OUT OF SPEC," see D above.
s. error amount, if out of spec, or 0. if in spec.

F. Tabulate Curve Data

This data consists of nominally 171 sets of X, Y and VPN in X direction and nominally 181 sets of X, Y, and VPN in the Y direction.

This data is to be printed in compact form.

PROCEDURE I

This procedure takes data stored in the plot file by Procedure H for Band 6 and forms two types of plots.

The first plot is the detector location plot. This consists of the outline of the 4 detectors in the band for ideal conditions with the X1, X2, XC and Y1, Y2, and YC measured points plotted on the outline.

The second plot consists of a presentation of the field of view data array for each axis on a 3 cycle semi-log paper. This will require 8 separate plots.

I Datector Location Plot

The ideal location of each detector edge is given by equations (5) through (8) of Procedure H. The ideal detector size for Band 6 is 170 microradians square. The plot scale should be chosen to give the best resolution possible. Since the 4-detector array is 14 IFOV units wide, a scale of 0.5 IFOV units per inch seems reasonable. The edge tolerance will be ±0.05 inches on this scale. Since the function of the plot is the illustration of any gross errors and systematic errors, the resolution should be adequate.

II Detector Field of View Plot

Each axis of a given detector is the subject for this plot. Thus, 8 plots will be required. The plot will be made on 3 cycle semi-log paper. This requires an abscissa of 48 IFOV units in X and 36 IFOV units for the Y plots. The scale of 0.5 IFOV units per inch will give an edge resolution of ±0.05 inches.

III Plot Priority

The plotting should not be allowed to slow up the test. The information is stored in a plot file, and plotted during theodolite setting after the Procedure H print is complete as time is available.

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Attachment

MEASUREMENT SEQUENCES

__Parameters__

NDSTRT is starting detector No.
NDSTOP is stopping detector No.
DSTEP is No. of detectors to step
NDETR is current detector in use
NSTEP is the No. of steps to take in IFOV
FSTEP is the step size in IFOV units

Sequence No. 1 (stepping in X direction, Post-data stepping)

1. NDETR=NDSTRT

2. Switch MUX to Detector NDETR, current band No.

3. Delay 160 milliseconds to allow 100 Hz filter to settle

4. Call VPEAK procedure to measure peak-to-peak voltage, VPP

5. Store X, Y step count, VPP, Detector No., Band No.

6. NDETR=NDETR+DSTEP

7. Repeat 2. through 7. until NDETR is greater than NDSTOP

8. Step FSTEP IFOV units in +X direction

9. Repeat 1. through 8. until sequence has been performed NSTEP times, then exit.

Sequence No. 2 (stepping in Y direction, Post-data stepping)

This sequence is the same as No. 1, except for 8. Step FSTEP IFOV units in +Y direction.

Sequence No. 3 (stepping in X direction, Pre-data stepping)

1. Step FSTEP IFOV units in +X direction
   NDETR=NDSTRT

2. through 7., same as Sequence 1.

8. Repeat 1. through 7. until sequence has been performed NSTEP times, then exit.

Sequence No. 4 (stepping in Y direction, Pre-data stepping)

Same as Sequence 3, except 1. uses +Y direction rather than X.

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VPEAK SUBROUTINE

This subroutine is called by the main spatial coverage procedure and by Procedures A and F indirectly through Sequences No. 1 through 4.

It is assumed that the ADAU has been set to a sample rate of 39 KHz, and that the SIU has selected the ADAU prior to calling this subroutine. It is further assumed that the 100 Hz center frequency filter with a 10 Hz bandpass is in place. It is also assumed that the 100 Hz filter, or associated amplifier in the ADAU, has a gain of 7.5 to boost the saturated output to the range of the A/D in the ADAU. This is necessary since a square wave of 2 volts peak-to-peak (saturation) gives rise to a fundamental sine wave of 2.5 volts peak-to-peak which corresponds to 1.25 volts peak-out of the 100 Hz filter (neglecting insertion loss). Since the A/D operates in the range of +/-10 volts (+/-2047 DN), the 1.25 volts must be amplified to use the full range of the A/D. A gain of 7.5 plus filter insertion loss compensation will boost the 1.25 volts to 9.375 volts (1920 DN). The additional range of the A/D is reserved for potential excursions.

This subroutine takes 4 independent cycles of the 100 Hz waveform which requires that every tenth cycle be sampled with the 10 Hz bandpass. Since Band 5 is expected to have the lowest signal-to-noise ratio, it is used to evaluate the expected data range. The 1 percent of saturation signal will give +/-19.2 DN from the A/D while the noise is shown in a separate memorandum to have a 95 percent probability of being within +/-2.0 DN for this Band 5, utilizing 4 independent 100 Hz cycles for peak-to-peak determination. This indicates that the error in determining the 1 percent level due to noise will be less than 5 percent of that level. The quantizing error can be as much as 3 percent of the 1 percent signal level. Both of these errors are quite acceptable in the far field measure, and the errors will be negligible for larger signals.

The subroutine also assumes that the detector has been connected by the MUX in the ADAU, and that the required settling time for the insertion of the 100 Hz filter (about 160 milliseconds) has elapsed before the subroutine call.

Subroutine Description

1. Sample the Data

   Command the ADAU to take data for 40 cycles of the 100 Hz output. This consists of taking data for 40*0.01 seconds which is 0.4 seconds. At the sample rate of 39.018 KHz this consists of 15607 samples. However, since the phase of the cycle is indeterminent, the first half cycle is discarded to be certain that the first peak or minimum are not missed. Also, the 31.5 cycle is last one used, so only 32 cycles are taken. Thus, 0.32 seconds of data are needed for 12486 samples. Each sample requires 2 bytes, since the A/D output is 11 bits plus sign.

2. Determination of the Peak-to-Peak Value

a. Spurious Peak Rejection

When the signal level gets to be very low, on the order of a few DN, spurious peaks may be determined. These spurious values may be deleted by requiring that all 4 peaks and minima must be separated by nominally 0.10 seconds from peak-to-peak or minimum to minimum (using every 10th cycle).

Set the number of good sets optimistically to 4 by NS=4.

b. First Sample Peak-to-Peak

Skip the first 195 samples, then search samples 196-585 for the maximum and minimum, call them VP and Vm and call the sample number NP and NM, respectively. Reduce NP and NM by 195 and store them.

c. Second Sample Peak-to-Peak

Search samples 4097-4487 for peak and minimum, as in b, except reduce NP and NM by 4096 before storing. These sample numbers have been obtained by skipping 9 cycles (586-4096).

d. Third Sample Peak-to-Peak

Search through samples 8000-8389, recording VP, VM, NP, and NM, reducing NP and NM by 7999 before storing.

e. Fourth Sample Peak-to-Peak

Search through samples 11901-12290, recording VP, VM, NP, and NM, reducing NP and NM by 11900 before storing.

f. Discard on the basis of peak to minimum separation. Check the 4 samples to see if they are in the range

$$175 \leq |NP-NM| \leq 215$$

If any set fails this test, discard it and reduce NS by 1. If NS=0 or 1, set VPP=0. and leave the subroutine.

g. Discard on the basis of NP variation for NS sets where NS = 2, 3 or 4.

Search the combinations and mark for use the first 2 values which satisfy

$$|NP(i)-NP(j)| \leq 40 \quad i=1,4 \quad j=1,4 \quad j \neq i$$

Average these 2 values, and keep any subsequent value which is within .40 of the average.

If NS=0, set VPP=0. and exit

h. VPP Determination

For each of the NS cycles remaining, calculate

VS=VP-VM

Then average the NS sets of VS to get VPP.

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HUGHES

INTERDEPARTMENTAL CORRESPONDENCE

TO T.B. VanHorne CC.

ORG

DATE: 13 June 1979

HS236-5610-2

SUBJECT Thematic Mapper Spacial Coverage Test Description, AC7R.

FROM: L.J. Richter

ORG. 40-91-30

BLDG. 373 MAIL STA. B322

LOC. SC EXT. 82358

History : G.R. Hyde, "Thematic Mapper Spacial Coverage Test Description", HS236-5610, 30 Jan 1978.

J.C. Celio, "Thematic Mapper Spacial Coverage Test Description revisited," HS236-5610-1, 8 August 1978.

This memo provides a second revision of the Spacial Coverage test description. This revision incorporates

1. Correct coordinates to agree with spacecraft coordinates
2. Collection of near detector data from all 16 channels in each band, but to save time, collection of a data far from the detector for only 4 channels in each band.
3. Incorporation of HP interferometer data
4. Addition of flowcharts for procedures A,B,E,F, and G which specify the steps to be accomplished by the software.

L J Richter

L.J. Richter

TB VanHorne

607C CS FEB 72

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This test is performed on the Thematic Mapper with the scan mirror stationary to determine the size and location of all 100 detectors.

The Thematic Mapper is mounted on a precision table. However, the position of the TM is determined by autocollimating a theodolite on the locked scan mirror to measure to the required precision. The source is projected towards the TM through a collimator which has a computer driven X-Y stepping stage to position the entrance slit. However, the collimator has a narrow field of view range, so it is necessary to move the TM four times during the test.

The software procedure for controlling the test is specified in the following steps. These steps in turn call procedures which are detailed in subsequent sections. The procedures perform the following functions.

Procedure A (Data Collection)

The data for the 16 detectors of one band are taken in X and Y and stored for reduction. Bands 1, 2, 3, 4, 5, and 7 use this procedure.

Procedure B (Data Reduction)

The data for one band are reduced to give normalized data, and the detector width is determined in X and Y.

Procedure C (Printing)

The detector size and location for the band are checked against specifications, and the size, location, and condition relative to specifications are printed on a priority basis to keep the test operator abreast of progress.

Procedure D (Plotting)

The field of view data are converted to radian measure relative to the optical axis of TM, and the data are sent to a plot file to be plotted as time is available, but with low priority.

Procedure E

The movement of TM is controlled and monitored, including all interaction with the optical technician operating the theodolite.

Procedure F,G,H, and I

These procedures are analogous to A,B,C and D, but they apply to band 6 only, which has 4 detectors.

VPEAK Subroutine

The data on any given detector are sampled and processed to determine the peak-to-peak output.

Sequence No. 1 (Post-Data Stepping)

This sequence is called by Procedures A and F to take data on a sequence of detectors over a specified slit step range. Data are taken, then the entrance slit is stepped in X.

Sequence No. 2 (Post-Data Stepping)

Analogous to No. 1, but it uses Y coordinates.

Sequence No. 3 (Pre-Data Stepping)

Similar to No. 1, but the slit step occurs before data are taken.

Sequence No. 4 (Pre-Data Stepping)

Similar to No. 2, but the slit step occurs before data are taken.

INDEX A Data Collect for algorithm VPEAK

The Test Procedure Follows

1. Instruct the operator to set the scan mirror to the center of scan and lock it in place.

2. Verify that the scan line corrector is off; if not, command it off, and verify.

3. Instruct the operator to align the collimator with TM.

4. Perform Procedure E with IBAND=1 to initialize all counters and position on the LED.

5. Instruct the operator to connect the auxiliary detector plane cooling equipment, but do not turn it on at this point in time.

6. Command all bands to "off."

7. Select the ADAU A/D in the SIU, 2 channel option

8. Select the 39 KHz sampling rate in the ADAU (the divide by 16 function).

9. Switch in the 100 Hz filter with a 10 Hz bandpass in the ADAU.

10. Drive the aperture table in the + y direction toward band 4 for the following IFOV distances

LED to axis	7.988	IFOV units
Axis to Band 4 center	10.394	IFOV units
Band 4 center to even detector center	1.250	IFOV units
total	19.632	IFOV units

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NOTE: The number of steps to use must be calculated from the collimator focal length FLC as follows

$$\text{STEP ANGLE} = \frac{0.0001 \text{ inch/step}}{\text{FLC inches}}$$

$$\text{NO. STEPS/IFOV} = \frac{42.5\times10^{-6} \text{ radians}}{\text{STEP ANGLE}}$$

Currently there are 2 possible collimators which may be used. They have FLC of 108.3 inches and 110 inches corresponding to 46.0275 and 46.75 steps/IFOV, respectively.

11. Command bands 1 to 4 to "ON," and instruct the operator to turn on the auxiliary cooling for Bands 5, 7 and 6.

12. Have operator turn on 100 Hz chopper and adjust the source current until the peak-to-peak signal is 18.8 volts (±1920 ADAU radiance levels). At the operator's request, collect Index A data from channels 2 and 16 of band 4. Reduce the data using the VPEAK algorithm and display the peak-to-peak signal of the two detectors and their difference (which should be less the 1 volt).

13. Perform Procedure E with IBAND = 2 to position between bands 3 and 4.

14. Slip to the center of band 4, 12.7 IFOV units in the -Y direction, then 0.2 IFOV in the +y direction in preparation for the execution of procedure A, the collection of a full set of field of view data from one band.

15. Perform Procedure A on Band 4.

16. Reduce the band 4 data by performing Procedure B.

17. Print the band 4 data using Procedure C which also checks the parameters against specification.

18. Plot the band 4 data by performing Procedure D.

19. Save the band 4 data on a 9 track mag tape for future reference including the associated parameters from Procedure E REFX, REFY, TMANGX, TMANGY, XOFFST, YOFFST, and FLC.

20. The narrow vertical slit is now at the center of band 4. Step it to the center of band 3 by moving in the +y direction by 25 IFOV units.

21. Perform procedures A,B,C, and D on Band 3.

22. Save the band 3 data on magnetic tape as above.

23. Perform Procedure E with IBAND=3 to position between bands 1 and 2.

24. Step the narrow vertical slit to the center of band 2 by moving it in the -y direction by 12.7 IFOV's. Then move in the +y direction 0.2 IFOV units.

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25. Perform Procedures A,B,C and D on band 2.

26. Save the Band 2 data on magnetic tape as above.

27. Step the narrow slit to the center of band 1 by stepping by 25 IFOV units in the +y direction.

28. Perform Procedures A,B,C, and D on band 1.

29. Save Band 1 data on magnetic tape, as above.

30. Perform Procedure E with IBAND = 4 to position between bands 5 and 7.

31. Step the narrow vertical slit to the center of Band 5 by moving it in the -y direction by 13.2 IFOV units, then move 0.2 IFOV units in the +y direction.

32. Perform Procedure A,B,C, and D on band 5.

33. Save band 5 data on magnetic tape as above.

34. Step the narrow vertical slit from the center of band 5 to the center of band 7 by moving in the +y direction by 26 IFOV units.

35. Perform Procedures A,B,C, and D on band 7.

36. Save the band 7 data on magnetic tape as above.

37. Instruct the operator to install the blackbody source for band 6, then command band 6 "ON."

38. Step to the center of the even detectors by stepping in the -y direction by 29.95 IFOV units. Then move 0.2 IFOV in the +y direction.

39. Step the slit wheel to position the band 6 vertical slit into place.

40. Adjust the source current until the peak-to-peak signal is 18.8 volts (±1920 ADAU radiance levels). At the operator's request, collect Index A data from the even detectors of band 6. Reduce the data using VPEAK and report the resulting peak-to-peak signal.

41. Step in the -y direction to the center of band 6 by stepping -5.2 IFOV units and then steping 0.2 units in the +y direction.

42. Perform Procedure F to acquire the data, Procedure G to reduce it, Procedure H to print and check against specifications, and Procedure I to plot it.

43. Save the band 6 data on magnetic tape as above.

44. Step the slit wheel to move the small vertical slit into place.

45. Drive the slit back to the LED to close the traverse by performing Procedure E with IBAND=5.

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46. Instruct the operator to switch the X,Y controller to local mode then position the vertical slit onto the LED by stepping in from the - to + direction in the final approach to remove backlash. Instruct the operator to select the narrow horizontal slit, then center the middle LED by stepping from -x to +x direction on the final approach.

47. Instruct the operator to switch the X,Y controller to remote.

48. Read the X and Y encoders, then using (.0001)/FLC as the number of radians per step calculate XERR and YERR where FLC is the effective focal length of the collimator.

XERR = (X-XOFFST) (.0001)/FLC radians
YERR = (Y-YOFFST) (.0001)/FLC radians

49. Command bands 1,2,3,4,5,6 and 7 to "OFF."

50. Instruct the operator to turn off the auxiliary detector plane cooling.

51. Instruct the operator to turn off the blackbody and visible detector sources.

52. Command the SIU back to internal MUX usage.

53. Print the message

"END OF SPATIAL COVERAGE TEST,

X closure error = (XERR value) radians,
Y closure error = (YERR value) radians."

Procedure A

This procedure is used to acquire the data from the field of view measurements for one detector band in a form suitable for reduction by Procedure B, and for print and plot by Procedures C and D.

This procedure assumes that the narrow vertical slit is in the center of the band in the y direction, and the narrow horizontal slit may be centered in the x direction by a 90-degree rotation of the slit wheel.

Data Storage Description

Data are described for the 2 collimators. The data step size and count must be adjusted here in Procedure B to accommodate practical step size as determined by the collimator focal lengths. This adjustment must respect IFOV boundary locations, but may allow more incremental steps within boundaries. For example, it takes 20 positions of 0.05 IFOV units (2.125 microradians each) to cover one IFOV. However, if the 111-inch focal length collimator were to be used each step is 0.9009 microradians, so each data point would require either two steps (1.8018 microradians) or three steps (2.727 microradians). In the case where a movement of 1 IFOV is required, 42.5 microradians/.9009 microradians indicates 47 of the .9009 microradians steps are required. Thus, 13 positions of 2 steps each plus 7 positions of 3 steps each will be equivalent to the desired 20 positions of 0.05 IFOV.

For the 108.3 in. focal length collimator, use 23 data steps of .0002 inches (2 steps) each to cover each IFOV unit. For the 110 in. focal length collimator, use 22 data steps of .0002 inches and one data step of .0003 inches.

Figure 1 illustrates the testing procedure to be followed in taking data in the y direction, and Figures 2 and 3 illustrate the procedure used in the x direction. Figure 4 illustrates the distribution between narrow slit data and wide slit data in the x direction.

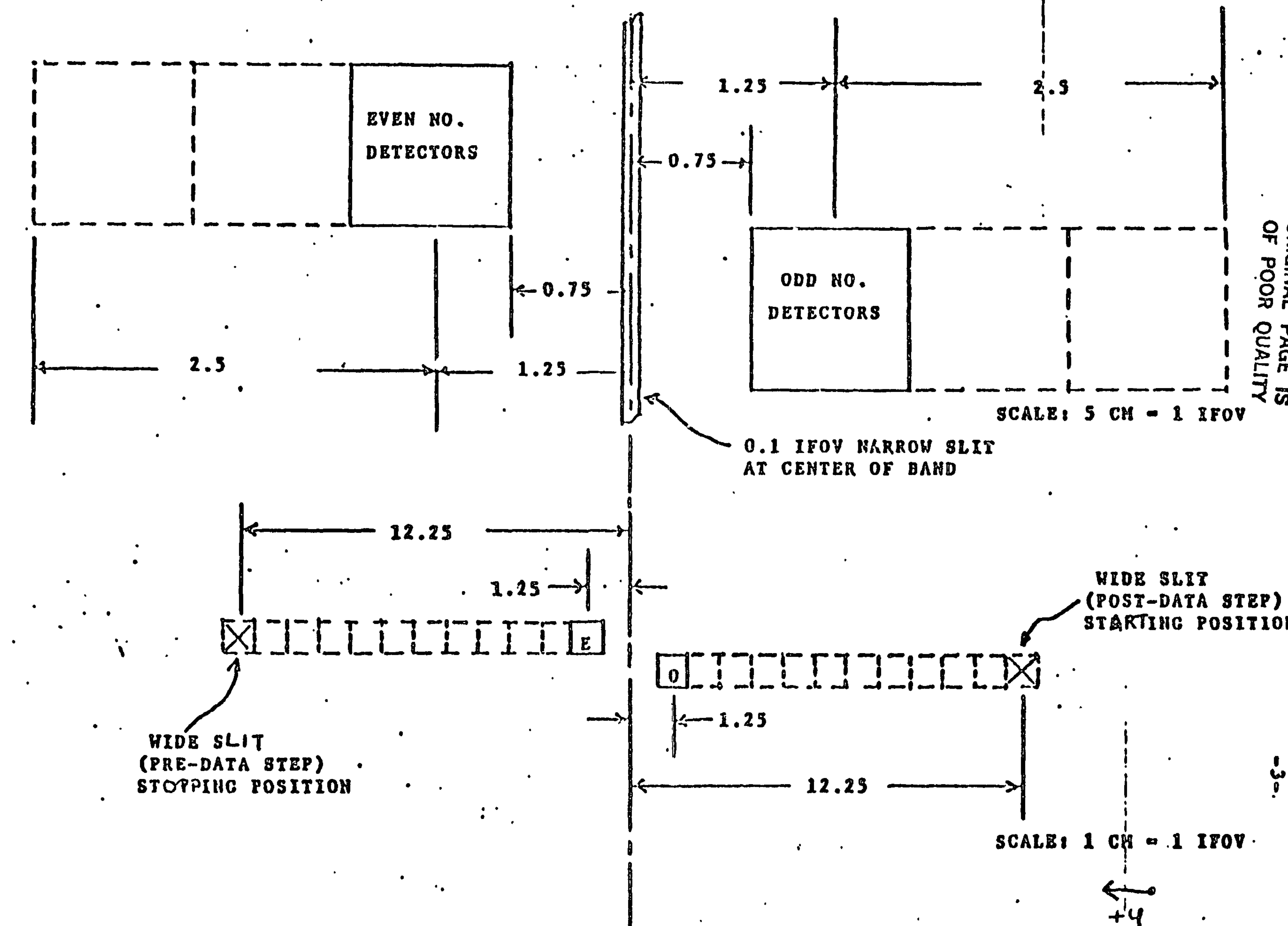
In the y direction, the wide slit is positioned -12.25 IFOV units from the center line (see Figure 1), then the slit is stepped in units of 1 IFOV to take the far field data. The wide slit is not used on the detectors since the signal level is 10 times saturation, so stepping stops at -2.25 IFOV. Narrow slit data is then taken after backing the narrow slit to y = -3.75 IFOV units. The narrow slit data is taken until y = +3.75 IFOV units. The slit location is moved to y = +2.25, the wide slit inserted, and the remaining data are taken. See Table I for the data storage sequence.

The x direction data acquisition proceeds in a similar fashion. The slit is moved to x = -17.5 IFOV units, then the wide slit is moved into place. At that position only detector 16 is within 10 IFOV of the slit, so only detector 16 is used. Finally, when the slit is at -8.5 IFOV, detectors 16, 9 and 8 are within 10 IFOV units of the slit. Since the power through the slit is 10 times saturation, the wide slit is not stepped across the detectors.

The slit is changes to narrow size, then backed up to the position illustrated in Figure 2. For the first IFOV, only detector No. 16 is within 2 IFOV units of the slit. When the slit is 1 IFOV unit from detector 16, data can also be taken on detector 15 since it is then 2 IFOV units away. As the slit is stepped further, more detectors come within the +/-2 IFOV data range. The data storage is listed in Table II, and the range of data are illustrated in Figure 4.

In the figure, the narrow slit range is illustrated by a T-shaped line on each side of the detector, and the wide slit data points are illustrated by an X.

The data acquisition steps will now be described.



Y DIRECTION MEASUREMENT PARAMETERS
FIGURE 1

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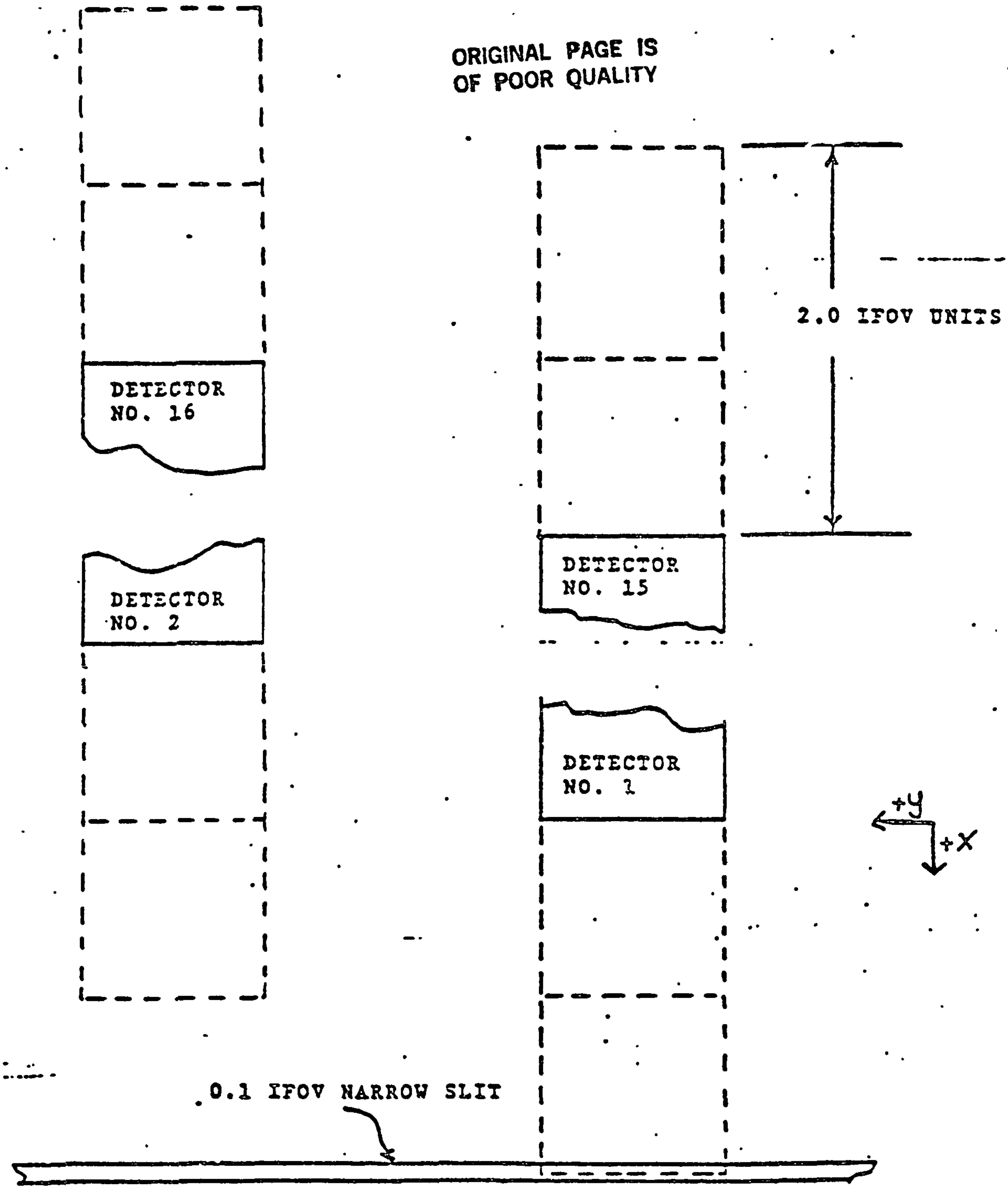
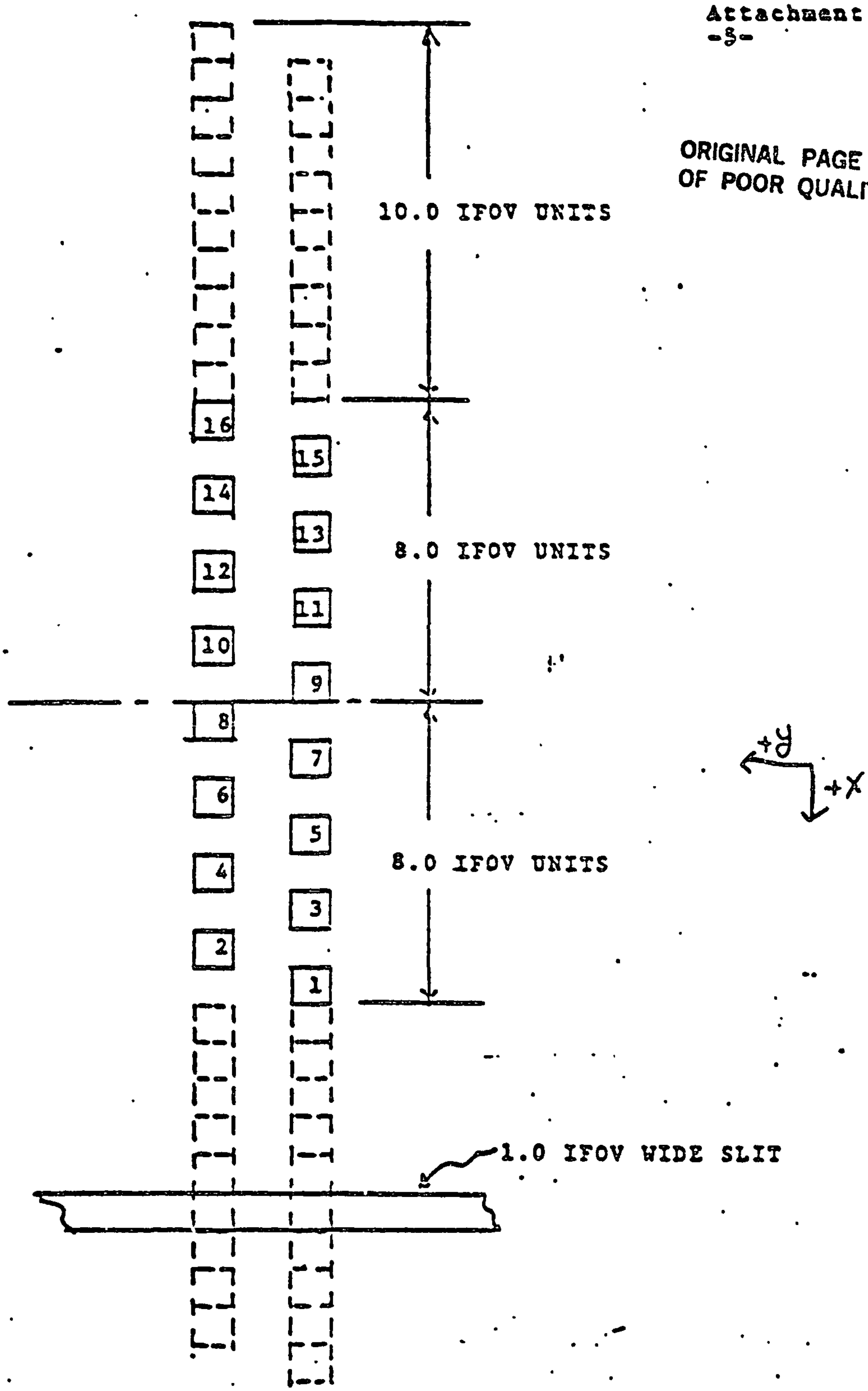
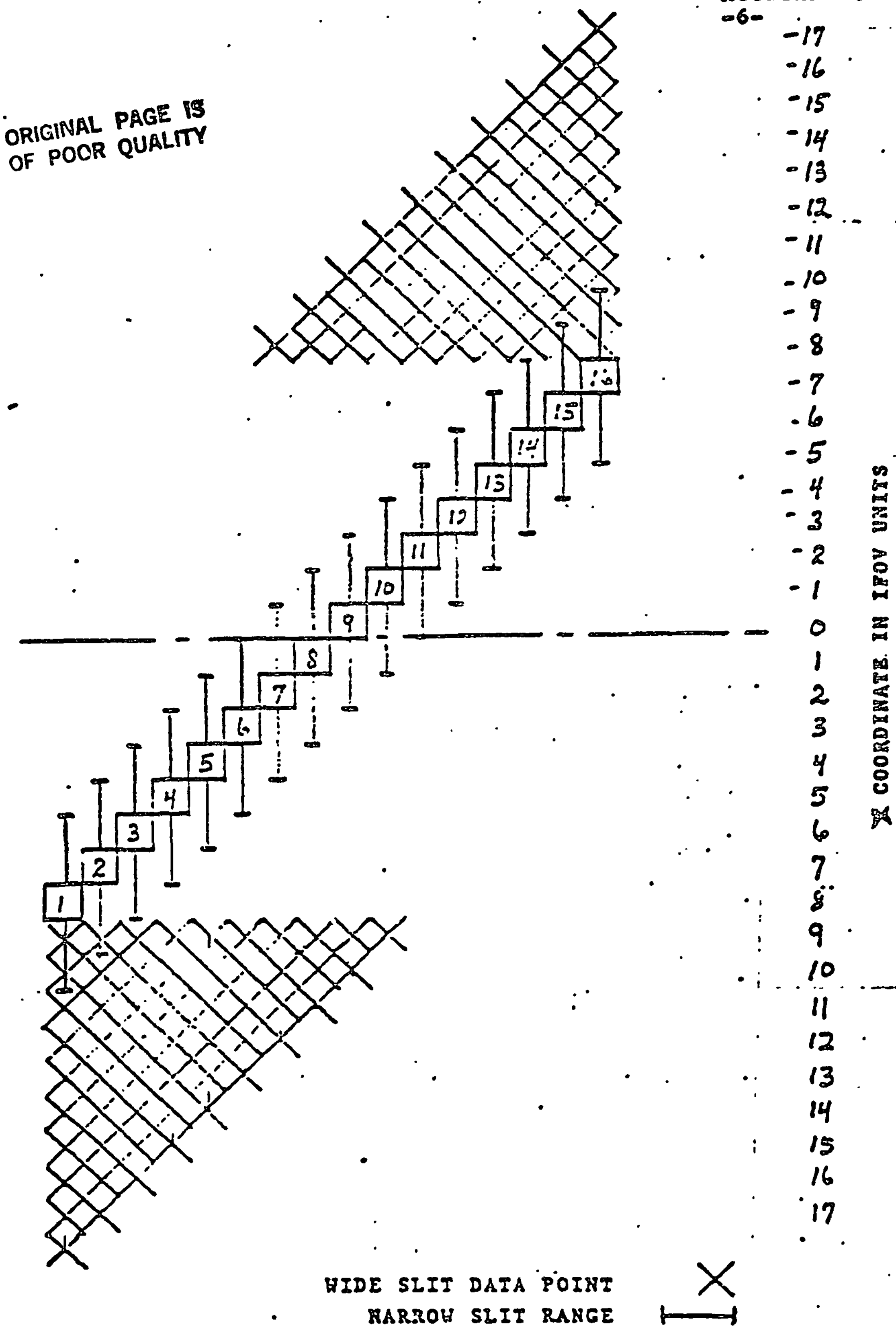


X DIRECTION NARROW SLIT MEASUREMENT.
FIGURE 2



X DIRECTION WIDE SLIT MEASUREMENT
FIGURE 3

Procedure A (contd)



RANGE OF DATA POINTS IN X COORDINATE

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1. Field of View Stepping in y Direction (along scan)

Note: Units are given here in IFOV units. See flowchart for distance give in 3-axis stage steps.

a. Step in the -y direction to a position which is 12.25 IFOV units from the band center line. Step 0.2 IFOV units further in -y direction, then step 0.2 IFOV units in the +y direction to minimize backlash.

b. Rotate the slit wheel to position the wide vertical slit over the source. This signal level is 10 times saturation, so it should not be stepped across the detectors.

c. Take data for 10 IFOV positions on the -y side of the odd detectors as called out on the flowchart (using a pre-data step to avoid the detector at the end).

d. Rotate the slit wheel to position the narrow vertical slit over the source. This signal level is set for saturation level. The narrow slit data will be taken from 2 IFOV units on the -y side of the odd detectors to 2 IFOV units on the +y side of the even detectors.

e. Move the slit 1.7 IFOV units in the -y direction, then move it 0.2 IFOV units in the +y direction to minimize backlash.

f. Take data for 7.5 IFOV units, 23 steps per IFOV unit, as called out on the flowchart.

g. Step back to the center of the first IFOV on the +y side of the even detectors by stepping in the -y direction by 1.8 IFOV units, then stepping by 0.2 IFOV units to remove backlash.

h. Rotate the slit wheel to position the wide vertical slit over the source. This signal level is 10 times saturation, so should not be stepped across the detectors.

i. Take data for 10 IFOV positions on the +y side of the even detectors as called out on the flowchart. (use post-data step to avoid the detectors).

j. This completes the acquisition of data in the y direction for this band. The slit will be set on the small size horizontal slit and the slit will be moved back to the center of the band. The center of the slit is currently 10.5 IFOV on the +y side from the even numbered detectors. Rotate the slit wheel. Step the slit in the -y direction 12.45 IFOV units, then step 0.2 IFOV units in the +y direction to remove backlash.

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2. Field of View for bands. Stepping in the X direction (across scan)

The narrow horizontal slit is now positioned between detectors 8 and 9 of the array.

a. Step the slit 18.7 IFOV units in the -x direction, then step 0.2 IFOV in +y to remove backlash. This leaves the center of the slit 10.5 IFOV units below detector No. 16.

b. Rotate the slit wheel to position the wide horizonal slit into place. Since the radiance level is 10 times the saturation level, this slit should not be stepped across the detectors.

c. Take signal data on detector 16 which is 10 IFOV away at this position, then step 1 IFOV and take data on detector 16 again, and continue until the slit is 3 IFOV from detector 16 at which time data will be taken on detectors 16, and 9. Twice move 1 IFOV and take data from 16, 9, and 8. This is accomplished as called out on the flowchart.

d. Step to a position 2.0 IFOV below detector No. 16 in preparation for fine slit measurements. The wide slit is currently centered 0.5 IFOV below detector 1. Proceed as follows. Step in the -x position 1.7 IFOV units, then step in the +y direction 0.2 units.

e. Rotate the small horizontal slit into place

f. Take data on all detectors which are within two IFOV of the slit, see Table II, until the small slit is 2 IFOV units above detector 1. The procedure is called out on the flowchart.

g. Step back to center the slit 0.5 IFOV above detector 1 by stepping in the -x direction by 1.7 IFOV, then stepping in +x by 0.2 IFOV to remove backlash.

h. Rotate the large horizontal slit into place.

j. Collect data with the wide slit as called out in the flowchart, moving 10 IFOV units.

k. The center of the slit is now located 10.5 IFOV above detector 1. Return the slit center to the band center reference between detectors 8 and 9 as follows.

   (1) Rotate the slit wheel to move the small vertical slit into place.

   (2) Step in the -x direction 18.7 IFOV units, then step 0.2 IFOV units in the +x direction to remove backlash.

PROCEDURE A FLOWCHART

Collecting narrow and wide slit data for one band. When two choices of step numbers are given, the smaller is for the 108.3$^{in.}$ collimator, the larger for the 110$^{in.}$ collimator.

Start y direction (across track)

Assume narrow vertical slit at band center

Step 574 or 589 steps in -y direction, then 10 steps in +y direction

Pause so operator can rotate wide vertical slit into place

Perform Seq. 3 ND1, ND2
N = 1 1,9
FSTEP= 46 or 47

Do 2 times

Perform Seq 3 ND1, ND2
N=2 1,9
FSTEP=46 or 47 8,16

Do 8 times

Pause so operator can rotate narrow vertical slit into place

Move the slit 79 or 80 steps in the -y direction then 10 steps in +y direction

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Procedure A

Perform Seq. 1 N=4 FSTEP=2 — ND1, ND2: 1,9; 3,11; 5,13; 7,15 — Do 22 times

Perform Seq 1 N=4 FSTEP = 2 or 3 — ND1, ND2 as above (all odd)

Do 2 times

Perform Seq 1 N = 4 FSTEP=2 — ND1, ND2 as above (all odd) — Do 12 times

Perform Seq 1 N = 8 FSTEP=2 — ND1, ND2: 1,9; 3,11; 5,13; 7,15; 2,10; 4,12; 6,14; 8,16 — Do 10 times

Perform Seq 1 N=8 FSTEP=2 or 3 — ND1, ND2 as above (all channels)

Perform Seq 1 N=8 FSTEP=2 — ND1, ND2 as above (all channels) — Do 22 times

Perform Seq 1 N = 8 FSTEP=2 or 3 — ND1, ND2 as above (all channels)

Do 2 times

Perform Seq 1 N = 4 FSTEP = 2 — ND1, ND2: 2,10; 4,12; 6,14; 8,16 — Do 22 times

Perform Seq 1 N=4 FSTEP=2 or 3 — ND1, ND2 as above (all evens)

Do 2 times

Procedure A

Perform Seq 1   ND1, ND2
N=4   2,10
FSTEP=2   4,12
6,14
8,16

Do 12 times

↓

Step 79 or 80 in -y direction; then 10 steps in +y direction

↓

Pause so operator can rotate wide vertical slit into place

↓

Perform Seq 1   ND1, ND2
N=8   1,9
3,11
5,13
FSTEP=46 or 47   7,15
2,10
4,12
6,14
8,16

Do 8 times

↓

Perform Seq 1   ND1, ND2
N=4   2,10
FSTEP=46 or 47   4,12
6,14
8,16

Do 2 times

↓

Pause so operator can set slit to narrow horizontal one and rotate into place

↓

Step slit 573 or 588 steps in -y direction then 10 steps in +y direction

End
y direction
(across track)

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Procedure A

Start
X direction
(along track)

Step slit 861 or 880
steps in -x direction
then 10 steps in +x
direction

↓

Pause while operator
rotates wide horizontal
slit into place.

↓

Perform Seq 4 ND1, ND2
N = [illegible] 16, dummy
FSTEP=46 or 47

Do 7 times

↓

Perform Seq 4 ND1, ND2
N = 1 9, 16
FSTEP = 46 or 47

↓

Perform Seq 4 ND1, ND2
N = 2 9, 16
FSTEP=46 or 47 8, dummy

Do 2 times

↓

Pause so operator can
rotate narrow horizontal
slit into place

↓

Move the slit 79 or 80
steps in the -x direction,
then 10 steps in the +x
direction

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Procedure A

Perform Seq 2 ND1, ND2
N=1 16, dummy
FSTEP=2
Do 22 times

Perform Seq 2 ND1, ND2
N = 1 16, dummy
FSTEP = 2 or 3

Perform Seq 2 ND1, ND2
N=1 15, 16
FSTEP = 2
Do 22 times

Perform Seq 2 ND1, ND2
N = 1 15, 16
FSTEP = 2 or 3

Perform Seq 2 ND1, ND2
N = 2 15, 16
FSTEP=2 14, dummy
Do 22 times

Perform Seq 2 ND1, ND2
N=2 15, 16
FSTEP = 2 or 3 14, dummy

Perform Seq 2 ND1, ND2
N=2 15, 16
FSTEP = 2 13, 14
Do 22 times

Perform Seq 2 ND1, ND2
N=2 15, 16
FSTEP= 2 or 3 13, 14

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Procedure A

Perform Seq 2 ND1, ND2
N = 3 from chart
FSTEP = 2 below

Do 22 times

Perform Seq 2 ND1, ND2
N = 3 from chart
FSTEP = 2 below

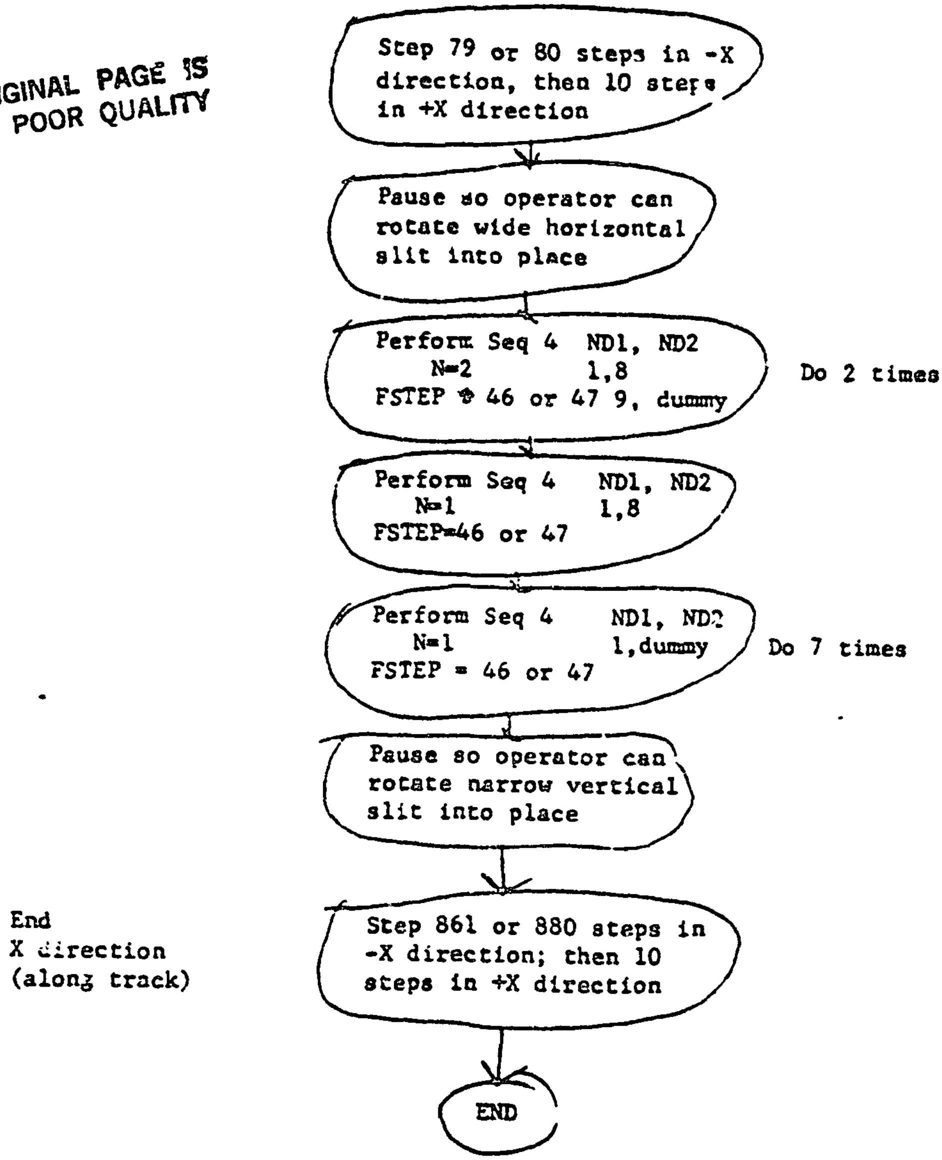
Do 12 times

Chart of detectors ND1, ND2

1	16, 15, 14, 13, 12 dummy
2	15, 14, 13, 12, 11 dummy
3	14, 13, 12, 11, 10 dummy
4	13, 12, 11, 10, 9 dummy
5	12, 11, 10, 9, 8 dummy
6	11, 10, 9, 8, 7 dummy
7	10, 9, 8, 7, 6 dummy
8	9, 8, 7, 6, 5 dummy
9	8, 7, 6, 5, 4 dummy
10	7, 6, 5, 4, 3 dummy
11	6, 5, 4, 3, 2 dummy
12	5, 4, 3, 2, 1 dummy

Procedure A

```
Perform Seq 2     ND1, ND2
N = 2             4,3              Do 22 times
FSTEP = 2         2,1

        ↓

Perform Seq 2     ND1. ND2
N = 2             4,3
FSTEP = 2 or 3    2,1

        ↓

Perform Seq 2     ND1, ND2
N = 2             3,2              Do 22 times
FSTEP = 2         1, dummy

        ↓

Perform Seq 2     ND1, ND2
N = 2             3,2
FSTEP = 2 or 3    1, dummy

        ↓

Perform Seq 2     ND1, ND2
N = 1             2,1              Do 22 times
FSTEP = 2

        ↓

Perform Seq 2     ND1, ND2
N = 1             2,1
FSTEP = 2 or 3

        ↓

Perform Seq 2     ND1, ND2
N = 1             1, dummy         Do 22 times
FSTEP = 2

        ↓

Perform Seq 2     ND1, ND2
N = 1             1, dummy
FSTEP = 2cr 3
```


Step 79 or 80 steps in -X direction, then 10 steps in +X direction
Pause so operator can rotate wide horizontal slit into place
Perform Seq 4 N=2 FSTEP = 46 or 47 ND1, ND2 1,8 9, dummy
Do 2 times
Perform Seq 4 N=1 FSTEP=46 or 47 ND1, ND2 1,8
Perform Seq 4 N=1 FSTEP = 46 or 47 ND1, ND2 1,dummy
Do 7 times
Pause so operator can rotate narrow vertical slit into place
End X direction (along track)
Step 861 or 880 steps in -X direction; then 10 steps in +X direction
END

PROCEDURE B

This procedure reduces the field of view data for one band, only. The 50 percent signal point is determined in X and Y for each detector, then the detector center coordinate is calculated. The narrow slit data taken 1. to 2. IFOV from a detector is used to compare with the wide slit data.

I Data Storage Description

A. Input Data

See Procedure A.

B. Output Data

1. The Y data output consists of 16 data records each with the following data items.

a. Detector No. C

Records 1 - 8 will be for detector numbers 1, 3, ...15
Records 9 - 16 will use detector numbers 2, 4, ...16

b. PEAKVY(C)

PEAKVY(C) is largest voltage for this detector which is used for normalization of the data samples.

c. Normalized Narrow Slit Data

This data set consists of nominally 115 sets of X, Y, and the normalized voltage VPNNY.

d. Y1, Y2, YC

Y1 is the Y coordinate (obtained by interpolation) of the signal which is 0.5 of the peak of the normalized data. Y1 is the value on the -Y side of the detector, Y2 is the value on the +Y side. YC is the average of Y1 and Y2.

e. Normalized Wide Slit Data

For channels 1, 8, 9, and 16 there is wide slit data. This data set consists of 18 sets of X, Y, and the normalized voltage VPNWY. Items 8 and 9 of this set (Y = -2.25 and +2.25 IFOV units) will not be plotted since they are adjacent to the detector and may show cross talk since the wide slit has a power density which is 10 times saturation. These two points will be printed for diagnostic interest, only.

f. VNAVEY(C) VWAVEY(C)

VNAVEY(C) is the averaged value of the narrow slit signals which together combine to make up the second IFOV away from the detector. This value is compared with VWAVEY(C)

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which is the normalized wide slit response at Y = -3.25 for the even detectors or Y = +3.25 for the odd detectors.

g. NBAND

The band no. of the data taken.

2. The X data output consists of 16 data records, each with the following data items.

a. Detector No. C

Records 1 - 16 will increase sequentially in detector number.

b. PEAKVX(C)

This is the same as Y, except the X data are used.

c. Normalized Narrow Slit Data

these date are similiar to the Y data.

d. X1, X2, XC

These are analogous with Y1, Y2, and YC, above.

e. NW(C) and Normalized Wide Slit Data

For data detectors 1, 8, 9, or 16 there is wide slit data. There will be a variable number of wide slit data points for each detector. The data record should save space for a point counter NW and up to 10 sets of X, Y, and VPN as follows.

Detector No. C	NW(C)
1 and 16	10
8 and 9	5

f. VNAVEX(C) and VWAVEX(C)

These are analogous to the Y data, <u>except</u> only detectors 1 and 16 have data entries.

g. NBAND

The band no. of the data taken.

II Y Data Reduction

A. Repeat the following for the odd no. detectors 1, 3, ..., 15.

1. Field of View in Y (Scan) Direction

For the detector with channel no. C, extract the 115 small slit data points VPPNY from the file. The peak value will nominally be the 58th, but search the array for the peak; call this PEAKVY(C) to get VPNNY. Save this data. Search the normalized data on both sides of the peak for the two values which are less than 0.5. These will be nominally at the 47th and 70th points. Take the two adjacent normalized data values which are just larger than 0.5 and by linear

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interpolation determine the two Y values for VPNNY = 0.5 as follows.

For the lower Y value edge.

Let i be the element such that VPNNY(i) <0.5 and VPNNY(i + 1) > 0.5. Then the half width coordinate is given by the linear interpolation formula.

$$YHW = \frac{(Y\ (i+1) - Y\ (i))\ (0.5 - VPNNY\ (i))}{VPNNY\ (i+1) - VPNNY(i)} + Y(i) \qquad (1)$$

Let Y1 = YHW for this coordinate on the -Y side of center. Similarly, the coordinate for the higher Y value edge is given by (1) where

Y(i) is the coordinate for VPNNY(i) $\geq$ 0.5

Y(i+1) is the coordinate for VPNNY(i+1) < 0.5

Let Y2 = YHW for this coordinate on the +Y side of center. Calculate the coordinate of the center of the detector, YC, from the two half width coordinates Y1 and Y2 as follows:

$$YC = \frac{Y1 + Y2}{2} \qquad (2)$$

Save the Y1, Y2, YC for future use.

If the detector is numbered 1 or 9, extract the wide slit data VPPWY(i). There will be 18 values; the first 10 are from the -Y side of the detector, and the remaining 8 are from the +Y side. The tenth value, coming from a position of Y = 2.25, is adjacent to the detector and may have cross talk obsuring its value since the wide slit has 10 times the detector saturation power, this value is not plotted with the field of view data, but is is printed for diagnostic value.

Normalize the 18 wide slit data values as follows:

$$VPNWY(i) = \frac{VPPWY(i)}{PEAKVY(C) * 10} \qquad i = 1, \ldots, 18 \quad (3)$$

and save these values.

2. Small Slit and Wide Slit data Match

The 24 values of the VPNNY array that come from positions Y = -3.25 to Y = -2.75 are averaged to compare with the wide slit data from position Y = -3.25. The first and 24th entries are divided by 2 to allow for the overlap of the narrow slit past the IFOV boundaries at those points.

$$VNAVEY(C) = \left[\frac{VPNNY(C,\ 1) + VPNNY(C,\ 24)}{2} + \sum_{i=2}^{23} VPNNY(C,i)\right]\frac{1}{23} \qquad (4)$$

The narrow slit average should be compared to

VWAVEY(C) = VPNWY(C,9)

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Save VNAVEY, VWAVEY. These numbers are the match between small slit data and wide slit data at 2 IFOV from the detector.

B. Repeat the following for the even number detectors 2, 4, ...16.

1. Field of view in the Y (scan) direction.

Extract the narrow slit data, normalize it, and calculate Y1, Y2, and YC as in A1 for the odd detectors.

If the detector is numbered 8 or 16, extract the wide slit data VPPWY(i), there will be 18 values; the first 8 are from the Y side of the detector, and the remaining 10 are from the +Y side. The ninth value, coming from position Y = +2.25. adjacent to the detector and may have cross talk obscuring its value since the wide slit has 10 times the detector saturation power. This value is not plotted with the field of view data, but is is printed for diagnostic value.

Normalize the 18 wide slit data values using equation (3) and save them for subsequent use.

2. Small slit and wide slit data match

The 24 values of the VPNNY array that come from positions Y = 2.75 to Y = 3.75 are averaged as in equation (4) to compare with the wide slit data from position 4 = 3.25. Thus far C = 8, 16.

$$\text{VNAVEY(C)} = \left[\frac{\text{VPNNY(C, 92)} + \text{VPNNY(C,115)}}{2} + \sum_{i=93}^{114} \text{VPNNY(C,i)}\right] \frac{1}{23} \qquad (6)$$

$$\text{Let VWAVEY(C)} = \text{VPNWY(C,10)} \qquad (7)$$

Save VNAVEY and VWAVEY as these are the comparison between the narrow and wide slit data.

III Data Reduction

Repeat the following for all detectors 1, 2, ...,16.

A. Field of View in Direction Normal to Scan (X)

Extract the 115 narrow slit VPPNX data values for the detector from the file. The starting X position is given by X5-NDET+11, and the ending X position is X5-NDET+6.044 where the data steps assumed are 1/23 IFOV.

The nominal peak value of the detector is at the 58th point.

Search the data array for the peak value; call this PEAKVX(C); save it. Normalize the data by dividing by PEAKVX(C) to get VPNNX save this array. Search the normalized data on both sides of the peak for the two values which are less than VPNNX ≤0.5. These will be nominally at the 47th and 70th point.

A. Cont'd.

Using these 2 values and the 2 adjacent values just larger than VPNNX >0.5 linearly interpolate for the X values corresponding to VPNNX = 0.5.

Let i be the number of the element such that VPNNX(i) ≤0.5 and VPNNX (i+1) >0.5. Then the half width coordinate is given by the linear interpolation formula.

$$XHW = \frac{(X(i+1) - X(i)\ )\ (0.5 - VPNNX(i))}{VPNNX(i+1) - VPNNX(i)} + X(i) \qquad (8)$$

Let X1=XHW for this coordinate on the -X side of center.

Similarly, the coordinate for the higher X half width is found by letting i be the element such that VPNNX(i) ≥0.5 and VPNNX(i+1) <0.5.

Let X2 = XHW for this coordinate on the +X side of the detector center.

Calculate the detector center coordinate XC by:

$$XC = \frac{X1 + X2}{2} \qquad (9)$$

Save X1, X2 and XC for future use.

The wide slit data exists for detector number C = 1, 8, 9, and 16 and is variable by detector number. The starting X value on the minus side of the detector XSM is given by:

$$XSM = -C -1.5\ IFOV \qquad (10)$$

The ending value on the minus side XEM is:

$$XEM = -\ 8.5\ IFOV \qquad (11)$$

Thus, only detectors 8, 9, and 16 have wide slit data points on the minus side.

The starting X value on the positive X side of the detector, XSP, is given by:

$$XSP = +8.5\ IFOV \qquad (12)$$

The ending value on the positive side, XEP, is:

$$XEP = 18.5 - C\ IFOV \qquad (13)$$

Thus, only detectors 1, 8, and 9 have wide slit data points on the positive side.

Thus detector 1 has 10 wide slit data points, VPPWX(1, P) for P=1, ...,10 all from the +X side. Detector 8 has 5 wide slit data points, VPPWX(8, P) for P=1, ...5. The first two from the -X side and the remaining three from the +X side. The five values

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A. Cont'd.

for detector 9, VPPWX(9,P) for P = 1,......5, come 3 from the -X side and then 2 from the +X side. Finally, detector 16 has 10 wide slit data points, VPPWX(16,P), P=1,.........10, all from the -X side.

Normalize the wide slit data forming the array VPNWX by the equation:

VPNWX(C,i) = VPPWX(C,i)/(10*PEAKVX(C)),i=1,.......5 and 10.

B. Small Slit and Wide Slit Data Match

For the odd detector number 1, the 24 values of the VPNNX array that come from positions X = 9.0 to X = 10.0 are averaged as in equation 4 to compare with the wide slit data from position X = 9.5. Thus:

$$\text{VNAVEX}(1) = \left[\frac{\text{VPVNX}(1,92) + \text{VPNNX}(1,115)}{2} + \sum_{i=93}^{114} \text{VPNNX}(1,i)\right]\frac{1}{23} \qquad (14)$$

This narrow slit average should be compared to:

$$\text{VWAVEX}(1) = \text{VPNWX}(1,\ 2) \qquad (15)$$

For the even detector number 16, the 24 values of the VPNNX array that come from positions X = -10.0 to X = -9.0 are averaged as in equation (4) to compare with the wide slit data from position X= -9.5. Thus:

$$\text{VNAVEX}(16) = \left[\frac{\text{VPNNX}(1,1) + \text{VPNNX}(1,\ 24)}{2} + \sum_{i=2}^{23} \text{VPNNX}(1,i)\right]\frac{1}{23} \qquad (16)$$

This narrow slit average should be compared to:

$$\text{VWAVEX}(16) = \text{VPNWX}(16,\ 9) \qquad (17)$$

Save the VNAVEX and VWAVEX values.

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PROCEDURE B

Data Reduction for one Band

Variables

XNY(C,P) C=1,......,16 P=1,.....,115	X-coordinate from which pth narrow slit sample came when sweeping in Y-direction, Channel C.	collected in Procedure A
YNY(C,P) C=1,......,16 P=1,.....,115	Y-coordinate from which pth narrow slit sample came when sweeping in Y-direction, Channel C.	Collected in Procedure A
VPPNY(C,P) C=1,......,16 P=1,.....,115	Peak-to-peak signed (from VPEAK) of Channel C, pth sample sweeping Y direction.	Collected in Procedure A
PEAKVY(C) C=1,......,16	Peak value in VPPNY(C,P)	Calculated here
VPNNY(C,P) C=1;......,16 P=1,.....,115	Normalized VPPNY array	Calculated here
XWY(C,P) C=1,8,9,16 P=1,.....,18	X-coordinate from which pth wide slit sample came when sweeping in Y-direction, channel C	Collected in Procedure A
YWY(C,P) C=1,8,9,16 P=1,....,18	Y-coordinate from which pth wide slit sample came when sweeping in Y-direction, Channel C	Collected in Procedure A
VPPWY(C,P) C=1,8,9,16 P=1,.....,18	Peak-to-peak signal (from VPEAK) of Channel C, pth sample sweeping Y direction.	Collected in Procedure A
VPNWY(C,P) C=1,8,9,16 P=1,.....,18	Normalized VPPWY array	Calculated here
VNAVEY(C) C=1, 8,9,16	Average value for Channel C of normalized narrow slit data	Calculated here
VWAVEY(C)	Channel C, normalized wide slit data for comparison with VNAVEX	Calculated here
Y1(C) C=1,....,16	-Y side 50% point for Channel C	Calculated here
Y2(C) C=1,.....,16	+Y side 50% point for Channel C	Calculated here
YC(C) C=1,......,16	Channel C center	Calculated here

PROCEDURE B

Data Reduction for one Band

<u>Variables</u>

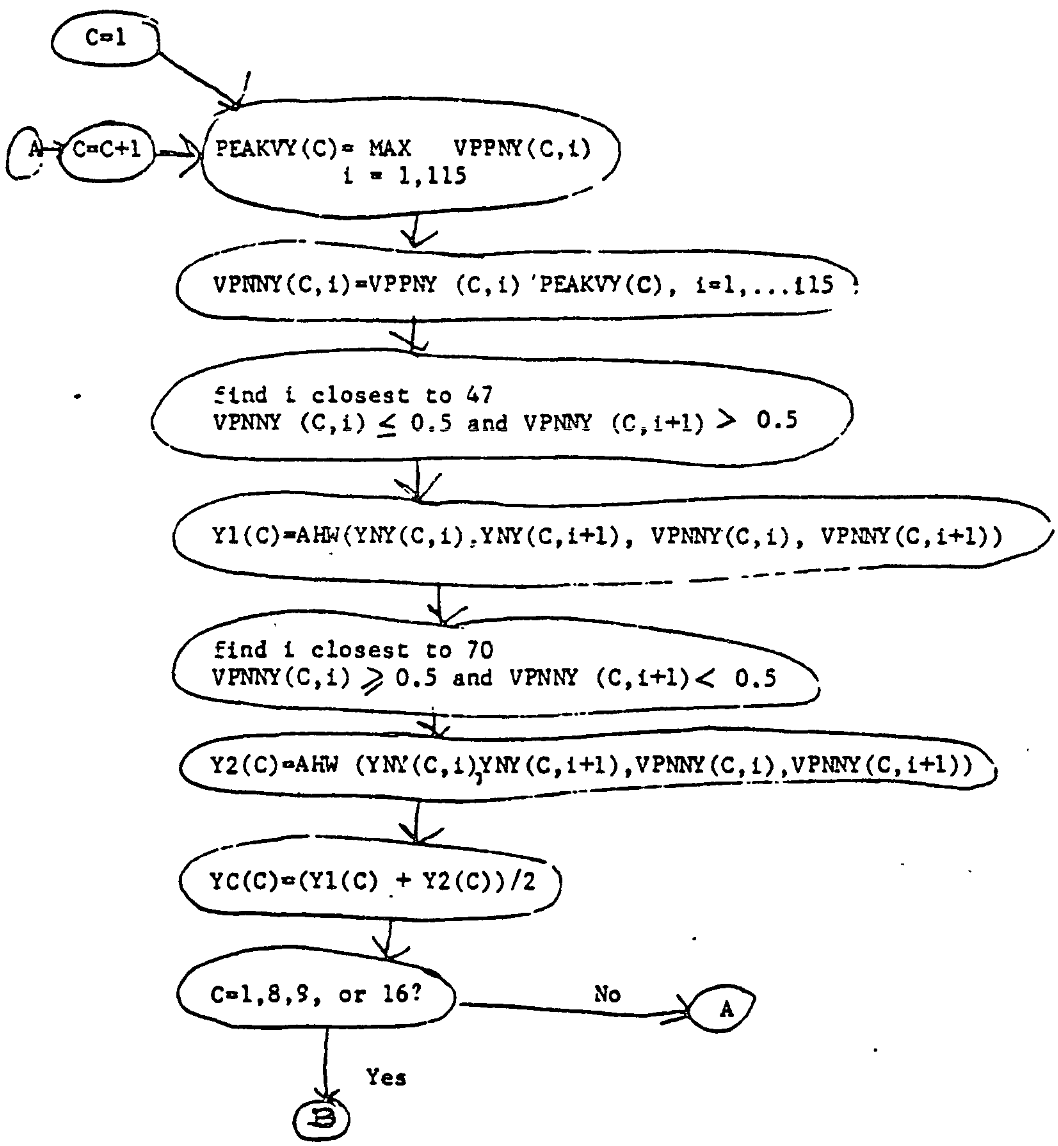
NW(C) C=1,8,9,16	Number of wide slit data points for ChannelC, X direction		Data Base
XNX(C,P) YNX(C,P) VPPNX(C,P) PEAKVX(C) VPNNX(C,P) X1(C) X2(C) XC(C)	C=1,.......,16 P=1,......,115	Same as above, except sweeping in X direction	
XWX(C,P) YWX(C,P) VPPWX(C,P) VPNWX(C,P)	C=1,8,9,16 P=1,...,NW(C)	Same as above, except sweeping in X direction	
VNAVEX(C) VWAVEX(C)	C=1,16	Same as above, except sweeping in X direction	
NBAND	Number of band data comes from		

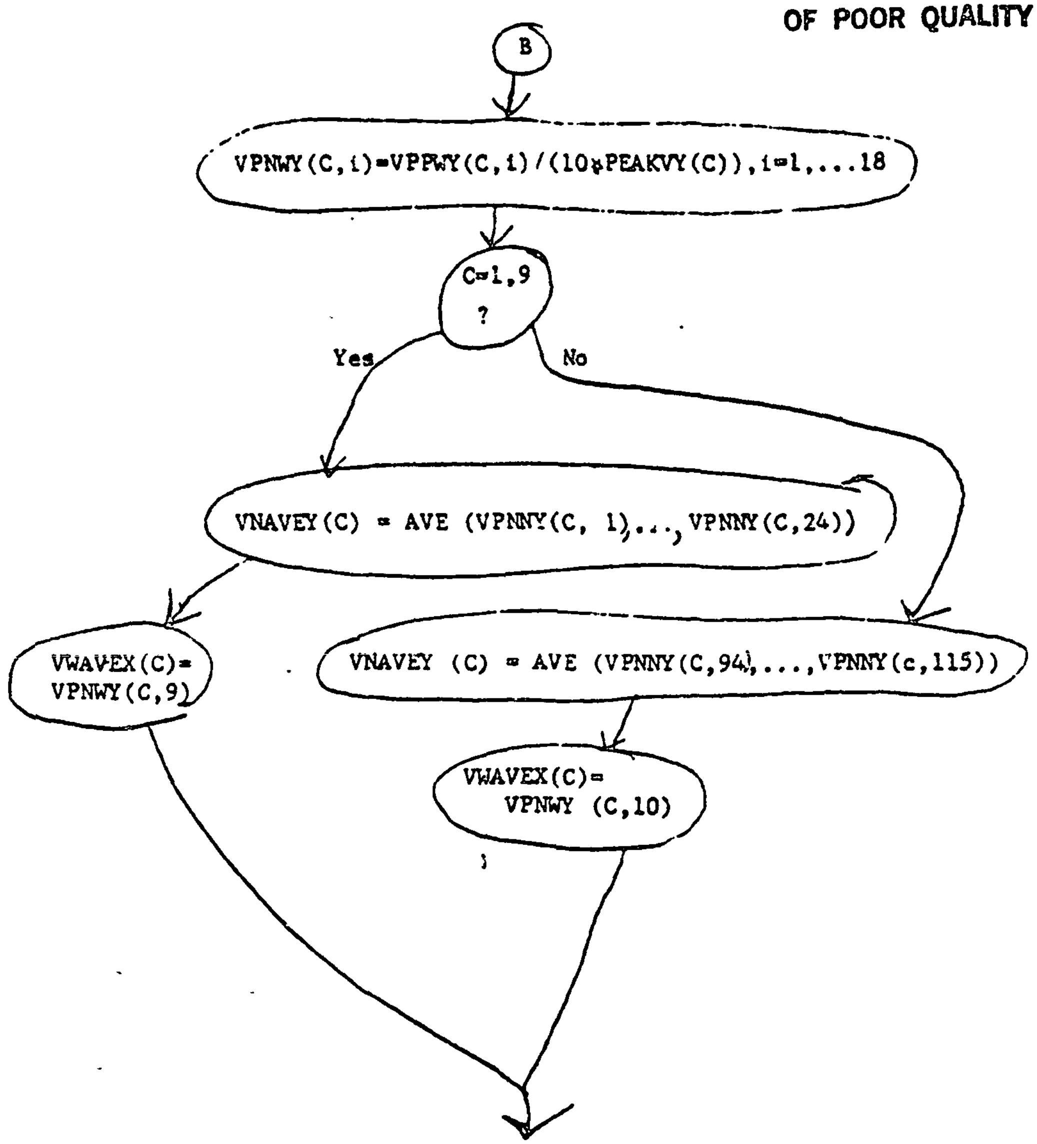
Functions

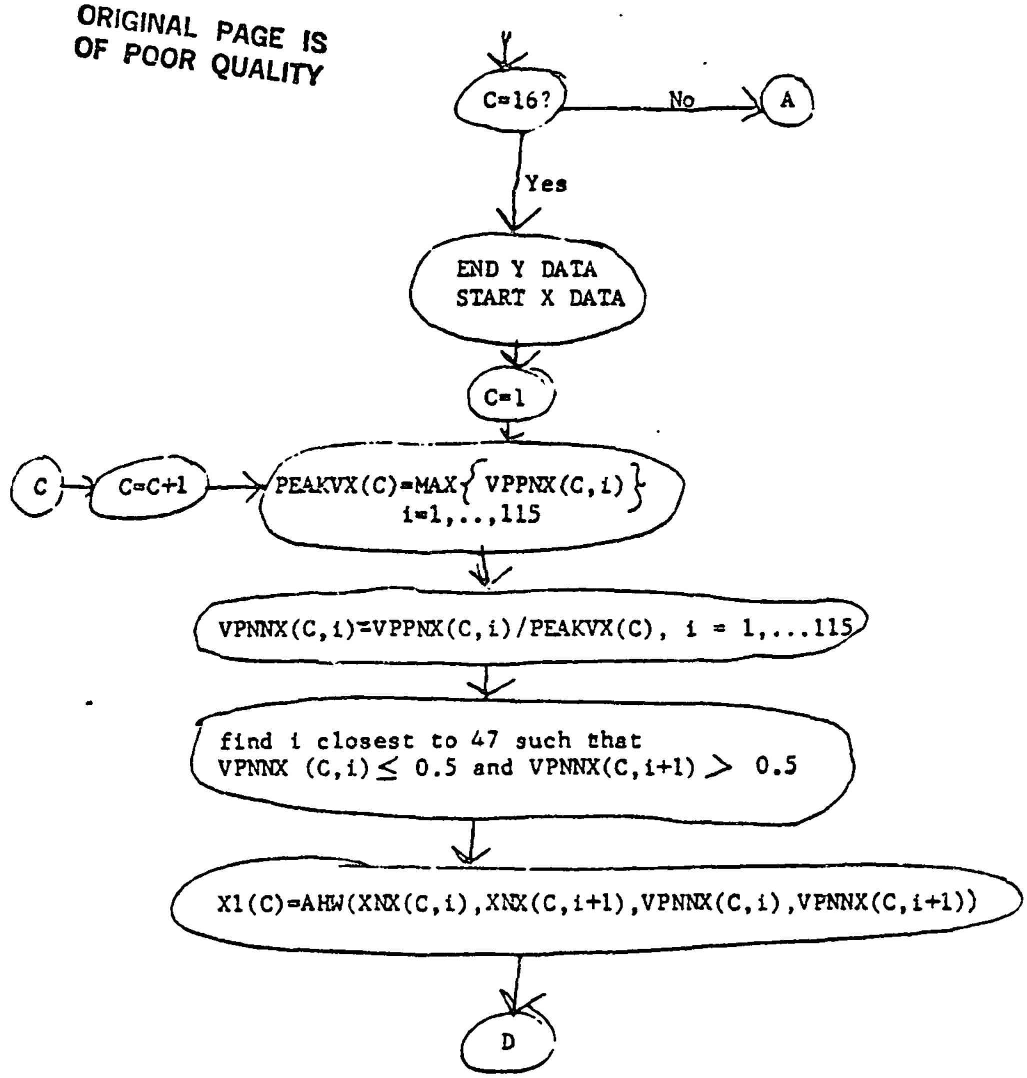
$$AHW(A1,A2,\ B1,\ B2) = \frac{(A2 - A1)\ \ (0.5 - B1)}{(B2 - B1)} + A1$$

$$AVE(V(1),\ V(24)) = \left[\frac{V(1) + V(24)}{2} + \sum_{I=2}^{23} V(I)\right]\frac{1}{23}$$

Procedure B flowchart




B
VPNWY(C,i)=VPPWY(C,i)/(10*PEAKVY(C)),i=1,...18
C=1,9
?
Yes
No
VNAVEY(C) = AVE (VPNNY(C, 1),..., VPNNY(C,24))
VWAVEX(C)=
VPNWY(C,9)
VNAVEY (C) = AVE (VPNNY(C,94),...,VPNNY(c,115))
VWAVEX(C)=
VPNWY (C,10)


C=16?
No
A
Yes
END Y DATA
START X DATA
C=1
C
C=C+1
PEAKVX(C)=MAX{VPPNX(C,i)} i=1,..,115
VPNNX(C,i)=VPPNX(C,i)/PEAKVX(C), i = 1,...115
find i closest to 47 such that
VPNNX (C,i) ≤ 0.5 and VPNNX(C,i+1) > 0.5
X1(C)=AHW(XNX(C,i),XNX(C,i+1),VPNNX(C,i),VPNNX(C,i+1))
D

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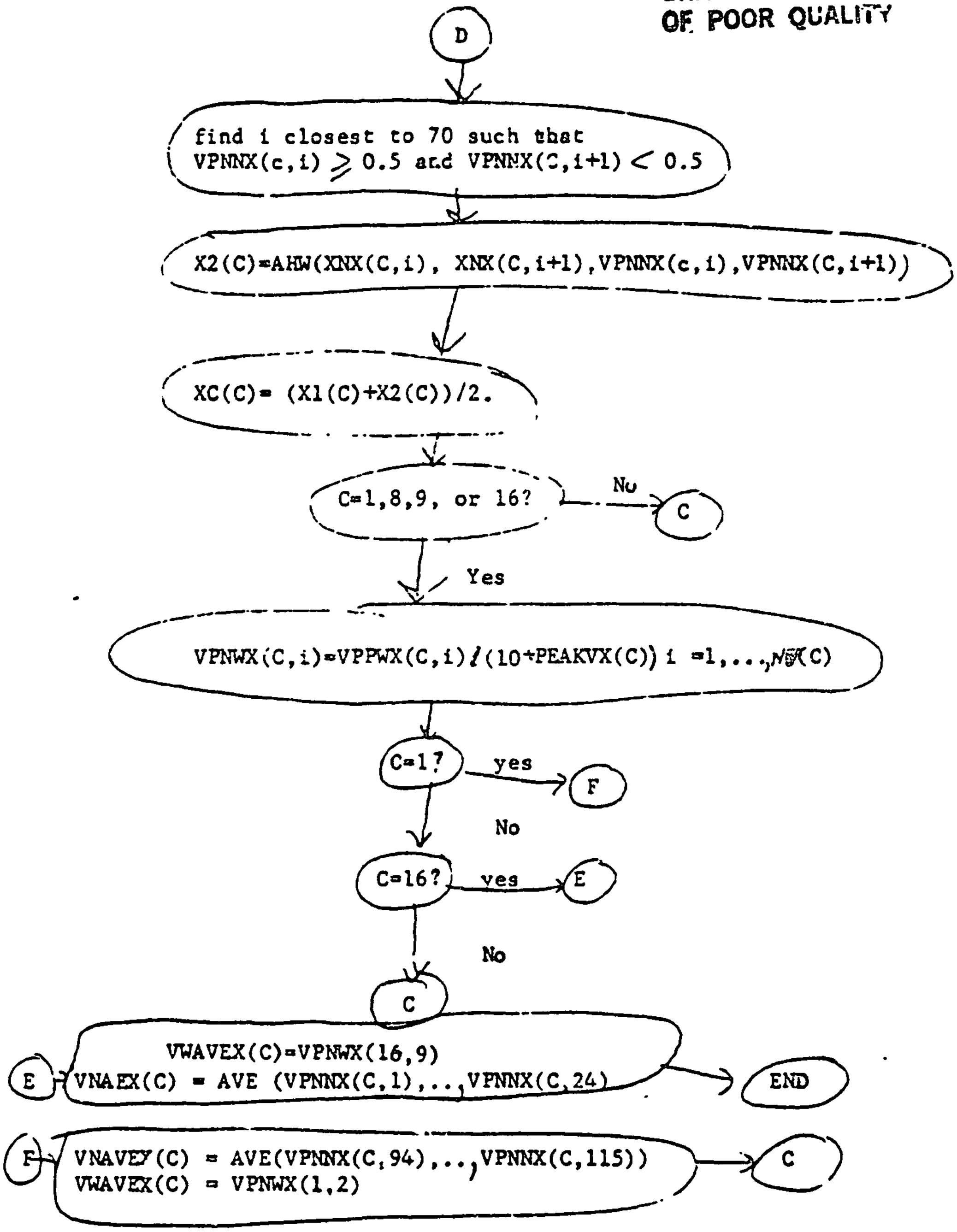

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PROCEDURE C

This procedure retrieves data stored by Procedures B and E which allow conversion of X and Y from steps to radians. The field of view data for the band is then checked against the specified parameters, and the results printed.

Input Data

The data from Procedure E includes REFX, REFY, TMANGX, TMANGY, XOFFST, YOFFST, and FLC. See Procedure E for definitions.

The data from Procedure B includes NBAND, Detector No., PEAKV, narrow slit array data in sets of X,Y, VPN where X,Y are in step count units, X1, X2, SC, Y1, Y2, YC all in step count units, wide slit data in sets of X,Y, and VPN, VNAVE, and VWAVE.

Conversion from Step to Radians

The conversion equations are described in Procedure E and are reporduced here.

RSTEP = .0001/FLC

ANGLEY = Y*RSTEP+TMANGY-REFY-0.01945π/180. (1)

ANGLX = X*RSTEP+TMANGX-REFX (2)

Specified Values for Each Band

A. Band Centers (in milliradians), BC relative to the optic axis

BAND	YBC	XBC
1	+3.6291	0.
2	+2.5667	0.
3	+1.5041	0.
4	+0.44174	0.
5	-2.5758	0.
6	-1.4708	0.
7	-4.0631	0.
LED	-0.33947	0.

B. Detector Center (in milliradians) for Bands 1-5, 7

1. Y Coordinate relative to band center (3)
   YDC = 1.25*.0425 (+1-2*MODULO(NDET,2))
   where NDET is the detector No.

2. X Coordinate relative to band center (4)
   XDC = (+0.5-NDET)*.0425

Procedure C

C. Optimum Detector EDGES X1P, Y1P, X2P, Y2P

The ideal location for the detector edges is given by

X1P = XDC+XBC-.02125 milliradians (5)

X2P = XDC+XBC+.02125 (6)

Y1P = YDC+YBC-.02125 (7)

Y2P = YDC+YBC+.02125 (8)

D. Detector Width, (X2-X1) OR (Y2-Y1) Specified

BAND	MINIMUM DIFFERENCE	MAXIMUM DIFFERENCE
1	.0419 milliradians	.0431 milliradians
2	.0419	.0431
3	.0419	.0431
4	.0419	.0431
5	.04115	.04635
6	.1656	.1744
7	.04115	.04635

E. Detector Location and Size Printout

Perform the following 16 times.

1. Input X and Y data records for this detector.
2. Convert all coordinates to radians.
3. Store the converted data in the plot file.
4. Calculate DX=X2-X1
   DY=Y2-Y1
5. Print the following
   a. Detector No.
   b. XDC+XBC
   c. XC
   d. X1P
   e. X1
   f. X2P
   g. X2
   h. DX
   i. "in spec" or "out spec", see D above

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j. error amount if out spec, 0. if in spec

k. YDC+YBC

l. YC

m. Y1P

n. Y1

o. Y2P

p. Y2

q. DY

r. "in spec" or "out spec", see D above

s. err amount if out spec, 0. if in spec

F. Tabulate Curve Data for Small and Large Slits

Print the following data in compact form.

1. Narrow Slit Data

   a. Y direction

      This data consists nominally of 115 sets of X, Y, VPN with X, Y expressed in radian measure from the axis and VPN is the normalized voltage.

   b. X direction

      This data consists nominally of 115 sets of X, Y, and VPN data as above.

2. Wide Slit Data for detectors 1,8,9, and 16

   a. Y direction

      This data consists of 18 sets of X,Y, and VPN, plus VNAVE and VWAVE.

   b. X direction

      This data consists of NW sets of X,Y, and VPN where NW is a function of detector No. Detectors 8 and 9 have 5 points. 1 and 16 have 10 points. Only detectors 1 and 16 have VNAVE and VWAVE values.

PROCEDURE D

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This procedure takes data stored in the plot file by Procedure C for each band and forms two types of plot. The first plot is the detector location plot. This consists of the outline of the 16 detectors in the band for ideal conditions with the X1, X2, XC and Y1, Y2, and YC measured points plotted on the outline.

The second plot consists of a presentation of the narrow and wide slit data for each axis This will require 32 plots for each band.

I Detector Location Plot

The ideal location of each detector edge is given by equation (5) through (8) of Procedure C. The ideal detector size for bands 1 through 5 is 42.5 microradians square. The plot scale should be chosen to give the best resolution possible. Since the 16 detector array is 3.5 IFOV wide (148.75 microradians), a scale of 5.0 IFOV in 10 inches would seem reasonable. This would produce a plot 3 feet in length with legend, but only one such plot will be made per band.

On this scale of 2 inches/IFOV unit, the edge tolerance will be +0.03 inches for bands 1-4 and +0.12 inch in band 5. Since the function of the plot is the illustration of any gross errors and systematic errors, this resolution should be adequate.

II Detector Field of View Plot

Each axis of a given detector is the subject for this plot. Thus, 32 plots will be required.

Both the narrow slit and wide slit data are to be included on the same plot. This requires an abscissa dimension of 23.5 IFOV units. One appropriate scale to use is 1 inches/IFOV for the central +3.75 IFOV, then, on the same plot, use a scale of 0.25 inches/IFOV for points outside these limits (wide slit data) for Y plots.

The X plots may use a scale of 2 inches/IFOV units for the central +2.5 IFOV units, then a scale of 0.5 inch/IFOV unit outside this range.

III Plot Priority

The plotting should not be allowed to slow up the test. The information is stored in a plot file, and plotted during theodolite setting after the Procedure C print is complete as time is available.

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Procedure E

This procedure is called when it is desired to move the Thematic Mapper instrument relative to the collimator in the field of view tests. The movement is monitored by manually autocollimating a theodolite on the TM scan mirror.

The TM will be located at the following points.

1. At the LED reference point.

2. Centered between Band 3 and Band 4.

3. Centered between Band 1 and Band 2.

4. Centered between Band 5 and Band 7.

5. Returned to LED at close of tests.

The procedure should be called with a switch parameter IBAND which will specify which of the 5 settings above is desired.

The following parameters must be kept in intermediate files in a fashion which allows access by this procedure.

REFY, the theodolite reading (converted to radians) when the narrow vertical slit is aligned with the LED.

REFX, the theodolite reading converted to radians when the narrow horizontal slit is aligned with the center of the 3 LED.

TMANGY, the theodolite reading converted to radians when the TM is positioned with the center of the collimator projected <u>near to</u> the position specified by switch IBAND.

YOFFST, the number of steps in Y required to bring the collimator axis on the position specified.

TMANGX, analogous to TMANY, but in X.

XOFFST, analogous to YOFFST, but in X.

FLC, data base value for effective focal length of collimator. It is used to calculate the number of radians per step.

I Set at LED Reference Point (IBAND=1)

A. Slit Setting

1. Instruct the operator to manually drive the Y slit table to center of scan.

2. Repeat for X.

3. Instruct the operator to move the narrow vertical slit into position.

4. Instruct the operator to step in Z until the slit is at the previously determined focal position.

5. Instruct the operator to set the X,Y,Z and slit wheel controller in the remote positions.

6. Zero X,Y,Z and slit wheel controller.

7. Ask the operator to input the readings for X,Y,Z slit wheel.

8. If readings in 7. are not all 0, repeat 5. to 7.

B. LED Alignment

1. Instruct the operator to align the slit on the LED by moving TM.

2. Step the slit wheel to position the narrow horizontal slit into place.

3. Instruct the operator to center the middle LED in the slit

4. Set the slit wheel to position the narrow vertical slit into place.

Note: It is assumed that the equipment registration has been previously perfected so recheck is unnecessary between X,Y in steps 1. to 4., otherwise, repetitive operator interaction is required.

5. Verify X, Y are still zero by reading their output. If not, re-zero them.

C. Set Reference Position

1. Instruct the operator to autocollimate the theodolite on the scan mirror--avoiding angles greater than 350 degrees or less than 10 degrees.

2. Request the operator to input the theodolite azimuth readings. Store it as

RYDEG, RYMIN, RYSEC

Convert to radian measure by

$$ANGY = (RYDEG+RYMIN/60.+RYSEC/3600.)\pi/180. \quad (1)$$

$$REFY = ANGY$$

If REFY is greater than 6.11 radians or less then 0.17 radians repeat 1.

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3. Request the operator to input the theodolite elevation angle. Store it as

RXDEG, RXMIN, RXSEC

Convert to radian measure by

ANGX = (RXDEG+RXMIN/60.+RXSEC/3600.)π/180. (2)
REFX=ANGX

NOTE: If RXDEG is negati assume that RXMIN ans RXSEC are also negative. That is , set

RXMIN = -ABS(RXMIN)
RXSEC = -ABS(RXSEC)
IF RXDEG IS -

NOTE: Standard theodolite procedure consists of taking a reading, then flipping the telescope for a second reading. However, since theodolites differ in their use, it is assumed that the operator does the averaging before input. This may be revised if desired, when the exact theodolite is chosen.

4. Set the Current Angle Indicators

TMANGX = REFX (3)
TMANGY = REFY (4)

5. Set the Offset

Since this is the reference position no steps will be required to move into the center position, so set

XOFFST = 0. (5)

YOFFST = 0. (6)

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II Set at center of Band 3 and Band 4 (IBAND = 2)

The center of Band 3 and Band 4 is specified to be 0.07519 degrees from the LEDS.

Set DELTAY = 0.07519
DELTAZ = 0.
then follow the common procedure at V.

III Set at center of band 1 and band 2 (IBAND=3)

The center of band 1 and band 2 is specified to be 0.19694 degrees from the LEDS.

Set DELTAY = 0.19694
DELTAX = 0

then follow the common procedure at V.

IV Set at center of band 5 and band 7 (BAND=4)

The center of band 5 and band 7 is specified to be -0.09647 degrees from the LEDs.

Set DELTAY = -0.09647
DELTAX = 0

then follow the common procedure at V.

V Common procedure for Bands 3,2, 5

A. Remove previous offset by

1. Step in the X direction by -XOFFST steps. Remove backlash by overtravel and return if "XOFFST" is -.

2. Step in the Y direction by -YOFFST steps. Remove backlash by overtravel and return if "-YOFFST" is -.

B. Calculate new theodolite setting

1. Convert reference to degrees

RXD=REFX*180./π (7)

RYD=REFY*180./π (8)

2. Add step to new band

XD=RXD+DELTAX (9)

YD=RYD+DELTAY (10)

3. Convert to theodolite coordinates

This procedure is most easily described in FORTRAN as follows:

```
IDEG=YD
RYMIN=(YD-IDEG)*60
IMIN=RYMIN
RYSEC=(RYMIN-IMIN)*60.
RYMIN=IMIN
RYDEG=IDEG
```

where IDEG and IMIN are integers.

RXDEG, RYMIN, and RXSEC are determined in a similar fashion. However, if XD is negative, it is easier to convert the absolute value, then apply the sign.

C. Move the Thematic Mapper

1. Instruct the operator to move the TM so the theodolite autocollimated on the scan mirror will be "approximately RXDEG, RXMIN, RXSEC in elevation and RYDEG, RYMIN, RYSEC in azimuth." Emphasize in the message that the exact value is not essential because it will be "trimmed" by the X-Y table.

2. Ask the operator to input the elevation and azimuth angles. Store them as RXDEG, RXMIN, RXSEC, RYDEG, RYMIN, RYSEC.

3. Calculate the current angle in radians using equations (1) and (2). Then

   TMANGX=ANGX (11)

   TMANGY=ANGY (12)

4. Calculate offset needed
   RSTEP=.0001/FLC

   XOFFST=(XD* π/180.-TMANGX)/RSTEP (13)

   XOFFST=(YD* π/180.-TMANGY)/RSTEP (14)

   NOTE: Round these to nearest step

5. Step off the Offset

   a. Step in the X direction XOFFST Steps. If OFFST is -, add in -10 steps, then return +10 steps to remove backlash. If XOFFST is +, no backlash compensation is needed.

   b. Step in the Y direction YOFFST steps, and remove backlash as in a.

   NOTE: The slit center should now be at band center. The calculation of angles from the axis TM axis using the present settings are given by

   RSTEP =.0001/FLC
   ANGLY=Y*RSTEP+TMANGY-REFY+0.01945* π /180. (15)
   ANGLX=X*RSTEP+TMANGX-REFX (16)

since X Y counters contain the offset between TMANGX AND XD as well as between TMANGY AND YD

VI Return to LED at End of Test (IBAND=5)

LED center is specified by

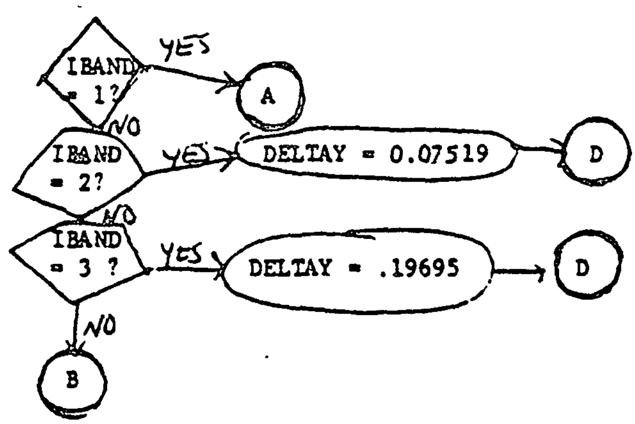
DELTAX=0
DELTAY=0

then follow the common procedure of V.

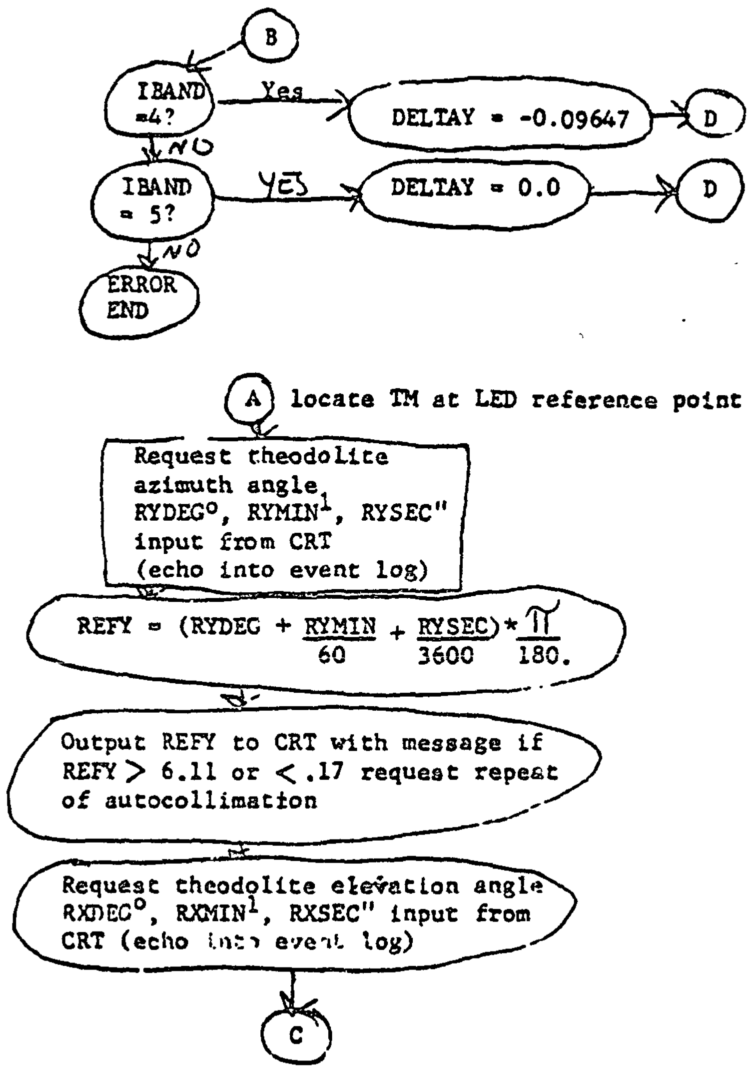
Procedure E

Variables

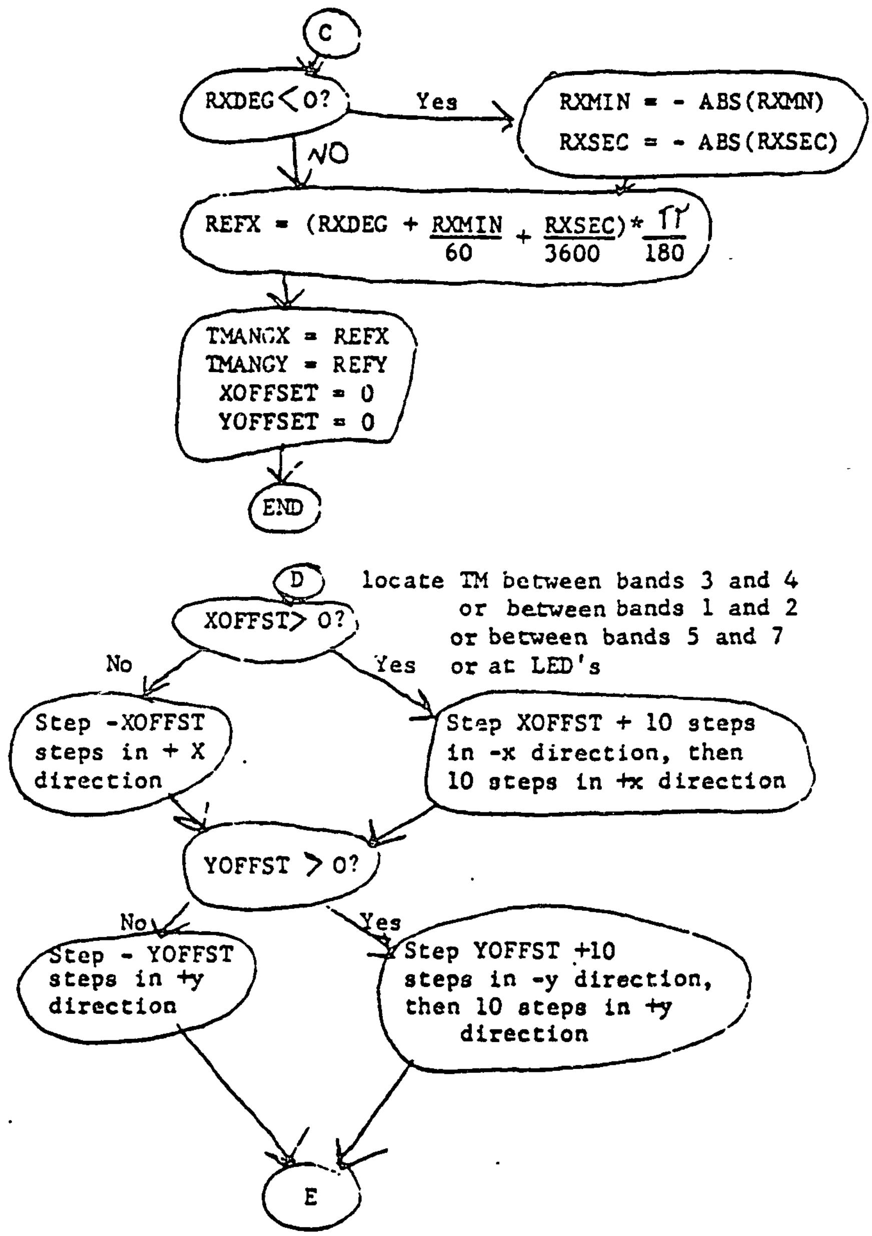
IBAND	TM location flag
REFY REFX TMANGY YOFFSET TMANGX XOFFSET	intermediate files
FLC	focal length of collimator, data base
RXDEG RXMIN RXSEG RYDEG RYMIN RYSEC	Input or Output



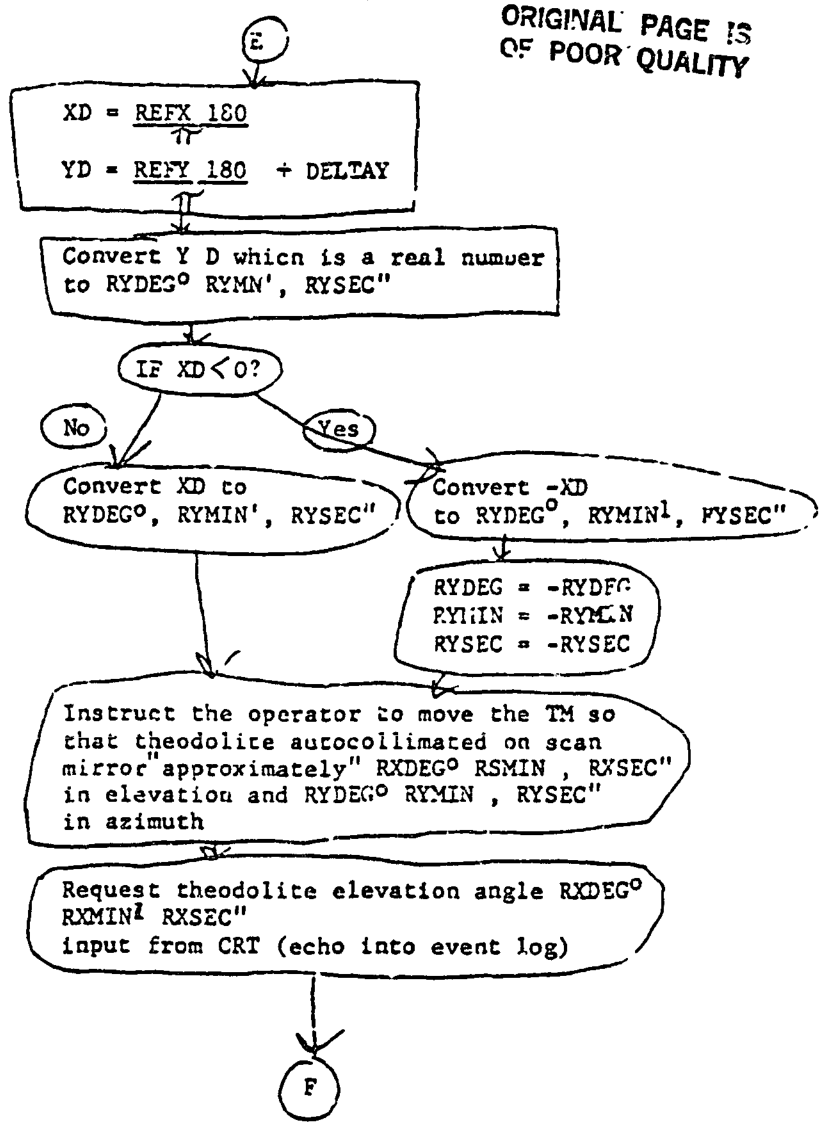
Procedure E


B
IBAND =4?
Yes
DELTAY = -0.09647
D
NO
IBAND = 5?
YES
DELTAY = 0.0
D
NO
ERROR END
A
locate TM at LED reference point
Request theodolite azimuth angle, RYDEG°, RYMIN', RYSEC" input from CRT (echo into event log)
REFY = (RYDEG + RYMIN/60 + RYSEC/3600)*π/180.
Output REFY to CRT with message if REFY > 6.11 or < .17 request repeat of autocollimation
Request theodolite elevation angle RXDEG°, RXMIN', RXSEC" input from CRT (echo into event log)
C

Procedure E


C
RXDEG < 0?
Yes
RXMIN = - ABS(RXMN)
RXSEC = - ABS(RXSEC)
NO
REFX = (RXDEG + RXMIN/60 + RXSEC/3600)* π/180
TMANGX = REFX
TMANGY = REFY
XOFFSET = 0
YOFFSET = 0
END
D
locate TM between bands 3 and 4 or between bands 1 and 2 or between bands 5 and 7 or at LED's
XOFFST > 0?
No
Yes
Step -XOFFST steps in + X direction
Step XOFFST + 10 steps in -x direction, then 10 steps in +x direction
YOFFST > 0?
No
Yes
Step - YOFFST steps in +y direction
Step YOFFST +10 steps in -y direction, then 10 steps in +y direction
E

Procedure E


E
XD = REFX 180 / π
YD = REFY 180 / π + DELTAY
Convert Y D which is a real number to RYDEG° RYMN', RYSEC"
IF XD < 0?
No
Yes
Convert XD to RYDEG°, RYMIN', RYSEC"
Convert -XD to RYDEG°, RYMIN', RYSEC"
RYDEG = -RYDEG
RYMIN = -RYMIN
RYSEC = -RYSEC
Instruct the operator to move the TM so that theodolite autocollimated on scan mirror "approximately" RXDEG° RSMIN , RXSEC" in elevation and RYDEG° RYMIN , RYSEC" in azimuth
Request theodolite elevation angle RXDEG° RXMIN' RXSEC" input from CRT (echo into event log)
F

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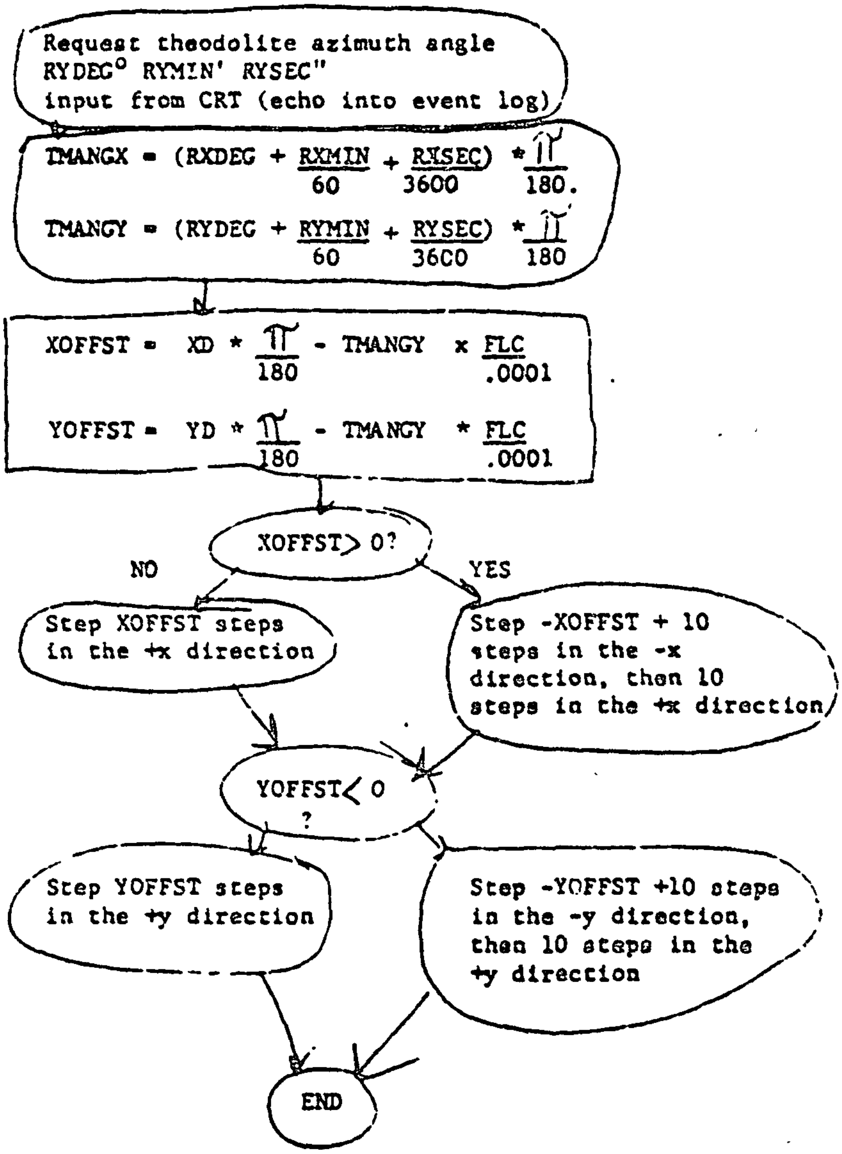
Procedure E



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PROCEDURE F

This procedure is used to acquire the data from the field of view measurements for detector Band 5 in a form suitable for reduction by Procedure G, and for print and plot by Procedures H and I.

This procedure assumes that the Band 6 vertical slit is in the center of the band in the Y direction, and the narrow horizontal slit may be centered in the X direction by a rotation of the slit wheel.

Data Storage Description

Data are described as though either a 108.3" or 110" focal length collimator is used. The data step size and count must be adjusted here and in Procedure G to accommodate practical step size as determined by the collimator focal lengths. This adjustment must respect IFOV boundary locations, but may allow more incremental steps within boundaries. For example, it takes 20 positions of 0.20 IFOV units (8.5 microradians) to cover one Band 6 detector of 4 IFOV units. However, if the 111-inch focal length collimator were to be used each step is 0.9009 microradians, so each data point would require either 9 steps (8.11 microradians) or 10 steps (9.01 microradians) whereas 2 IFOV units are 8.5 microradians. In the case where movement of 1 detector size is required, 170.0/.9009 microradians indicates 189 steps. Thus, 11 positions of 9 steps each plus 9 positions of 10 steps each give the required 189 steps of 20 positions, averaging 0.2 IFOV units.

Figure 1 illustrates the testing procedure to be followed in taking data in the X or the Y directions. Only one size slit is used on Band 6. It is 0.4 IFOV units wide.

The Y data are acquired by stepping the slit from Y=-18.0 IFOV units from the band center to Y =+18.0 IFOV units in 208 steps. The X direction is similar.

The data acquisition steps will now be described.

1. Field of View stepping in the Y direction (along scan)

    a. Step in the -Y direction to a position which is 18.0 IFOV units from the band center. Step 20 steps further in -Y direction, then step 20 steps in +Y to remove backlash.

    b. Take data on all four detectors from Y= -18.0 to +18.0 IFOV units as called out in flowchart.

    c. Rotate the slit wheel to position the horizontal Band 6 slit into place.

    d. Return Y to band center by stepping in the -Y direction by 18.2 IFOV units +0.2 units for overtravel for a total of 18.4 IFOV units then step in the +Y direction by 0.2 units to remove the backlash.

e. Step in the -X direction 18.2 IFOV units, then step in the +X direction by 0.2 units to remove the backlash.

f. Take data on all four detectors from X= -18.0 to +18.0 IFOV units as called out in the flowchart.

g. Rotate the slit wheel to position the vertical slit into place for Band 6.

h. Return X to band center by stepping in the -X direction by 18.2 IFOV units +0.2 units for overtravel for a total of 18.4 IFOV units, then step in the +X direction by 0.2 units to remove the backlash.

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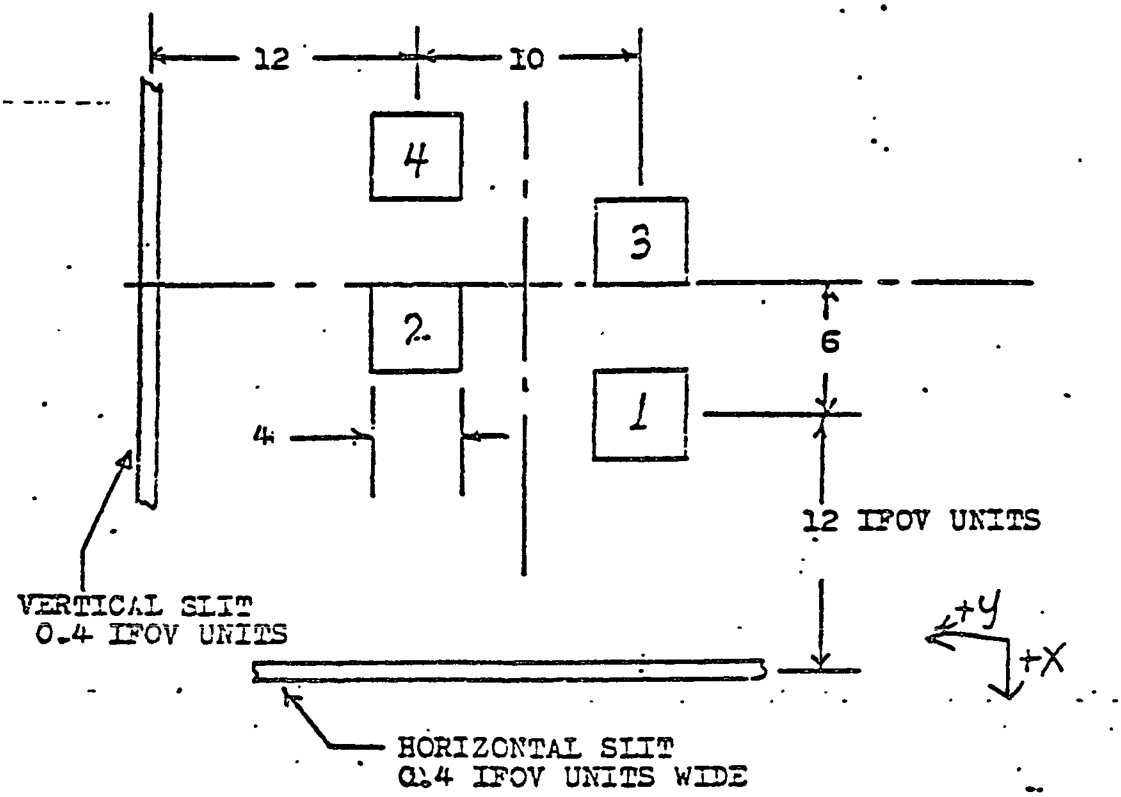


X AND Y DIRECTION MEASUREMENT PARAMETERS FOR BAND 6

FIGURE 1

Procedure F

Collecting data for Band 6
along and across track
(X and Y direction)

When two choices of step numbers are given, the smaller is for the 108.3 in. collimator, the larger for the 110 in. collimator.

Assume vertical Band 6 slit at Band 6 Center

Start y direction

Step 842 or 855 steps in the -y direction, then 10 steps in the +y direction

Perform Seq 1	ND1, ND2	
N = 2	1,2	20 times
FSTEP = 8	3,4	

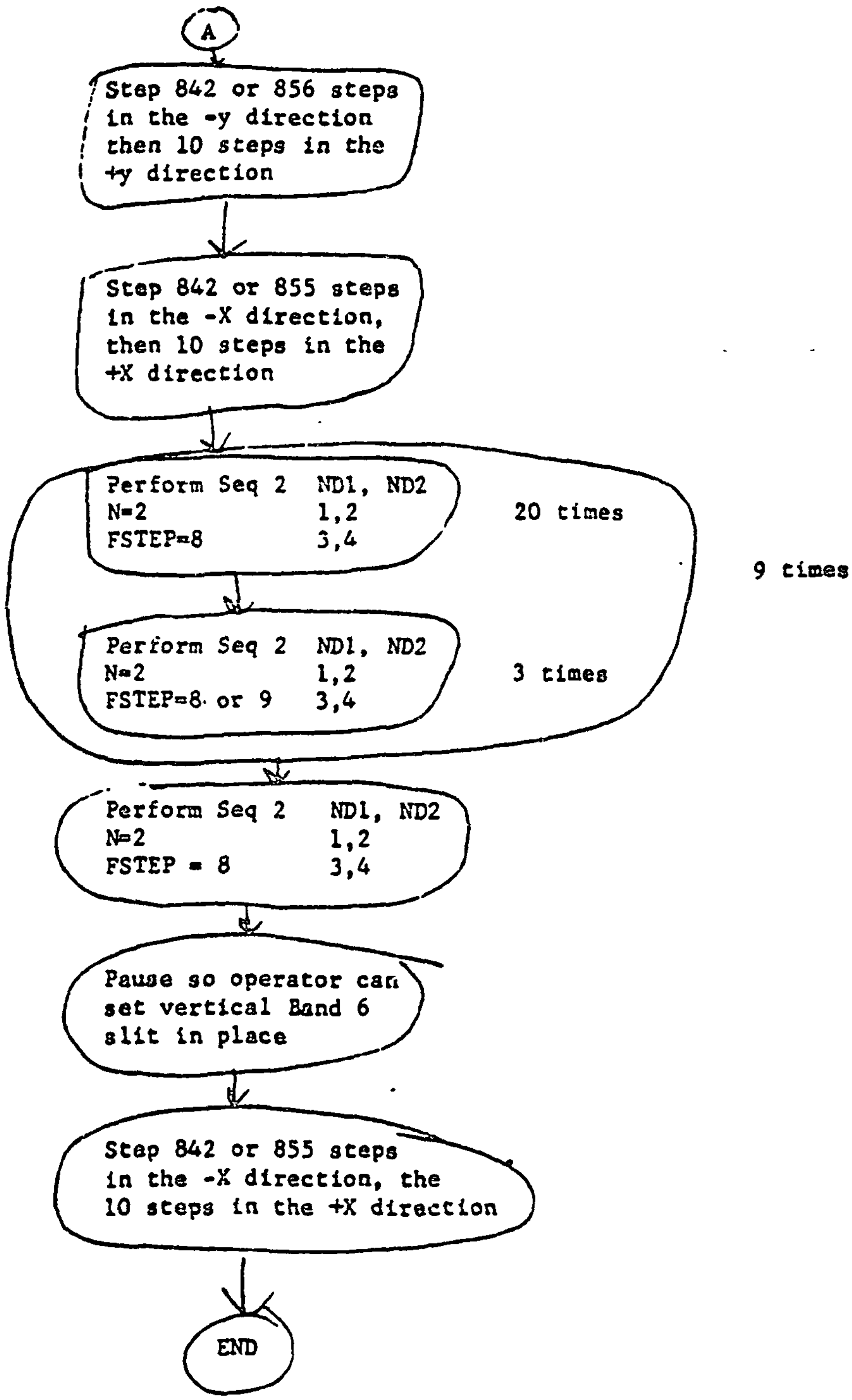
Perform Seq 1	ND1, ND2	
N = 2	1,2	3 times
FSTEP = 8 or 9	3,4	

9 times

Perform Seq 1	ND1, ND2
N = 2	1,2
FSTEP = 8	3,4

Pause so operator can set slit to horizontal band 6 slit

A


A
Step 842 or 856 steps in the -y direction then 10 steps in the +y direction
Step 842 or 855 steps in the -X direction, then 10 steps in the +X direction
Perform Seq 2 ND1, ND2
N=2 1,2
FSTEP=8 3,4
20 times
9 times
Perform Seq 2 ND1, ND2
N=2 1,2
FSTEP=8 or 9 3,4
3 times
Perform Seq 2 ND1, ND2
N=2 1,2
FSTEP = 8 3,4
Pause so operator can set vertical Band 6 slit in place
Step 842 or 855 steps in the -X direction, the 10 steps in the +X direction
END

PROCEDURE G

This procedure reduces the field of view data for Band 6, only. The 50 percent signal point is determined in X and Y for each detector, then the center coordinate is calculated.

I Data Storage Description

NOTE: Data are described as though either a 108.3" or 110" focal length collimator is used. The data step size and count must be adjusted here and in Procedure F to accommodate practical step size as determined by the collimator focal length.

A. Input Data

See Procedure F

B. Output Data

The Y data output consists of 4 data records, each with the following data items.

1. Detector No., C.
   Records 1-4 correspond to detector 1-4, respectively.

2. PEAKVY(C)

   PEAKVY(C) is the largest voltage for this detector which is used for normalization of the data samples.

3. Normalized Data

   This set consists of nominally 208 sets of XY, YY, and the normalized voltage VPNY.

4. Y1, Y2, YC

   Y1 is the Y coordinate (obtained by interpolation) of the signal which is 0.5 of the peak of the normalized data. Y1 is the value on the -Y side of the detector, X2 is the value on the +Y side. YC is the average of Y1 and Y2.

The X data output is similar to the Y data.

II Y Data Reduction

Repeat the following for detectors 1 through 4 field of View in Y directon.

Exact the Y data from the file, consisting of nominally 208 sets of XY, YY, and VPPY data. Search the array for the peak value which will nominally be VPPY(i) where i is the average of NOMY16(C) and NOMY26(C).

Detector No. C	NOMY16(C)	i	NOMY26(C)
1	64	75	86
2	122	133	145
3	64	75	86
4	122	133	145

Call this peak value PEAKVY(C) and save it. Normalize the data by dividing by PEAKVY(C) to get VPNY, save this date array.

Search the normalized data on both sides of the peak for the two values which are less than 0.5. These will be nominally at array elements i = NOMY16(C) and NOMY26(C). In addition to these two values, use the two adjacent values which are just larger than 0.5 and by linear interpolation, determine the two X values for VPNY= 0.5 as follows.

For the lower Y value edge,

Let i be such that $VPNY(i) \leq 0.5$ and $VPNY(i+1) > 0.5$

The half width coordinate YHW is given by

$$\frac{(YY(i+1)-YY(i))(0.5-VPNY(i))}{VPNY(i+1)-VPNY(i)}+YY(i) = YHW$$

Let Y1=YHW for this coordinate on the -Y side of center.

Similarly, the coordinate for the higher Y value edge is given by (1) where

i is such that $VPNY(i) \geq 0.5$ and $VPNY(i+1) < 0.5$

Let Y2=YHW for this coordinate on the +Y side of center. The coordinate of the center of the detector YC is then given by

$$YC = \frac{Y1+Y2}{2}$$

Save Y1, Y2, and YC for later use.

III X Data Reduction

Repeat the following for detectors 1 through 4 field of view in the X direction

Extract the X data from the file, consisting of nominally 208 sets of XX, YX, and VPPX data. Search the array for the peak value which will nominally be VPPX(i) where i is the average of NOMX16(C) and NOMX26(C).

Detector No. C	NOMX16(C)	i	NOMX26(C)
1	127	138	150
2	104	115	127
3	81	92	104
4	58	69	81

Call this peak value PEAKVX(C) and save it. Normalize the data by dividing by PEAKVX(C) to get VPNX. Save this data array.

Search the array and determine X1, X2, and XC in an analogous fashion to the procedure used for Y in II, above.

Save X1, X2, and XC for future use.

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Procedure G

Data Reduction for Band 6

<u>Variables</u>

XY(C,P) C=1,...,4 P=1,...208	X-coordinate from which p-th sample for channel C came when sweeping in the Y-direction	Collected in Procedure F
YY(C,P) C=1,...,4 P=1,...,208	Y-coordinate from which pth sample for channel C came when sweeping in the y-direction	Collected in Procedure F
VPPY(C,P), VPNY(C,P) C=1,...,4 P=1,...,208	Peak-to-Peak signal (from VPEAK) of channel C, pth sample sweeping y direction, and normalized value	Collected in Procedure F
PEAKVY(C) C=1,...,4	Peak value in VPP(C,P)	Calculated here
Y1(C) C=1,...,4	-Y side 50% point for Channel C	Calculated here
Y2(C) C=1,...,4	+Y side 50% point for Channel C	Calculated here
YC(C) C=1,...,4	Channel C center	Calculated here

XX(C,P); YX(C,P); VPPX(C,P); PEAKVXCC,P); X1(C); X2(C); VPNX(C,P)

XC(C) same as above for sweeping in X-direction

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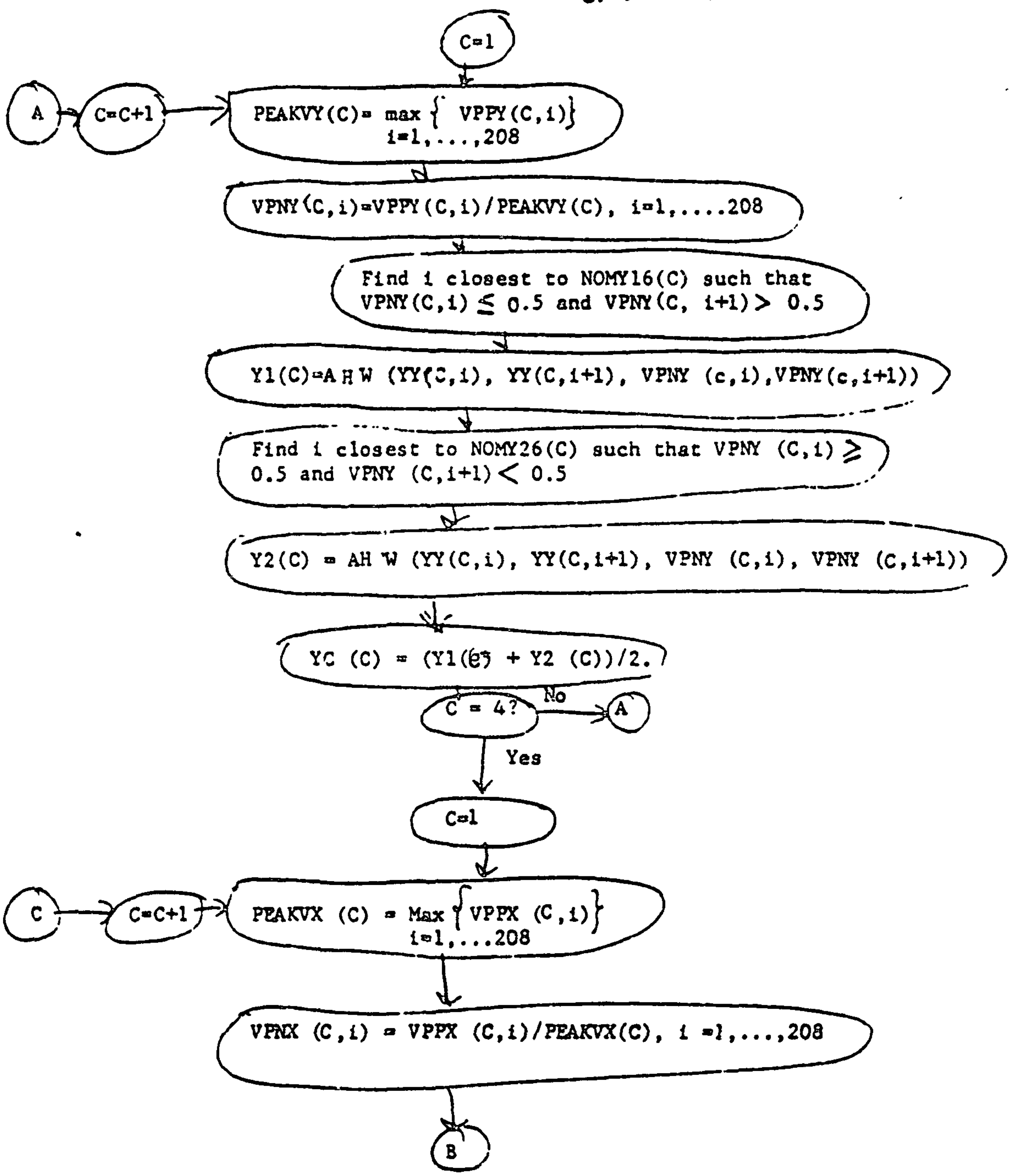
Data Base Arrays

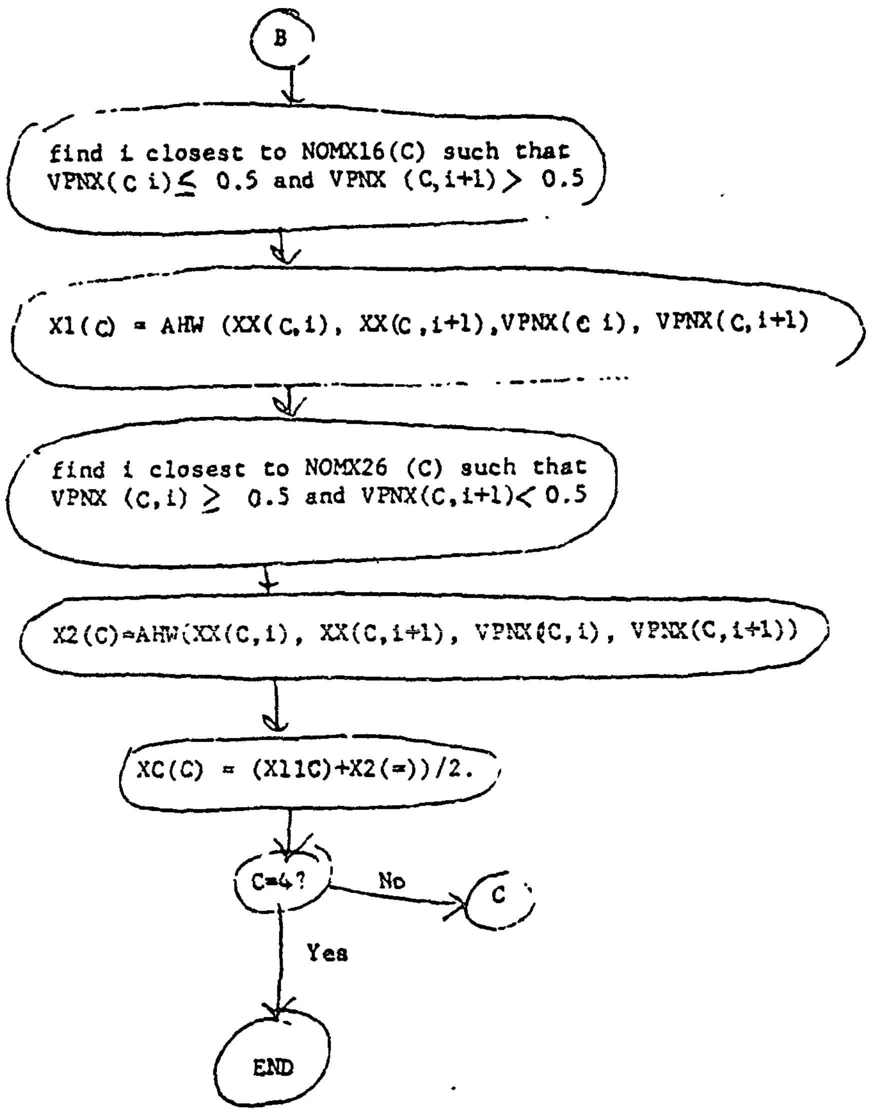
NOMY16(C)

i \ C	1	2	3	4
1	64	122	64	122
2	86	145	86	145

NOMX16(C)

i \ C	1	2	3	4
1	127	104	81	58
2	150	127	104	81


C=1
A
C=C+1
PEAKVY(C)= max { VPPY(C,i)} i=1,...,208
VPNY(C,i)=VPPY(C,i)/PEAKVY(C), i=1,....208
Find i closest to NOMY16(C) such that VPNY(C,i) ≤ 0.5 and VPNY(C, i+1) > 0.5
Y1(C)=AHW (YY(C,i), YY(C,i+1), VPNY (c,i),VPNY(c,i+1))
Find i closest to NOMY26(C) such that VPNY (C,i) ≥ 0.5 and VPNY (C,i+1) < 0.5
Y2(C) = AH W (YY(C,i), YY(C,i+1), VPNY (C,i), VPNY (c,i+1))
YC (C) = (Y1(C) + Y2 (C))/2.
C = 4?
No
A
Yes
C=1
C
C=C+1
PEAKVX (C) = Max {VPPX (C,i)} i=1,...208
VPNX (C,i) = VPPX (C,i)/PEAKVX(C), i =1,...,208
B


B
find i closest to NOMX16(C) such that VPNX(C i) ≤ 0.5 and VPNX (C,i+1) > 0.5
X1(C) = AHW (XX(C,i), XX(C,i+1),VPNX(C i), VPNX(C,i+1)
find i closest to NOMX26 (C) such that VPNX (C,i) ≥ 0.5 and VPNX(C,i+1) < 0.5
X2(C)=AHW(XX(C,i), XX(C,i+1), VPNX(C,i), VPNX(C,i+1))
XC(C) = (X11C)+X2(=))/2.
C=4?
No
C
Yes
END

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PROCEDURE H

This procedure retrieves data stored by Procedures G and E which allow conversion of X and Y from steps to radians. The field of view data for Band 6 is then checked against specified parameters, and the results printed.

Input Data

The data from Procedure E includes REFX, REFY, TMANGX, TMANGY, XOFFST, YOFFST, and FLC. See Procedure E for definitions.

The data from Procedure G includes NBAND, Detector No., PEAKV, step array data in sets of X, Y, and VPN where X, Y are in step count units, X1, X2, X6, Y1, Y2, YC all in step count units.

Conversion from Step to Radians

The conversion equations are described in Procedure E and are reproduced here. RSTEP = .0001 / FLC

ANGLY = Y*RSTEP+TMANGY-REFY+0.01945 /180. (1)

ANGLX = X*RSTEP+TMANGX=REFX (2)

Specified Values for Band 6

A. Band Center (in milliradians), BC relative to the optic axis.

YBC = -4.0631

XBC = 0.

B. Detector Center (in milliradians) for Band 6

1. Y Coordinate Relative to Band Center, BC

   XDC = 5.0*.0425 (+1-2*MODULO (NDET,2)) (3)

   where NDET is the detector No.

2. Y Coordinate Relative to Band Center

   XDC = +10 - 4*NDET (4)

C. Optimum Detector Edges X1P, Y1P, X2P, Y2P

The ideal location for the detector edges is given by

X1P = XDC+XBC-0.085 milliradians (5)

X2P = XDC+XBC+0.085 (6)

Y1P = YDC+YBC-0.085 (7)

Y2P = YDC+YBC+0.085 (8)

D. Detector Width, (X2-X1) or (Y2-Y1) specified

Minimum Difference = 0.1656

Maximum Difference = 0.1744

E. Detector Location and Size Printout

Perform the following 4 times

1. Input the X and Y data records for this detector.
2. Convert all coordinates to radians.
3. Store the converted data in the plot file.
4. Calculate

   DX=X2-X1
   DY=Y2-Y1

5. Print the following

   a. Detector No.
   b. XDC+XBC
   c. XC
   d. X1P
   e. X1
   f. X2P
   g. X2
   h. DX
   i. "IN SPEC" or "OUT OF SPEC," see D above
   j. error amount, if out of spec, or 0. if in spec.
   k. YDC+YBC
   l. YC
   m. Y1P
   n. Y1
   o. Y2P
   p. Y2
   q. DY
   r. "IN SPEC" or "OUT OF SPEC," see D above.
   s. error amount, if out of spec, or 0. if in spec.

F. Tabulate Curve Data

This data consists of nominally 208 sets of X, Y and VPN in X direction and nominally 208 sets of X, Y, and VPN in the Y direction.

This data is to be printed in compact form.

PROCEDURE I

This procedure takes data stored in the plot file by Procedure H for Band 6 and forms two types of plots.

The first plot is the detector location plot. This consists of the outline of the 4 detectors in the band for ideal conditions with the X1, X2, XC and Y1, Y2, and YC measured points plotted on the outline.

The second plot consists of a presentation of the field of view data array for each axis This will require 8 separate plots.

I Detector Location Plot

The ideal location of each detector edge is given by equations (5) through (8) of Procedure H. The ideal detector size for Band 6 is 170 microradians square. The plot scale should be chosen to give the best resolution possible. Since the 4-detector array is 14 IFOV units wide, a scale of 0.5 IFOV units per inch seems reasonable. The edge tolerance will be $\pm$ 0.05 inches on this scale. Since the function of the plot is the illustration of any gross errors and systematic errors, the resolution should be adequate.

II Detector Field of View Plot

Each axis of a given detector is the subject for this plot. Thus, 8 plots will be required. This requires an abscissa of 36 IFOV units in X and 36 IFOV units for the Y plots. The scale of 4 IFOV units per inch would give sufficient resolution.

III Plot Priority

The plotting should not be allowed to slow up the test. The information is stored in a plot file, and plotted during theodolite setting after the Procedure H print is complete as time is available.

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SUBROUTINE VPEAK

Numbers in brackets are for use with the dual channel option of data capture. This subroutine is called by the main spatial coverage procedure and by Procedures A and F indirectly through Sequences No. 1 through 4.

The ADAU has been set to a sample rate of 39 KHz, single channel dual channel option, and that the SIU has selected the ADAU prior to callings this subroutine. It is further assumed that the 100 Hz center frequency filter with a 10 Hz bandpass is in place. It is also assumed that the 100 Hz filter, or associated amplifier in the ADAU, has a gain of 7.5 to boost the saturated output to the range of the A/D in the ADAU. This is necessary since a square wave of 2 volts peak-to-peak (saturation) gives rise to a fundamental sine wave of 2.5 volts peak-to-peak which corresponds to 1.25 volts peak-out of the 100 Hz filter (neglecting insertion loss). Since the A/D operates in the range of +/-10 volts (+/-2047 DN), the 1.25 volts must be amplified to use the full range of the A/D. A gain of 7.5 plus filter insertion loss compensation will boost the 1.25 volts to 9.375 volts (1920 DN). The additional range of the A/D is reserved for potential excursions.

This subroutine takes I independent cycles of the 100 Hz waveform which requires that every tenth cycle be sampled with the 10 Hz bandpass. Since Band 5 is expected to have the lowest signal-to-noise ratio, it is used to evaluate the expected data range. The 1 percent of saturation signal will give +/-19.2 DN from the A/D while the noise is shown in a separate memorandum to have a 95 percent probability of being within +/-2.0 DN for this band 5, utilizing I independent 100 Hz cycles for peak-to-peak determination. This indicates that the error in determining the 1 percent level due to noise will be less than 5 percent of that level. The quantizing error can be as much as 3 percent of the 1 percent signal level. Both of these errors are quite acceptable in the far field measure, and the errors will be negligible for larger signals.

The subroutine also assumes that the detector has been connected by the MUX in the ADAU, and that the required settling time for the insertion of the 100 Hz filter (about 160 milliseconds) and the aerotech stages (TBD seconds) has elapsed before the subroutine call.

Subroutine Description

1. Sample the Data

   Command the ADAU to take data for I*10 cycles I*10 of the 100 Hz output. This consists of taking data for I*10*0.01 seconds. Each sample requires 2 bytes, since the A/D output is 11 bits plus sign.

2. Determination of the Peak-to-Peak value

   a. Set the number of good sets, ns, optimistically to the number of tenths of a second of data captured.

MEASUREMENT SEQUENCES

Parameters

N is number of pairs of detectors from which video data is collected.

NDI(i), ND2(i) are arrays of length N containing the channel numbers from which data is to be collected.

FSTEP is the number of Aerotech table steps to move.

Sequence No. 1 (stepping of Y direction, post-data stepping)

1. I = 1
2. Collect Index A data from the detectors in the bend with channel numbers ND1 (I) and ND2(I).
3. Call VPEAK twice to reduce the index A data from the two detectors.
4. Store the following in a form that is useable by data reduction procedures:

   Outputs VPP from VPEAK
   Position of X-axis stage from HP interferometer
   Position of Y-axis stage from HP interferometer
5. If I = N, then continue with Step 6, otherwise increment I (I = I+1) and repeat steps 2 through 5.
6. Finally, Step FSTEP steps in the + Y direction.

Sequence No. 2 (stepping in the X direction, post data stepping)

1. through 5. Same as Sequence I.

6. Finally, step FSTEP steps in the +X direction.

Sequence No. 3 (stepping in the Y direction, pre-data stepping)

1. Set I = 1, and step FSTEP steps in the +Y direction

2. through 5. Same as Sequence 1.

6. Exit.

Sequence No. 4 (stepping in the X direction, pre-data stepping)

1. Set I = 1, and step FSTEP steps in the +X direction

2. through 5. Same as Sequence 1.

6. Exit.

Index A Collect 4 samples of .0.1 sec. of video data fro 2 channels as specified in the data collect procedures. Use the ADAU with the 2-channel

b. Find a peak and minimum in a .01 second span of data 400 [200] samples. Call

   VPi - peak value
   VMi - minimum value
   NPi - location of peak
   NMi - location of minimum

c. Skip .09 seconds of data, 3500, [1750] samples

d. Repeat steps b and c for the number of tenths of a second of data to capture, for example i = 1 to 4 for .4 seconds of data.

e. Spurious Peak Rejection

   Discard on the basis of peak to minimum separation. Check the i samples to see if they are in the range.

   When the signal level gets to be very low, on the order of a few DN, spurious peaks may be determined. These spurious values may be deleted by requiring that all 4 peaks and minimum must be separated by nominally 0.10 seconds from peak-to-peak or minimum to minimum (using every 10th cycle).

   Check to see that

   $L1 \leq |NP-NM| \leq U1$ where L1, L2, U1, U2 are data base values,
   [$L2 \leq |NP-NM| \leq U2$] nominally L1 = 175, U1 = 215, L2 = 88, and U2 = 108.

If any set fails this test, discard it and reduce NS by 1. If NS = 0 or 1, set VPP=0. and leave the subroutine

VPP Determination

For each of the NS cycles remaining, calculate

$$VS=VP-VM$$

Then average the NS sets of VS to get VPP.

Also determine the standard deviation of the NS samples of VS to get VPP.

Index A (cont'd) option, 39K Hz (low) rate and 100 Hz filter.

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SANTA BARBARA RESEARCH CENTER
A Subsidiary of Hughes Aircraft Company

INTERNAL MEMORANDUM

TO: J. L. Engel

CC: Distribution
Data Bank

DATE: 20 May 1981

REF: HS236-7454
2221.291

FROM: AC07R Test Team

SUBJECT: T.M. AC07R Test Result Summary, Protoflight Model.

BLDG. 774 MAIL STA. 78
EXT. 4151

References:

1. TP32015-514 Rev. A, Spatial Coverage Test Procedure AC07R, 7 April 1981.

2. HS236-5610 Thematic Mapper Spatial Coverage Test Description, AC07R, 30 Jan. 1978.

3. HS236-5610-2 Thematic Mapper Spatial Coverage Test Description, AC07R, 13 June 1979.

4. History Tapes: D02030, D02032, D02034, D02036 and D02037 (April 14 through April 23, 1981).

5. Special Tape: Number 502 dated May 1, 1981, used to record AC07R Video Files.

6. BTCE #2 Event Log for period April 14 through April 23, 1981.

1.0 Introduction

This report summarizes the results of performing the AC07R Spatial Coverage Test on the Thematic Mapper Protoflight Model. The test is an ambient collimator level test performed on the assembled T.M. The test is computer controlled using computer commands with telemetry verification.

The test objective is to accurately determine the response of database selected detectors to a narrow slit source illuminating positions on the focal plane whose distances from the detectors vary. Specific attention is given to detector half-width response size and far field effects.

GSFC measurement specifications are given in terms of angular requirements. The along track (X-direction) dimension and across track (Y-direction) dimension is defined for each detector as the angular difference between the points where the detectors response is 50 percent of maximum when sweeping in the respective direction. Maximum half-width dimensions are given as 43.2 microradians for Bands 1 through 4, 46.35 microradians for Bands 5 and 7, and 174.4 microradians for Band 6, the thermal band. The far field requirement is that the measured response be less than one percent of maximum for angular distances equal to or greater than twice the detector width.

2.0 Test Description

The test is performed at SBRC with the Thematic Mapper mounted on a precision rotary table. The T.M.is aligned to a collimator with the scan mirror and scan line corrector off and locked at midscan. The angular orientation of the T.M. is determined and monitored by autocollimating a theodolite on a reference mirror attached to the T.M. However, as the collimator is subject to off axis image degradation, it is necessary to move the T.M. four times during the test. These movements and subsequent orientations are determined and also monitored using the theodolite. The source is projected towards the T.M. through the collimator which uses a computer driven X-Y stepping stage to position the illuminated slit. Interferometric monitoring is used to measure stage movement.

For Bands 1-5 and 7 measurements, a tungsten ribbon filament lamp is used as the source. The lamp and slit are initially mounted together on the stages in a vertical position (for sweeping in the Y-direction). The source and slit are subsequently rotated 90 degrees about a horizontal axis for sweeping in the X-direction. The larger input signal needed to resolve far field response is achieved by increasing the lamp current.

For Band 6, a blackbody source is used. The change from vertical to horizontal scanning is achieved using separate perpendicular slits mounted in a reticle wheel.

3.0 Test Results

Test data has been obtained for all Bands in the form of reduced data tabulations and field-of-view plots for selected channels and each type of scan (X or Y). Measurements were made on detectors 2 and 16 for Bands 1, 3, 4, 5 and 7. Detectors 1 and 15 were used for Band 2 while detectors 1, 2,3 and 4 were used for Band 6. Reduced data tabulations indicate that all detectors (with the possible exceptions of Band 2 Detector 15 and Band 6 Detectors 1 and 2) exhibit some calculated half-widths in excess of those desired by the specifications. Band 2 Detector 15 had severe noise problems making meaningful calculations for it impossible. Band 6 detectors as the thermal channels have much wider nominal fields-of-view than the other detectors and should therefore be considered separately. Far field response for all Bands is typically greater than the desired 1 percent at least for regions immediately adjacent to the twice detector width field points. In addition, normalization problems were encountered in matching the far field to near field data. Even after software corrections, residual effects are evident in some of the plots. (See Appendix A for plots.)

The following tables summarize the test results in general and help to point out some of the problem areas. Table 1 is a summary of LSF (Field-of-View) half-widths identified by band, channel, and type of scan. Noisy channels and out-of-spec. conditions are identified where they occurred. Table 2 is a listing of detector spacings within each array as obtained from the reduced data tabulations. Table 3 is a summary of out-of-field response values obtained graphically from the field-of-view response plots. Out-of-field response has been calculated first as the percentage of total out-of-field signal to total in-field signal and then again as an average per IFOV spacing over the total length of the non-zero skirts.

TABLE 1.

LSF Half-Widths

Collection Date	Band	Channel	Scan	LSF Width (μr)	In Spec.	Out of Spec.
4/25	1	2	Y	43.95		✓
4/25	1	2	X	44.43		✓
4/25	1	16	Y	42.26	✓	
4/25	1	16	X	43.36		✓
4/25	2	1	Y	44.85		✓
4/25	2	1	X	44.78		✓
4/25	2	15	Y	* 0.00		✓
4/25	2	15	X	*32.27		✓
4/24	3	2	Y	45.10		✓
4/24	3	2	X	45.52		✓
4/24	3	16	Y	44.86		✓
4/24	3	16	X	43.87		✓
4/24	4	2	Y	44.07		✓
4/24	4	2	X	44.01		✓
4/24	4	16	Y	44.50		✓
4/24	4	16	X	43.60		✓
4/25	5	2	Y	42.55	✓	
4/25	5	2	X	47.45		✓
4/25	5	16	Y	42.48	✓	
4/25	5	16	X	46.91		✓
4/25	7	2	Y	45.53	✓	
4/25	7	2	X	47.77		✓
4/25	7	16	Y	44.82	✓	
4/25	7	16	X	49.58		✓

*Very Bad "Noise"

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TABLE 1. (Continued)

Collection Date	Band	Channel	Scan	LSF Width	In Spec.	Out of Spec.
4/29	6	1	Y	172.99	✓	
4/29	6	1	X	172.16	✓	
4/29	6	2	Y	170.24	✓	
4/29	6	2	X	173.79	✓	
4/29	6	3	Y	178.34		✓
4/29	6	3	X	177.46		✓
4/29	6	4	Y	173.97	✓	
4/29	6	4	X	175.34		✓

TABLE 2.

Detector Spacings

Collection Date	Band/ Channels	Distance Between Channels In X-Direction (μ-radians) (Measured)	(Nominal)
4/25	B1/D2, D16	595.06	595.00
4/25	B2/D1, D15	594.41	595.00
4/24	B3/D2, D16	591.28	595.00
4/24	B4/D2, D16	593.80	595.00
4/25	B5/D2, D16	590.24	595.00
4/25	B7/D2, D16	590.83	595.00
4/29	B6/D1, D3	334.95	340.00
4/29	B6/D2, D4	337.77	340.00

REF: HS236-7454
J.L. Engel from AC07R Test Team

TABLE 3.

Out-of-Field Response
Bands 1-5, and 7

Processing/ Date	Band	Channel	Scan	In-Field Response* (±2 IFOVS)	Out-of-Field Response* (Skirts)	Total Percent	Average (Per IFOV) Percent
5/6	1	2	Y	1849	131	7.1	.49
5/6	1	2	X	1960	217	11.1	.71
5/6	2	1	Y	2231	456	20.4	1.38
5/8	2	1	X	2434	581	23.9	1.48
5/7	3	2	Y	2024	307	15.2	1.03
5/8	3	2	X	2226	371	16.7	1.08
5/6	4	2	Y	1692	28	1.65	.88
5/6	4	2	X	1726	50	2.90	.62
5/6	5	2	Y	1669	61	3.65	.55
5/6	5	2	X	18[illegible]2	98	5.26	.70
5/6	7	2	Y	1866	137	7.34	.87
5/6	7	2	X	2461	361	14.67	.97

*Arbitrary Units (graph paper units)

4.0 Discussion and Conclusion

A number of difficulties were encountered during the running of these tests. These may be roughly divided into hardware and software type problems. The former consist of problems with vibration, alignment, temperature and electronics. The latter include problems with command files, databases, and plot normalizations. In addition some evidence exists which indicates that optical effects may be degrading the data by producing raised skirts and rounded off IFOVS. Many difficulties were at least partially resolved during the testing by modifications of the test setup and/or by corrections to the software. Others await the performance of "special tests" intended to determine their causes.

A. Hardware Problems

- Vibration problems were encountered from the start as we attempted to mount the 100 Hertz chopper wheel. In an attempt to maintain a constant relationship between the chopper blades and the source/slit assembly as the source/slit assembly was rotated for successive X and Y scans, a modified mounting plate was fabricated to hold source, slit and chopper wheel. Unfortunately, the whole assembly vibrated in resonance when the chopper was turned on. This problem was resolved by suspending the chopper from a separate pedestal which was rigidly attached to the collimator table. The chopper was then repositioned each time the source/slit assembly was rotated.

In addition to vibration, an electronics problem arose as the result of repositioning the chopper wheel. D.C. restore failed to work properly making it impossible to collect meaningful data. The effect was later identified as the result of a phasing error associated with the chopper wheel positioning. The "fix" was to modify the procedure to require appropriate adjustment of phase whenever the chopper positioning is changed or translation is made of the slit across the chopper wheel.

Electronics problems were also present for Band 6, but not due to the chopper wheel. Rather the Band 6 box for plugging the Band 6 signals into or around AOTS failed to work. A revised BTCE set-up was adopted which provided necessary DC restore and other electronic functions as required. (See Figure 1.)

High frequency noise was observed on Band 2 Detector 15 which distorted the signal and resulted in meaningless calculations and plots. This was unfortunate as we had been told ahead of time that there was a noisy detector 2 on Band 2 which should be avoided. A reidentification of the detector from the array position to channel number resulted in our choosing the exact detector we were trying to avoid.

Room environmental effects were present in the form of air turbulence and temperature variations. To minimize these effects additions were made to the plastic tunnel surrounding the collimator prior to the test. When a preliminary check showed that the running of the room air handlers drastically distorted the signals, they were turned off for the duration of the tests which ran well over 24 hours of total operating time. The room stabilized at between 68° and 72° F as recorded in the data master and log books. Specific heat sources present in the initial test setup included the laser used with the collimator table/T.M. alignment monitor and the motors which drive the aerotech stages and chopper wheel. The laser used with the alignment monitor was identified as a specific source of thermally induced air turbulence. Its use is not essential to the performance of the test and has been deleted for all further AC07R testing.

Alignment problems (or at least uncertainties) arose as the source/slit and T.M. were positioned and repositioned at various points during the test. The source/slit had to be detached from its mount and the lamp removed in order to reposition it each time a change was made between X and Y scans. This resulted in some uncertainty in the alignment position of the filament image on the slit for the various sets of data. Since the filament image is oversize with respect to the slit, the main effects were observed on the skirts of the IFOV plots. This combined with non-zero transmittance in the opaque portions of the slit may help to account for the problems of raised skirts and rounded-off IFOVS. Positioning of the T.M. for the various bands is accomplished by rotation using a theodolite for reference. For bands 5 and 7 rotation through the nominal angle from the T.M. axis failed to bring T.M. into proper alignment. At this point an alternate procedure was used whereby the T.M. was boresighted on bands 5 and 7 separately to obtain signals. The corresponding theodolite readings were then averaged to obtain the common center.

Other areas of concern were source non-uniformity and system focus. The lamp filament image was centered on the slit each time the lamp was repositioned and should be fairly uniform in intensity over the slit area. However, for Band 5 Y-direction measurements initial voltage readings from channels 2 and 16 were significantly out of balance. Channel 2 read 17.5 volts P-P compared to 11.0 volts P-P for channel 16. This imbalance was corrected by stepping the slit-stage 508 Aerotech steps along the filament in the -X direction before making the Y-scan measurements. All data was collected at the nominal focal plane of the collimator. Previous IA4 test data indicates that this position is .006 to .008 inch from best focus as determined by MTF. A small degradation (less than 1 microradian image blur) is expected to result from this condition.

B. Software Problems

Software problems occurred in selecting an appropriate step size and in matching far-field with near-field data. The initial step size was chosen to be 0.2 IFOV units for near-field data and 0.4 IFOV units for far-field. It was evident from examination of preliminary near-field data plots that the sampling density was too coarse for good resolution. A change to 0.1 IFOV step size improved the quality of the figures, but increased the test time significantly. In addition the computer programs had to compensate for the fact that the finite Aerotech stage steps weren't exact divisors of an IFOV. In order to maintain average stepping units, the number of Aerotech stage steps per unit had to vary by an occasional step. Another type of problem occurred in "normalizing" far-field to near-field data. The matching was done by comparing several overlapping points on the far-field and near-field curves and using an average normalization factor. The problem arose as the far-field curve ran into its saturation region (slit crossing the detector) and started to undergo distortions. Several software changes were needed to keep the computer from selecting data from the saturated region. In general the final plots were improved and the problem has essentially gone away. However, Band 4 detectors still exhibit some normalization problems. These may not be due to software, but rather to electronics. The detector signals, while in saturation, are depressed significantly.

One factor which may have contributed to the normalization problem was the inadvertant omission of a parameter from the database knows as the "bright field recovery time". This was a waiting period of a few seconds

Figure 1 Revised BTCE Set-Up For Band 6

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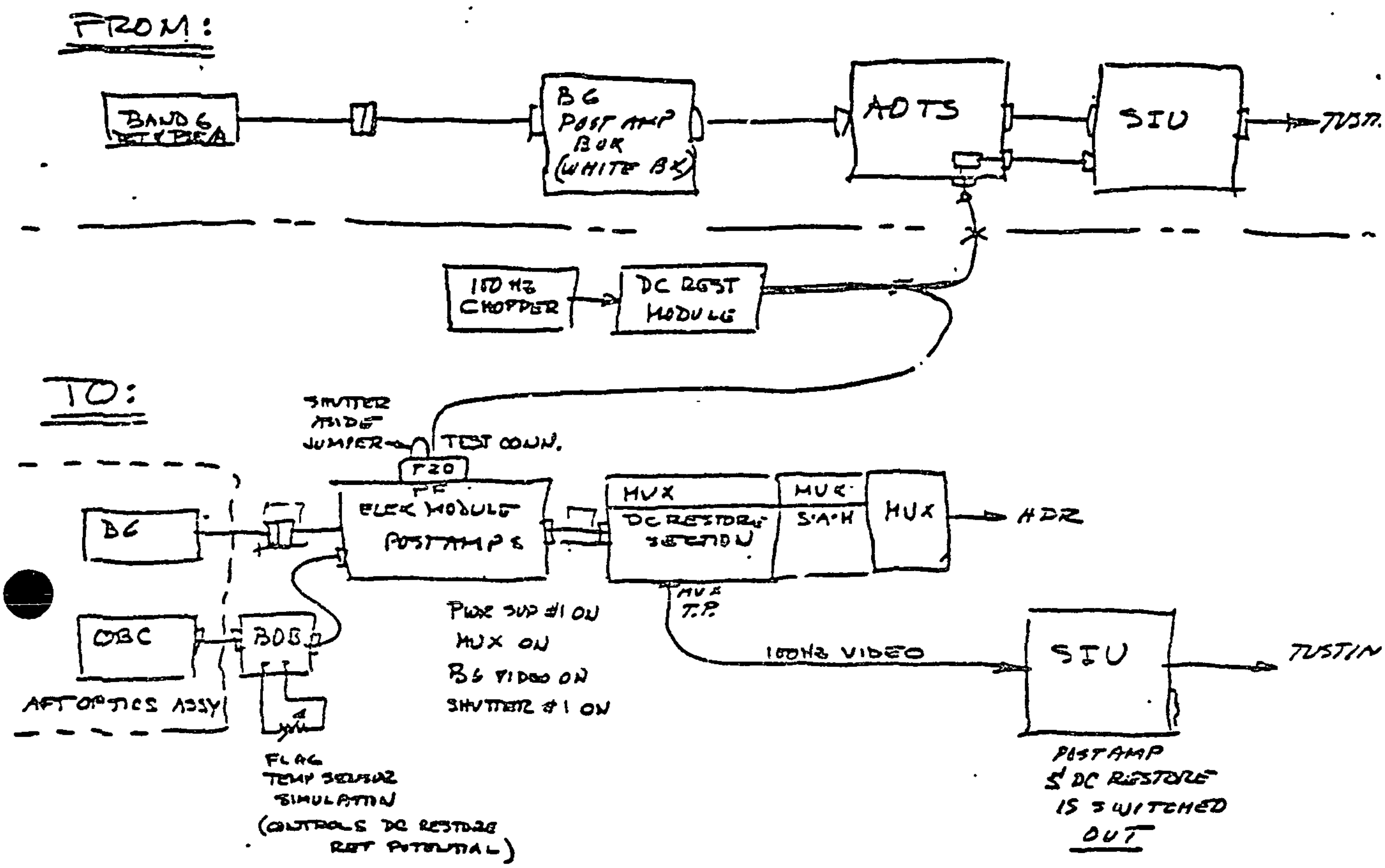


intended to allow a detector to recover from the shock of saturation received during the near-field portion of the far-field scan. This parameter has been put back into the database and will be available for future data collects. However, this may not help very much as there was no hint of recovery evident in the test data.

Another software problem area was the seemingly arbitrary omission of some of the collected data from certain data tabulations and plots. A change to the database and command file was needed to get all of the data printed and plotted out.

C. Conclusion

This report has described the results of running the AC07R Spatial Coverage Test on the Protoflight Model T.M. The test technique has been proven to be valid though the results are less than desired. The test procedure and command files have been debugged and will be ready for future testing. Several problems have been successfully resolved while others will be investigated further by a special test scheduled for the near future. It is unfortunate that this test had to be run for the first time on the Protoflight T.M. without the benefit of a preliminary run on the Engineering Model.

Prepared by: J.C. Campbell
J.C. Campbell: Optics

Concurrence: J. Young for T.D. Wise
T.D. Wise: Optics

Concurrence: R. Osgood
R. Osgood: Systems Analysis

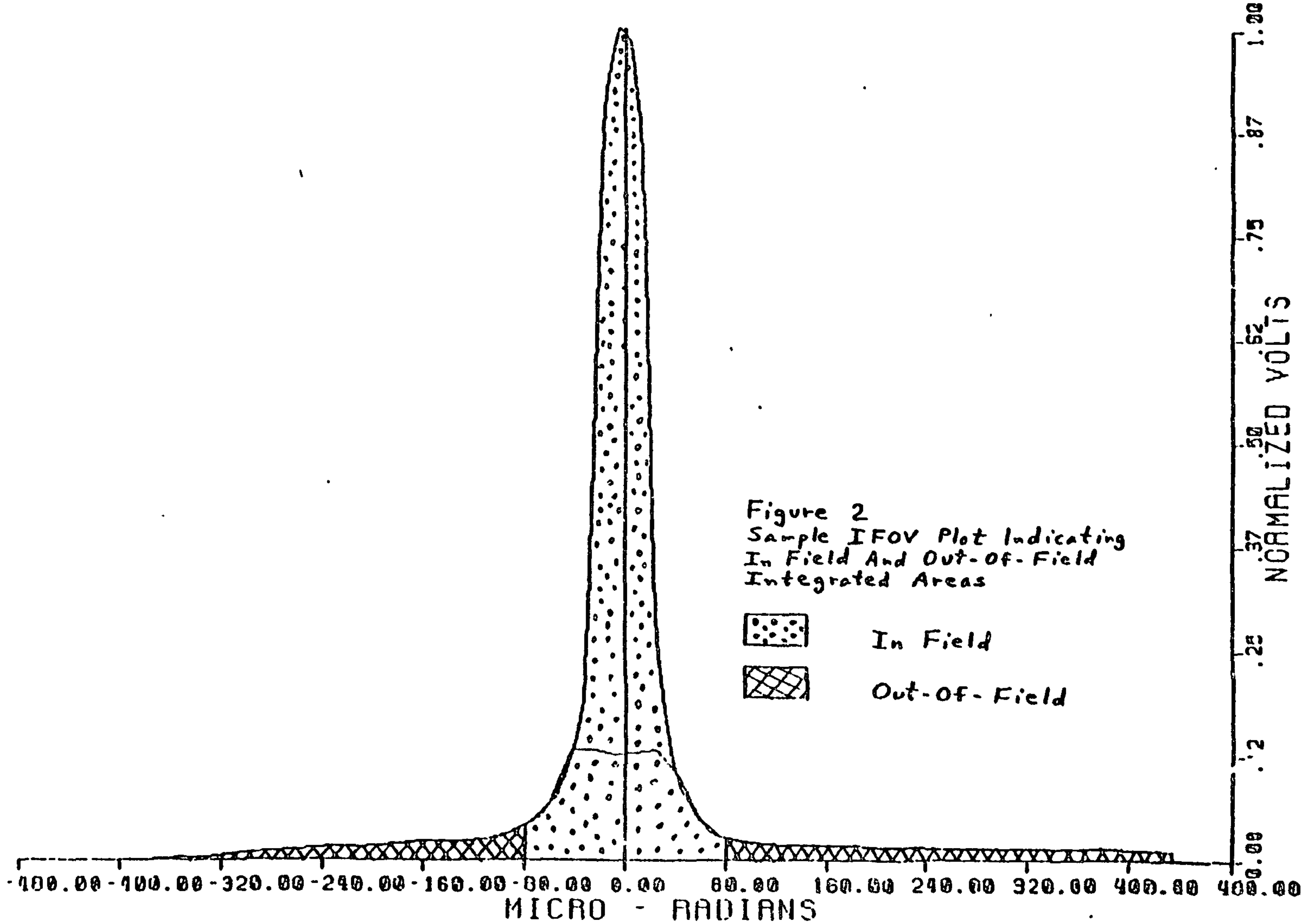
Approval: J.L. Engel
J. Engel: Manager Systems Engineering

Approval: W.H. Freudenstein
W.H. Freudenstein: Manager Systems Test

JC:ph

NEAR AND FAR FIELD DATA FOR Y - AXIS, BAND 3 CHANNEL 2.

07-MAY-81 14:46:09



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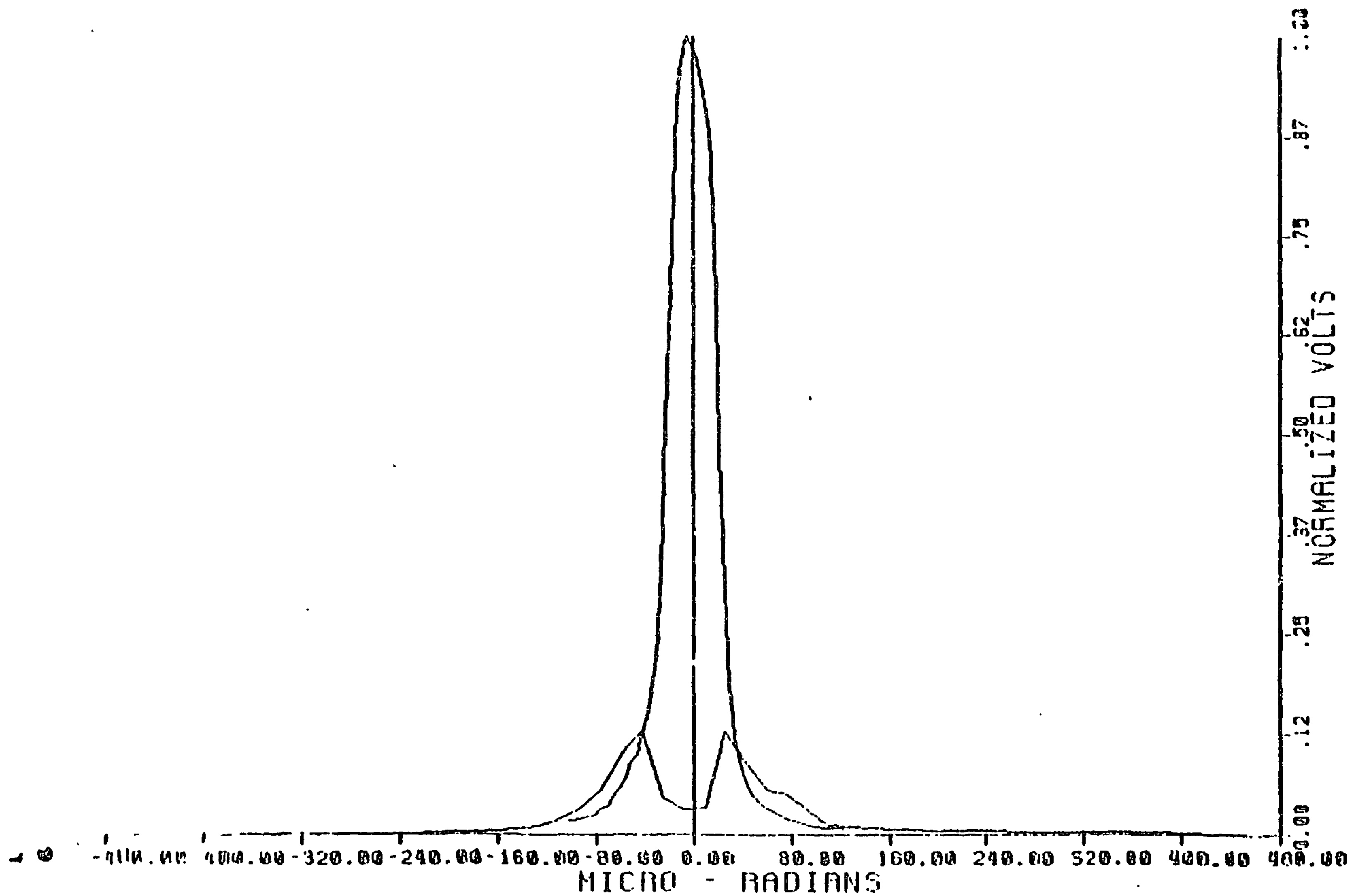
APPENDIX A

FIELD OF VIEW PLOTS

NEAR AND FAR FIELD DATA FOR X - AXIS, BAND 4 CHANNEL 16

06-MAY-81 15:16:53



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NEAR AND FAR FIELD DATA FOR Y - AXIS. BAND 4 CHANNEL 16

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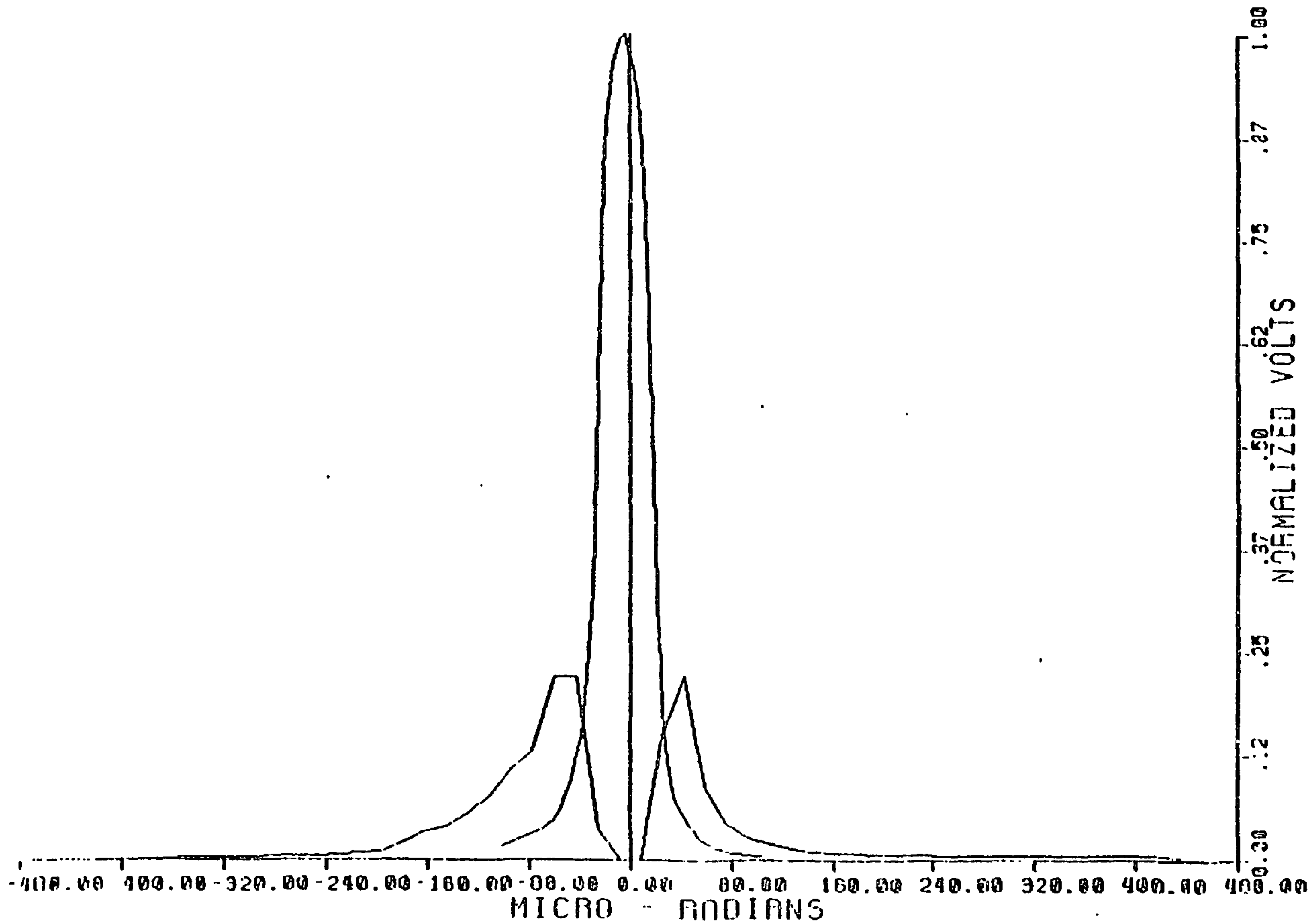

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... ..IU FAR FIELD DATA FOR X - AXIS, BAND 4 CHANNEL 2

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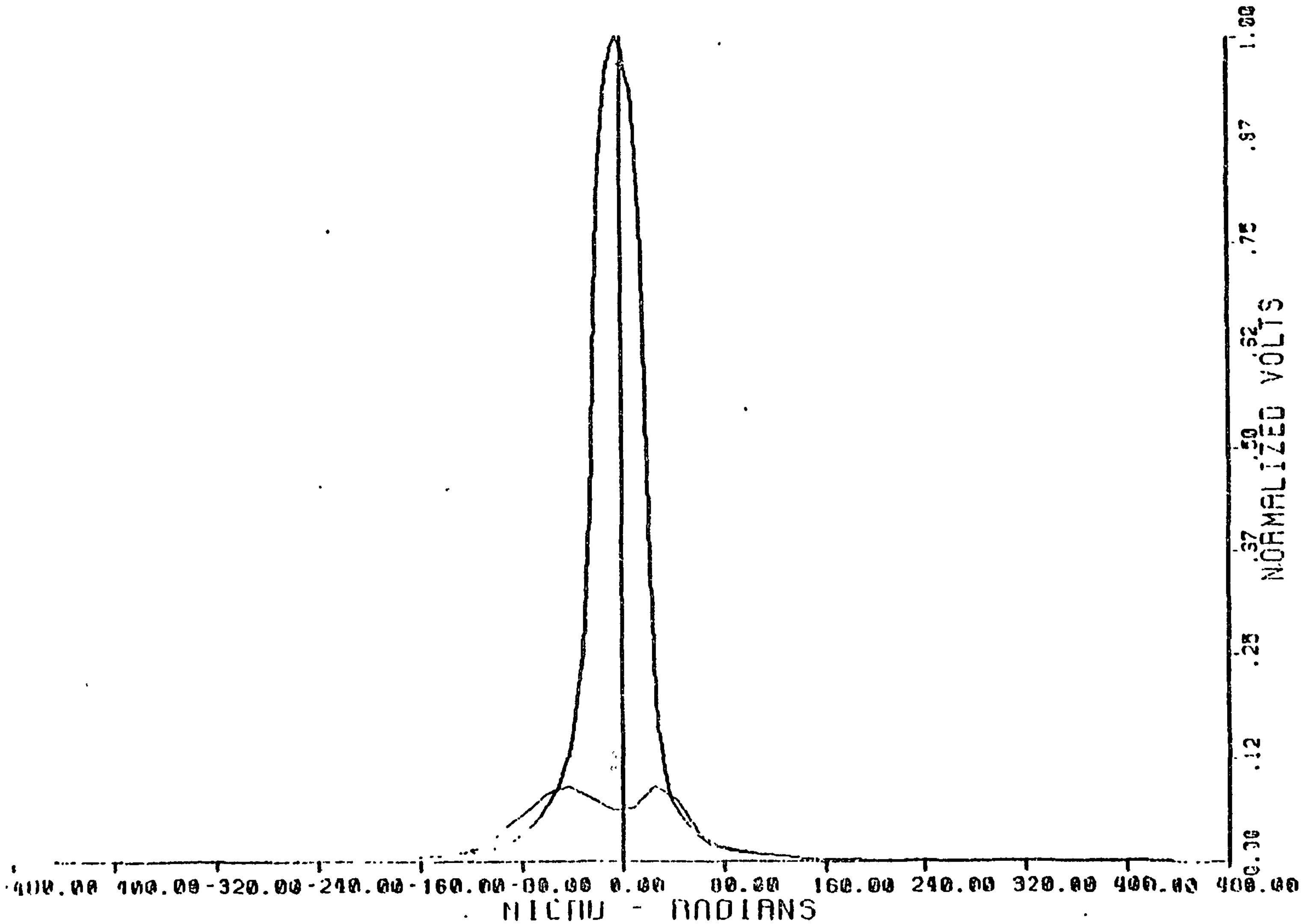

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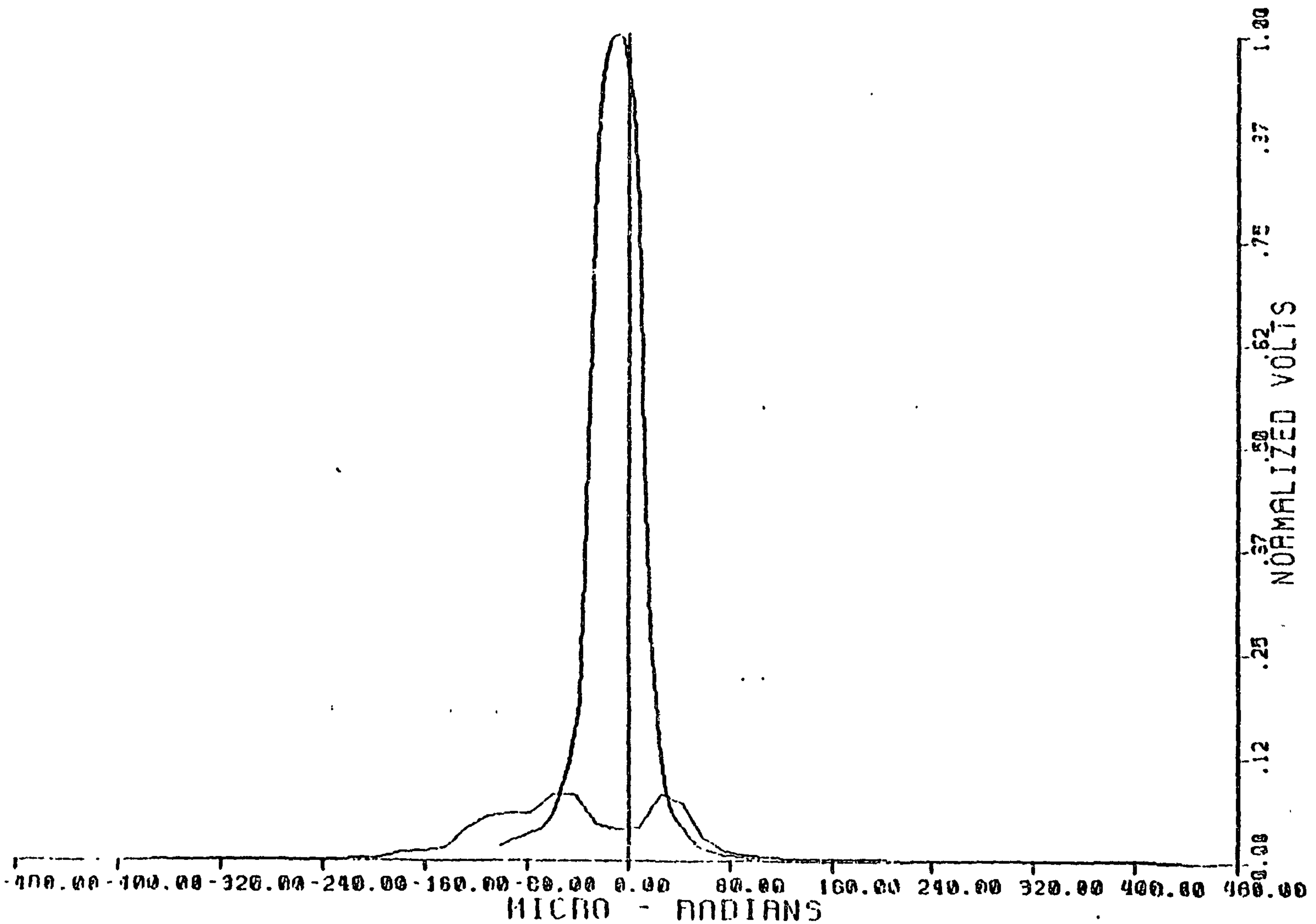

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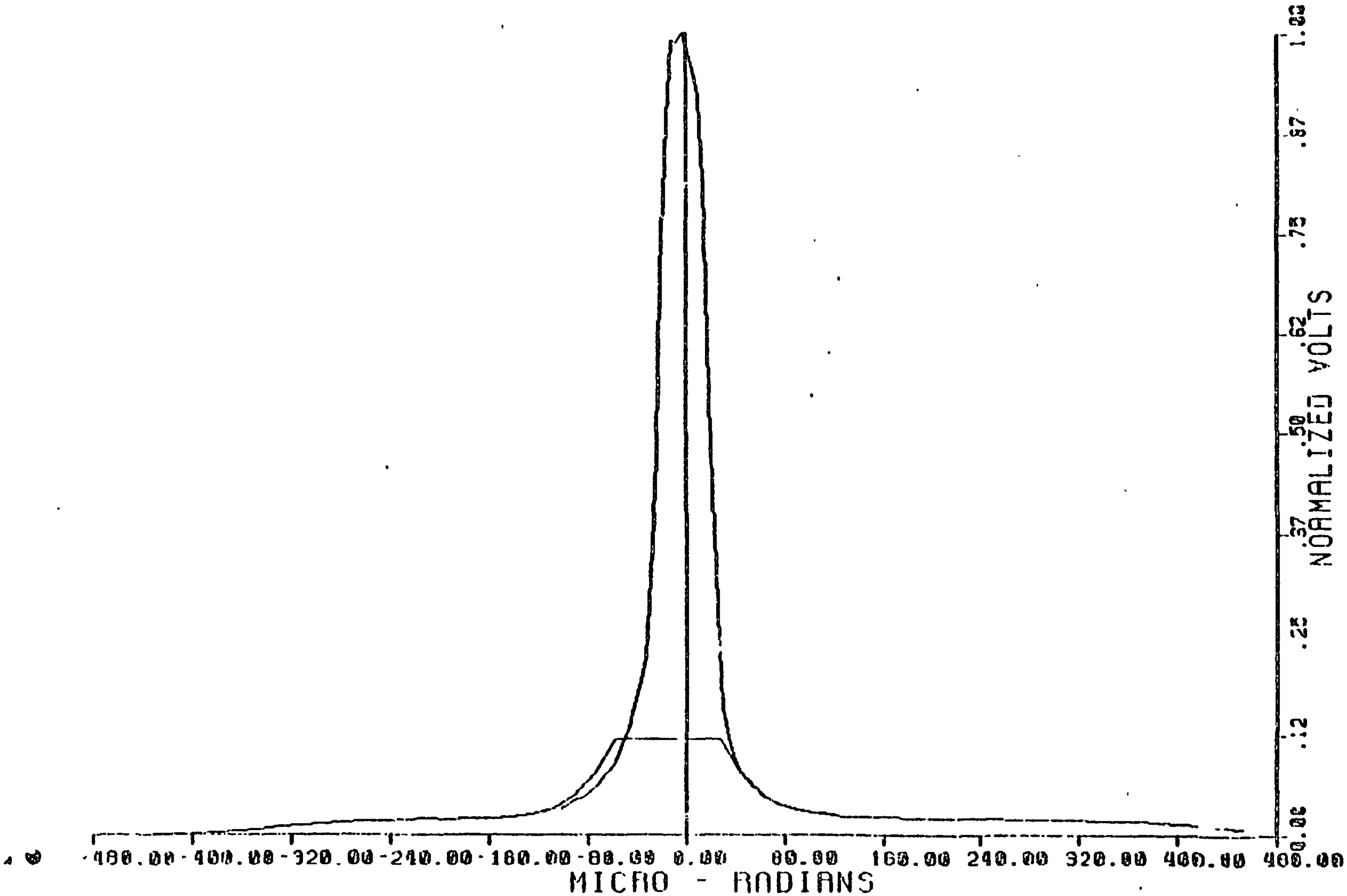

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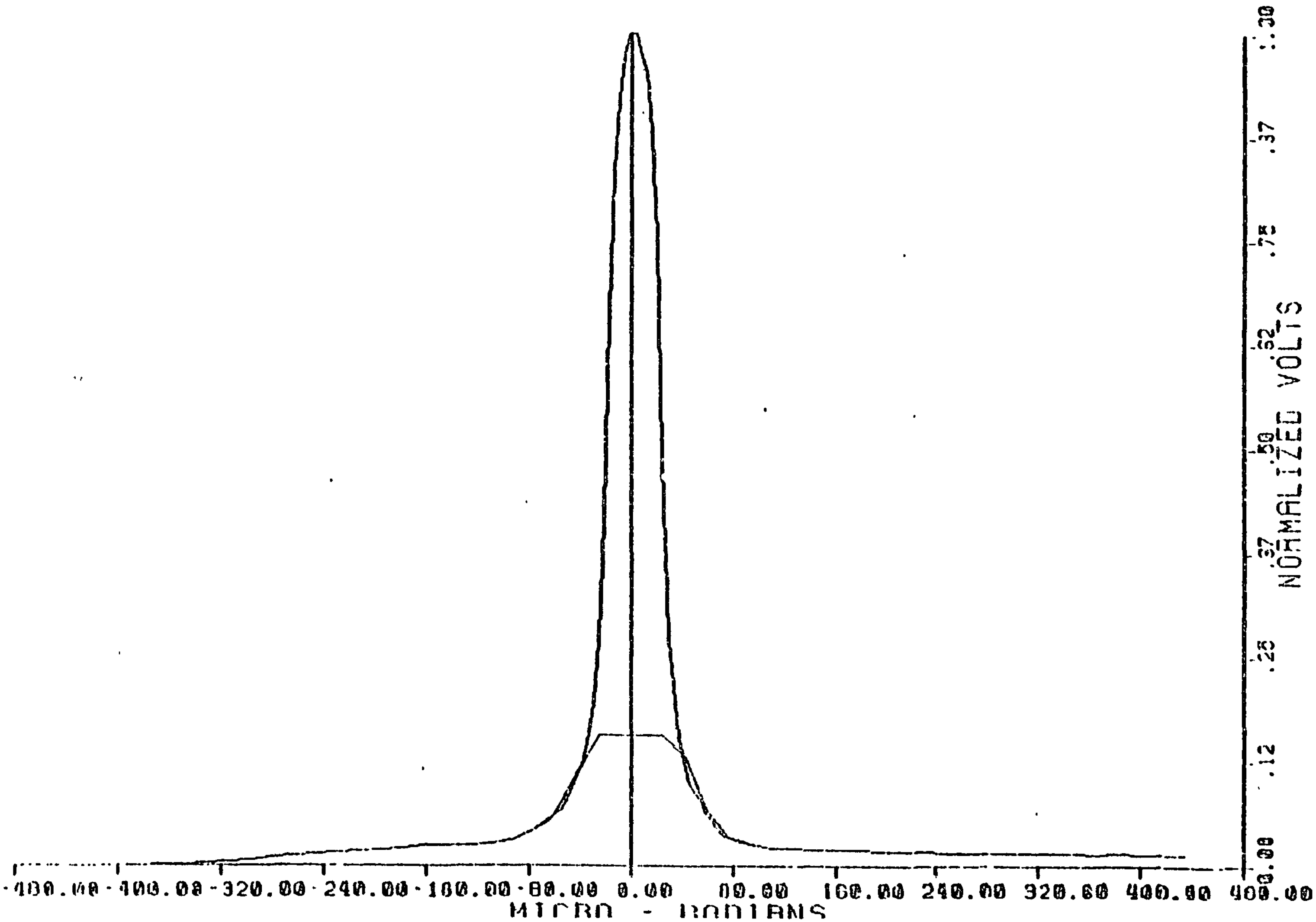

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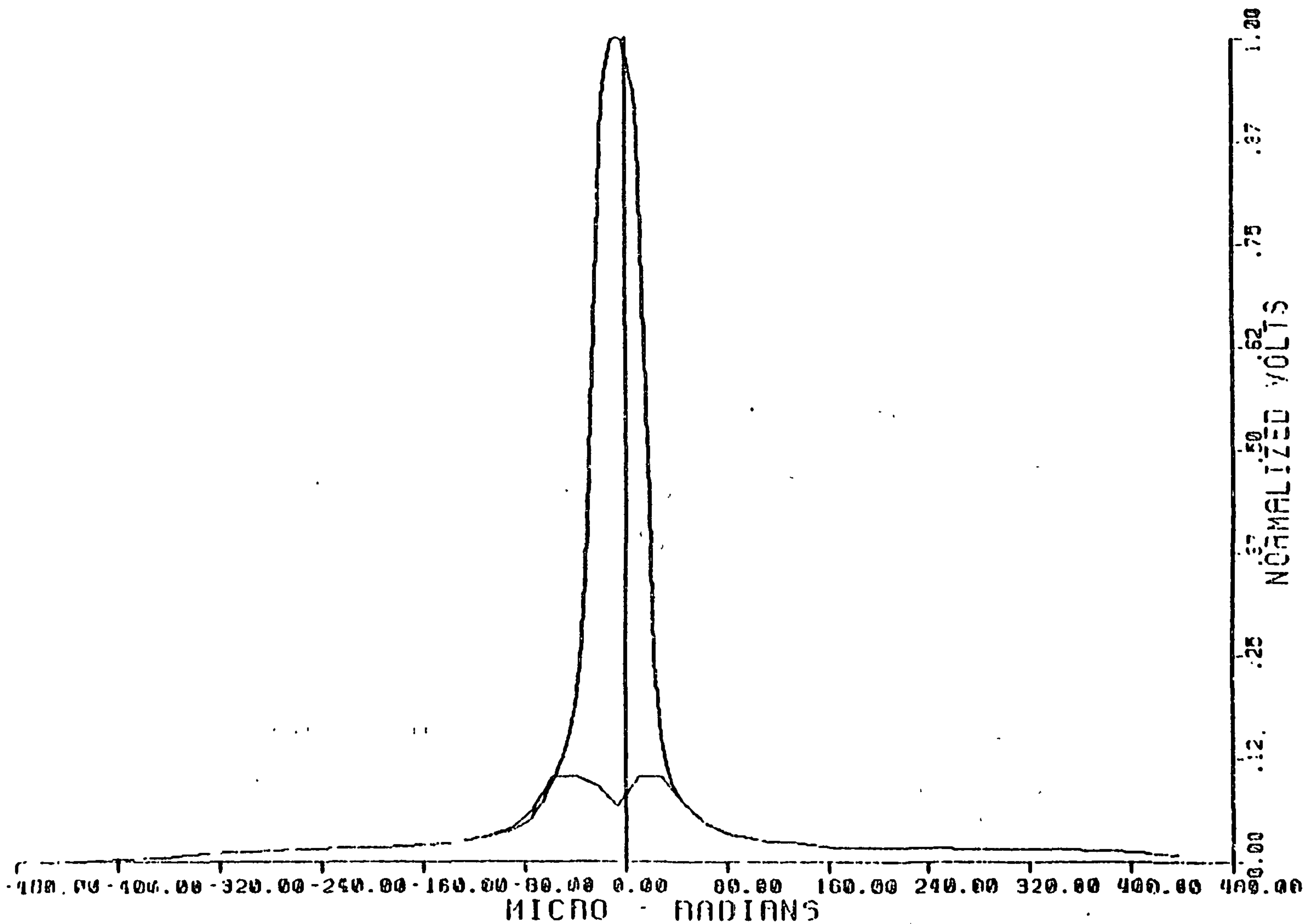

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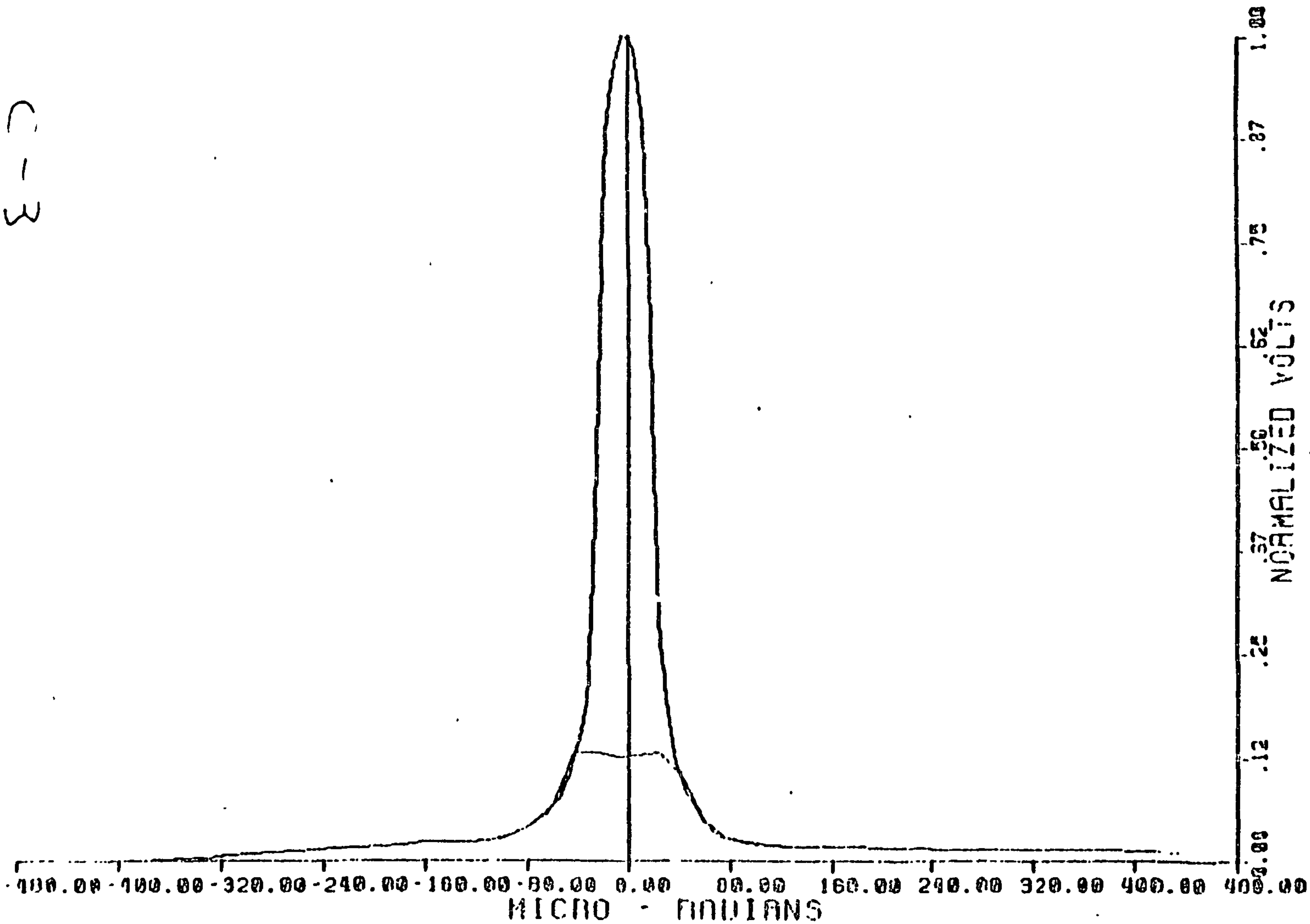

NEAR AND FAR FIELD DATA FOR X - AXIS, BAND 2 CHANNEL 15

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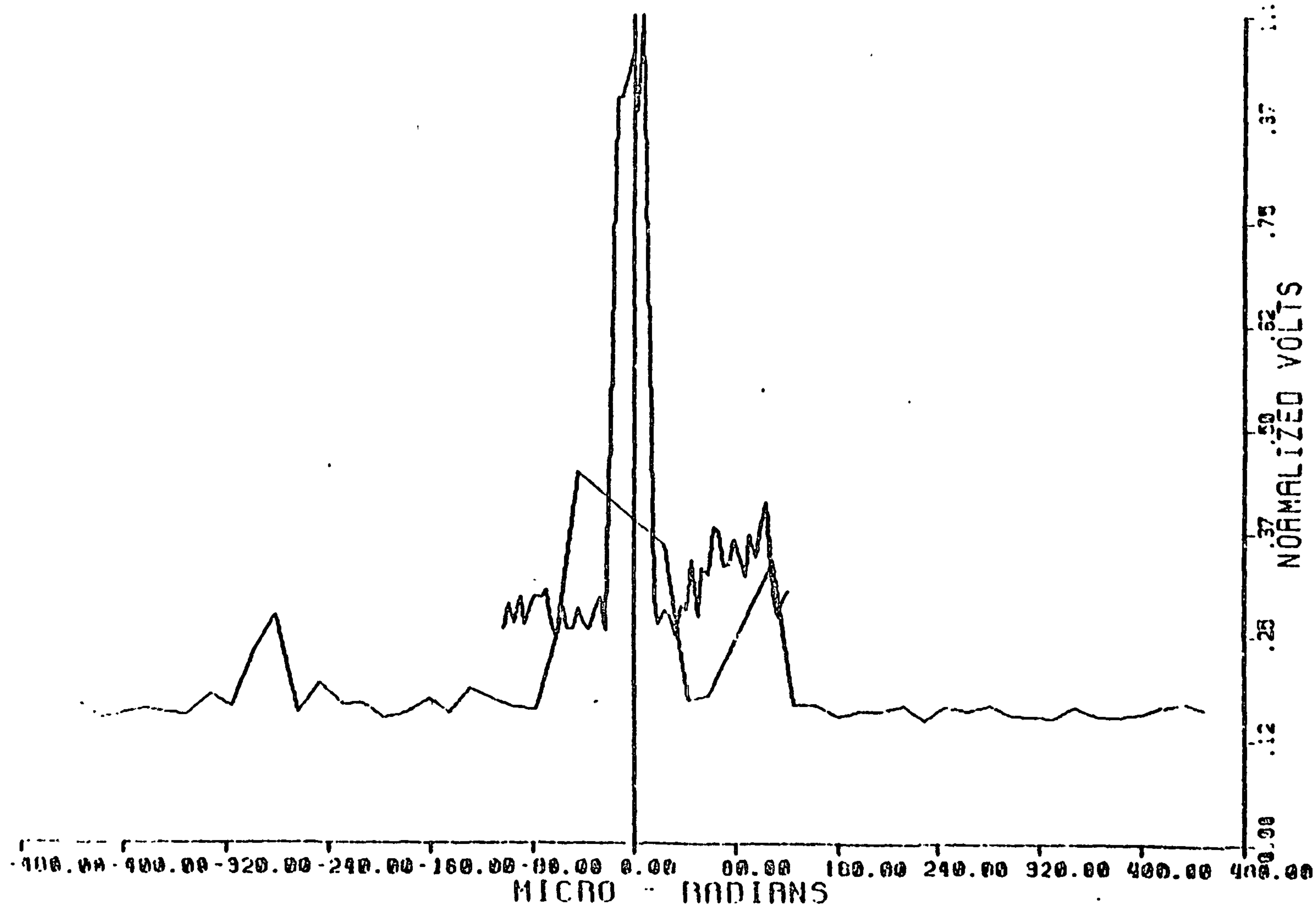

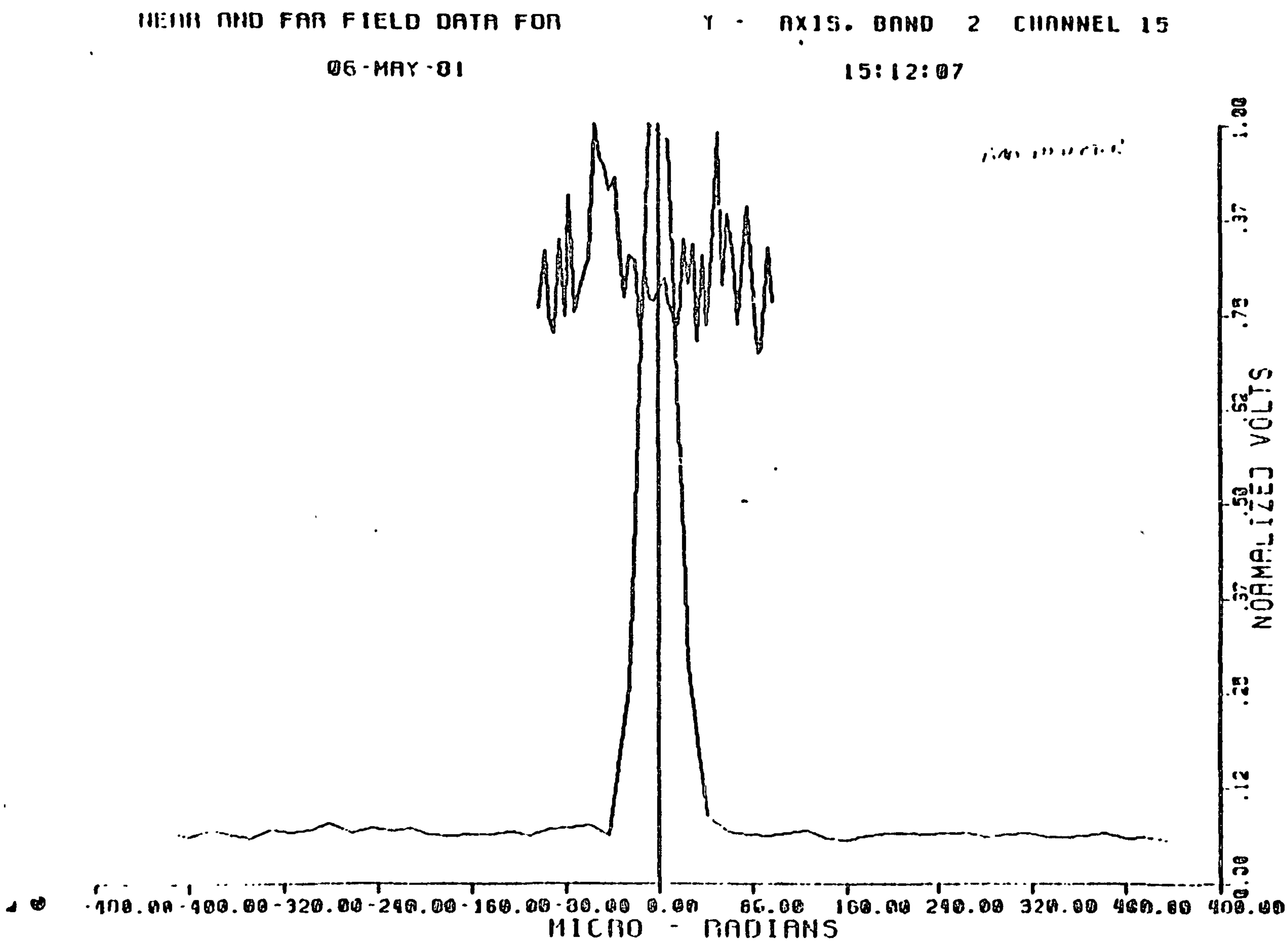

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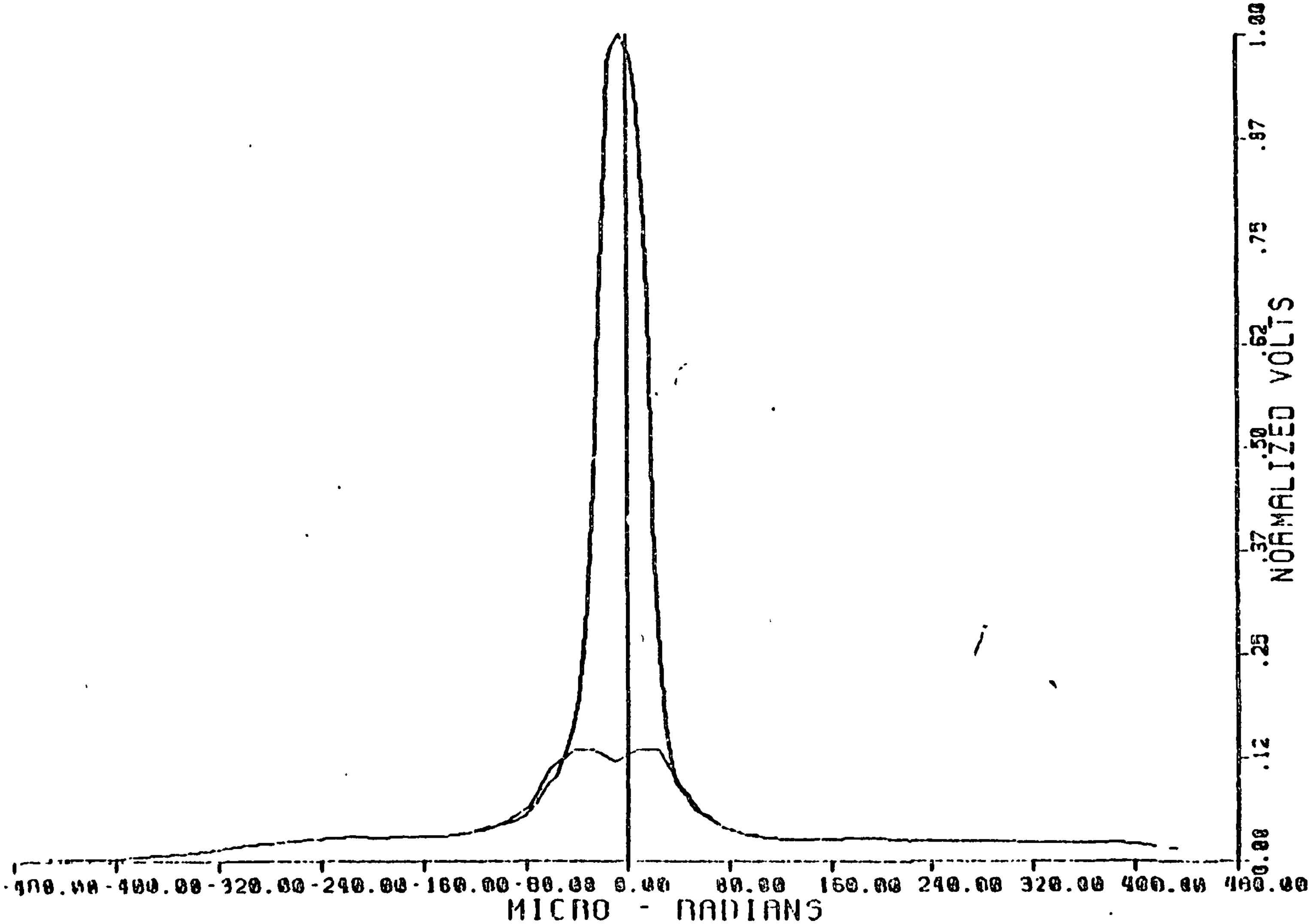

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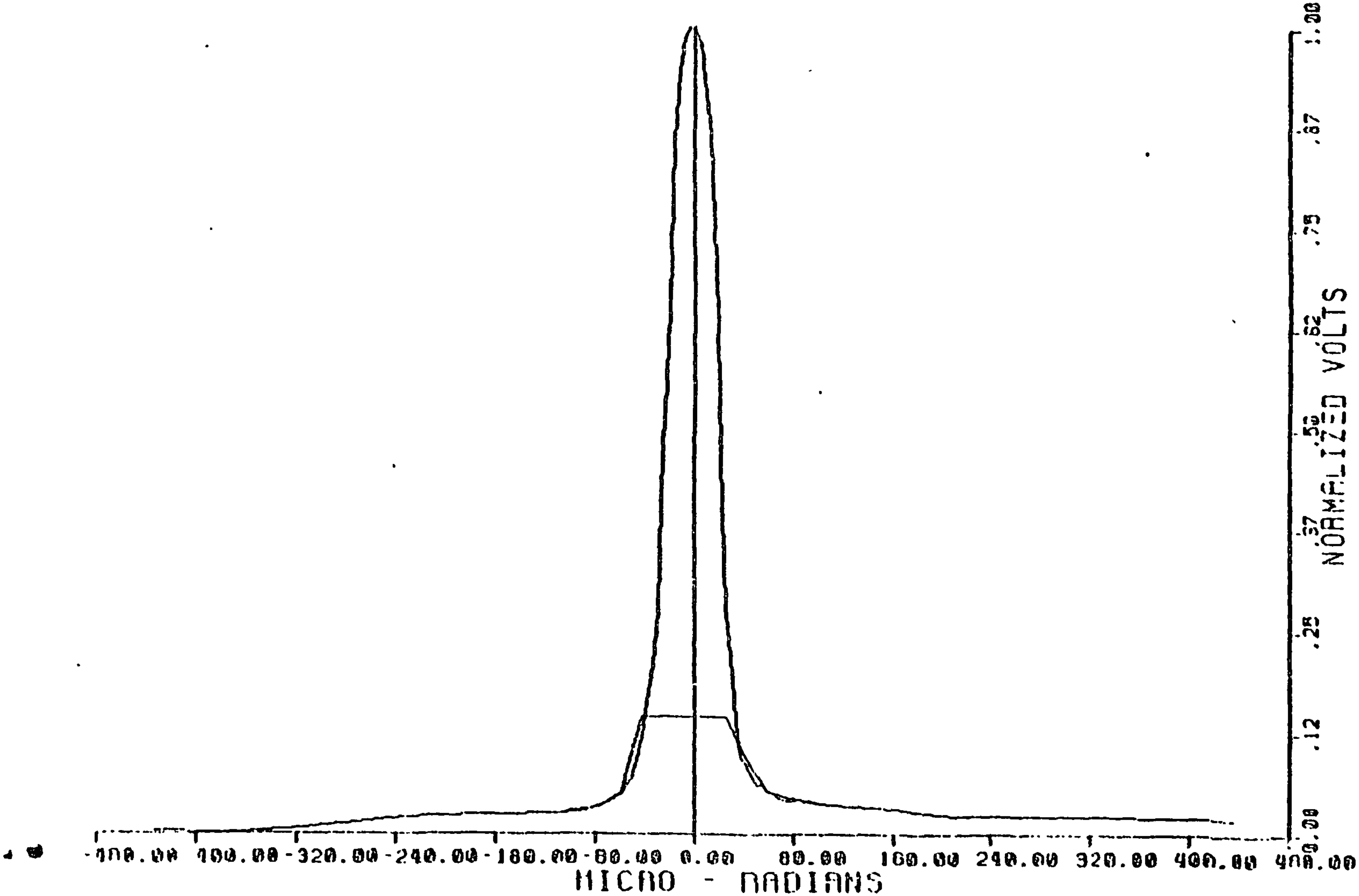

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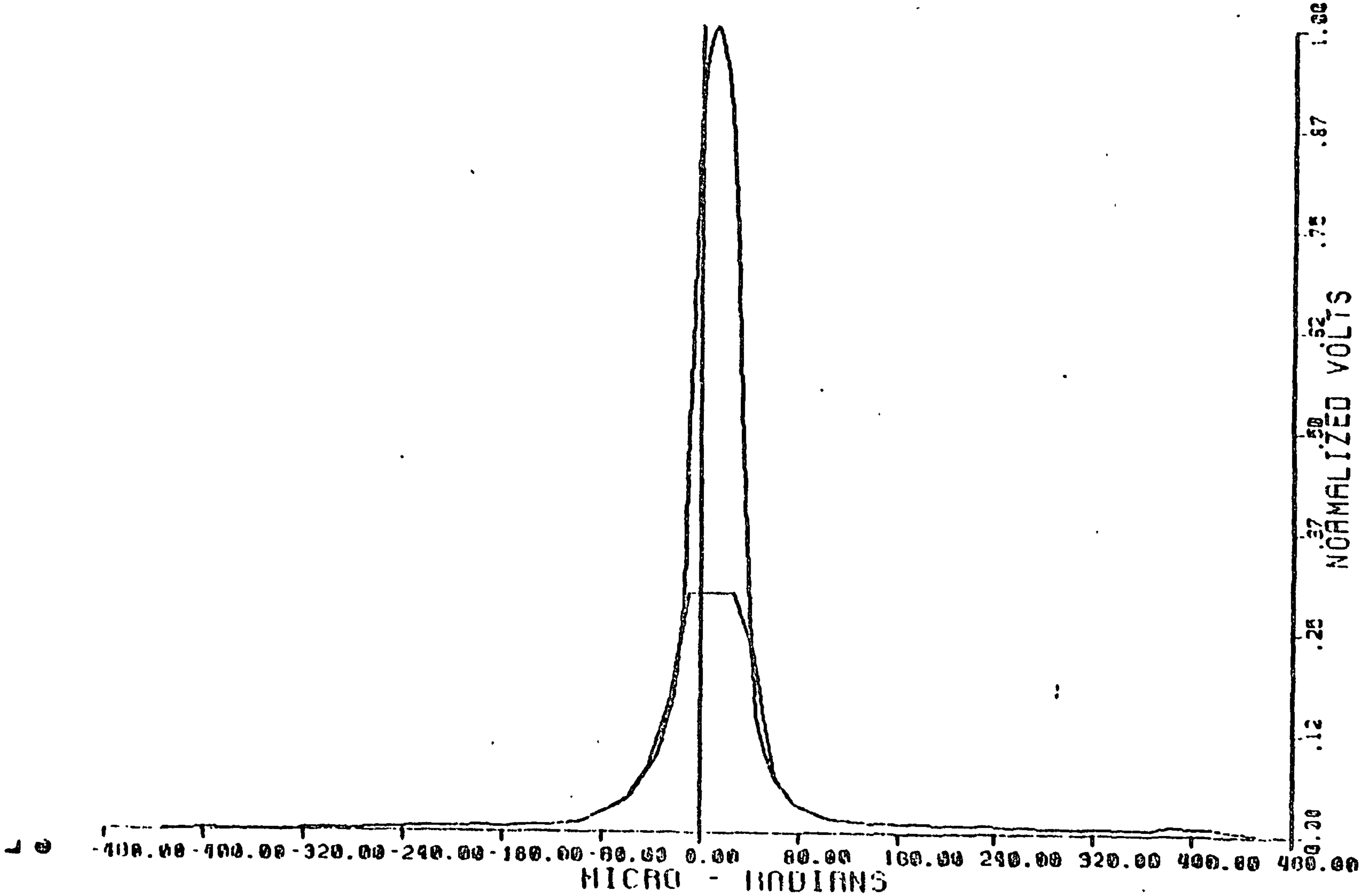

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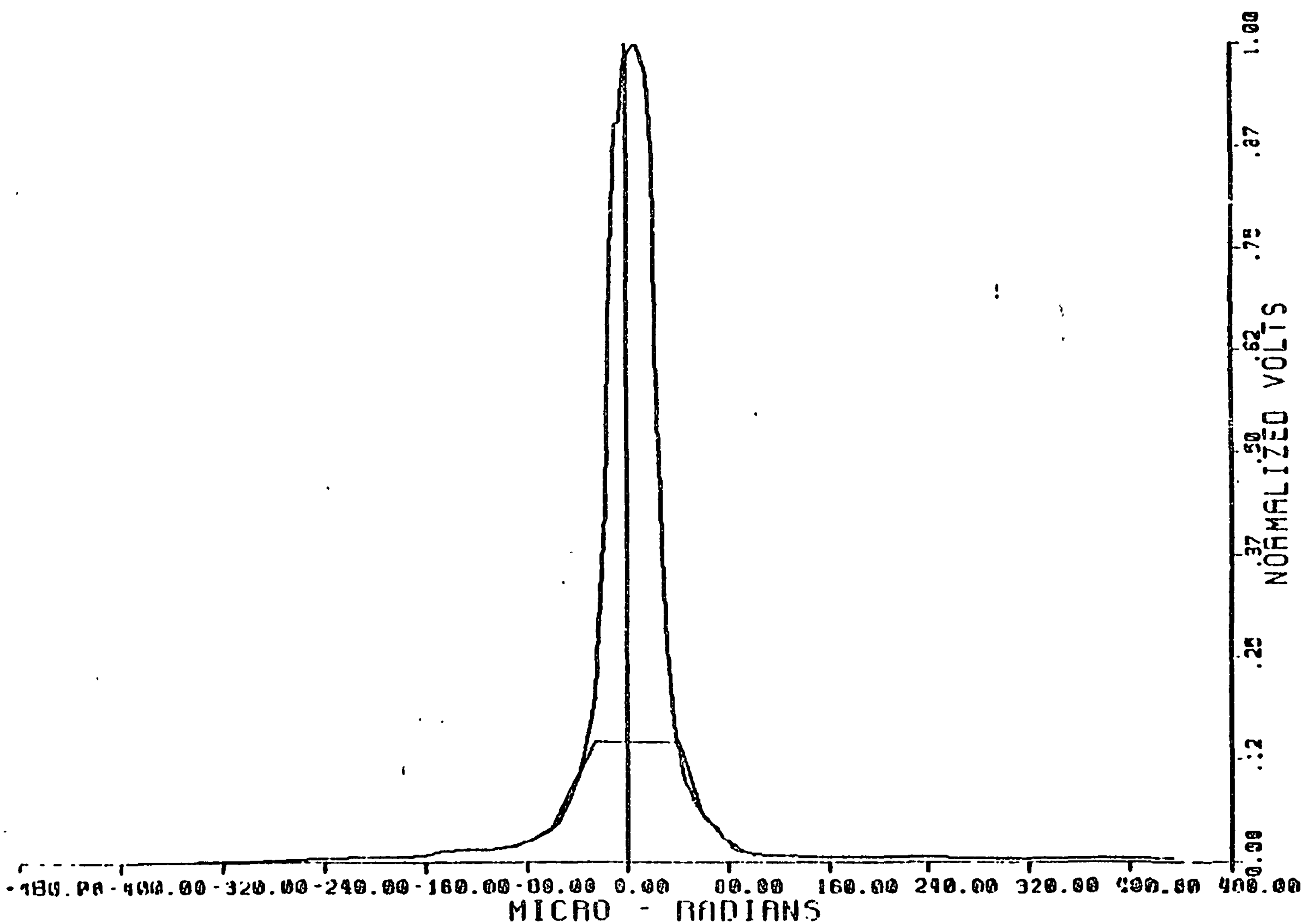

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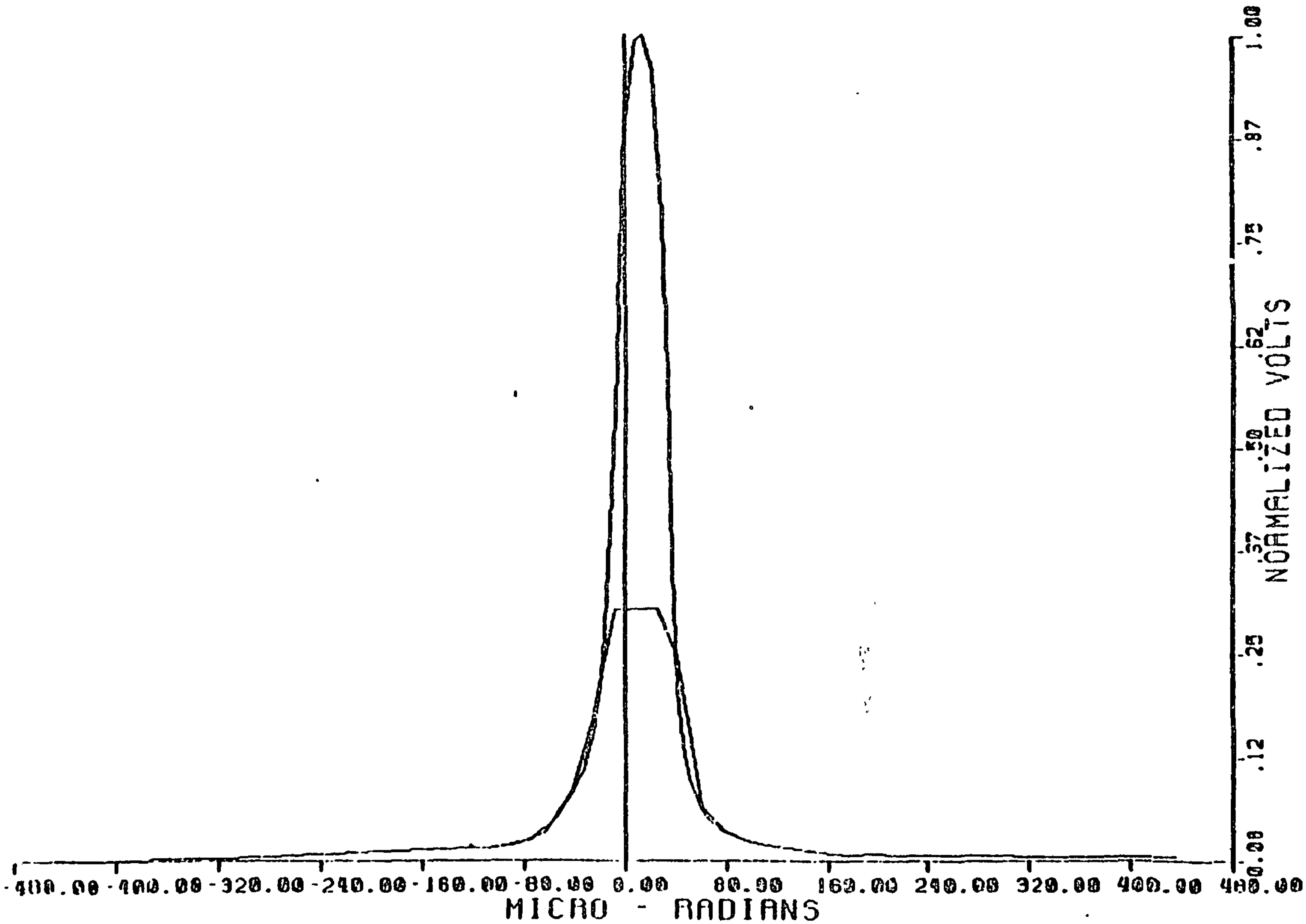

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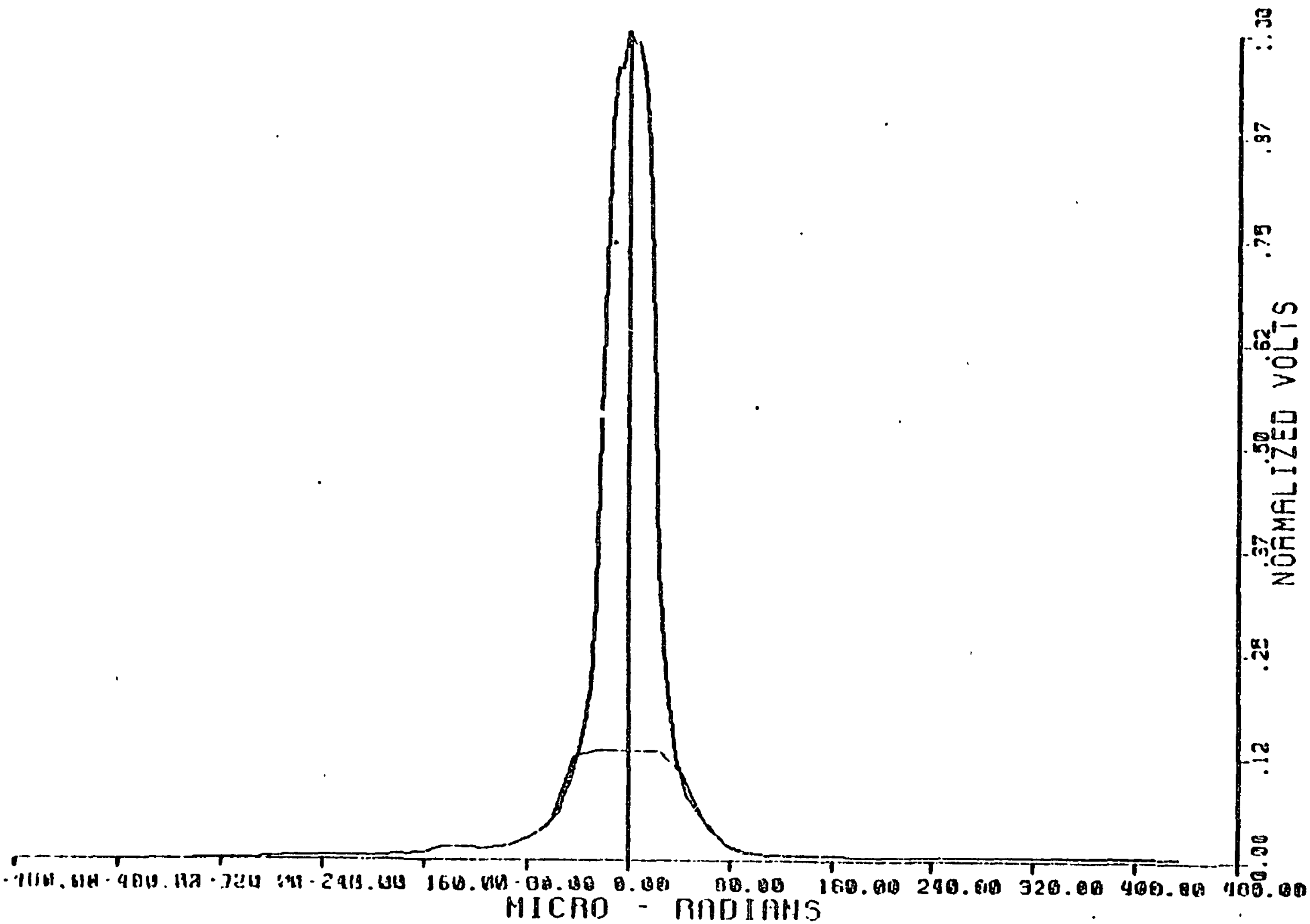

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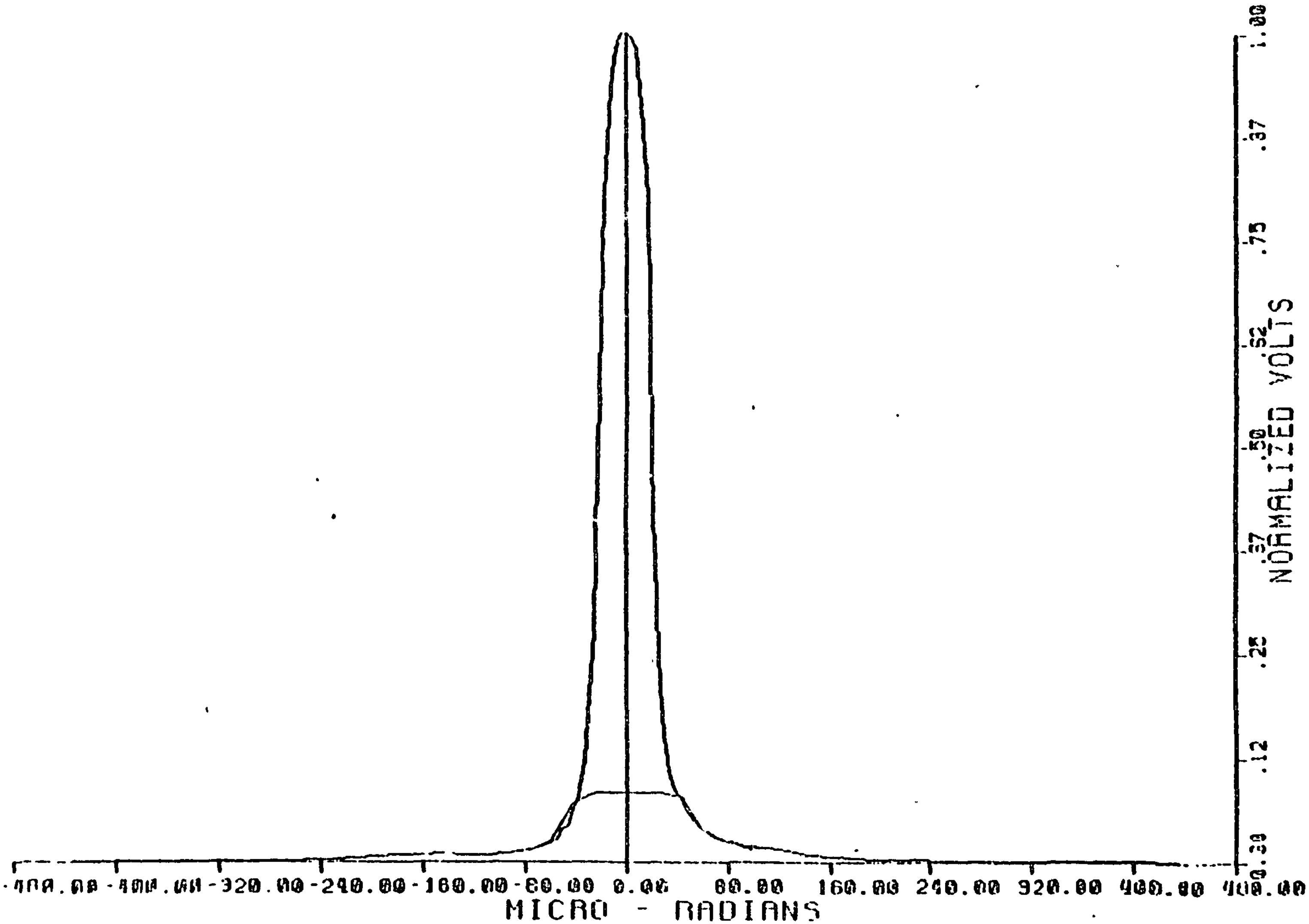

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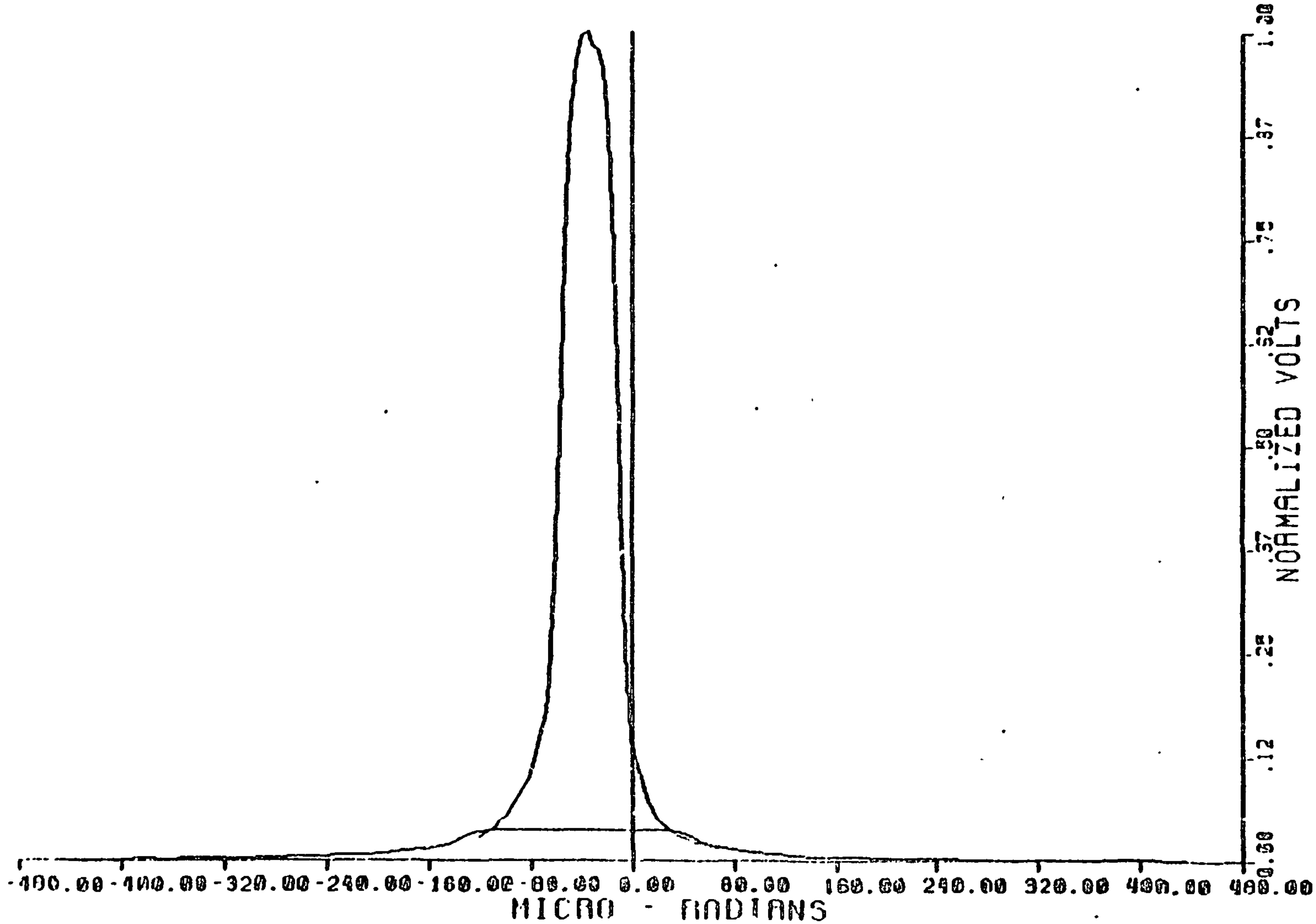

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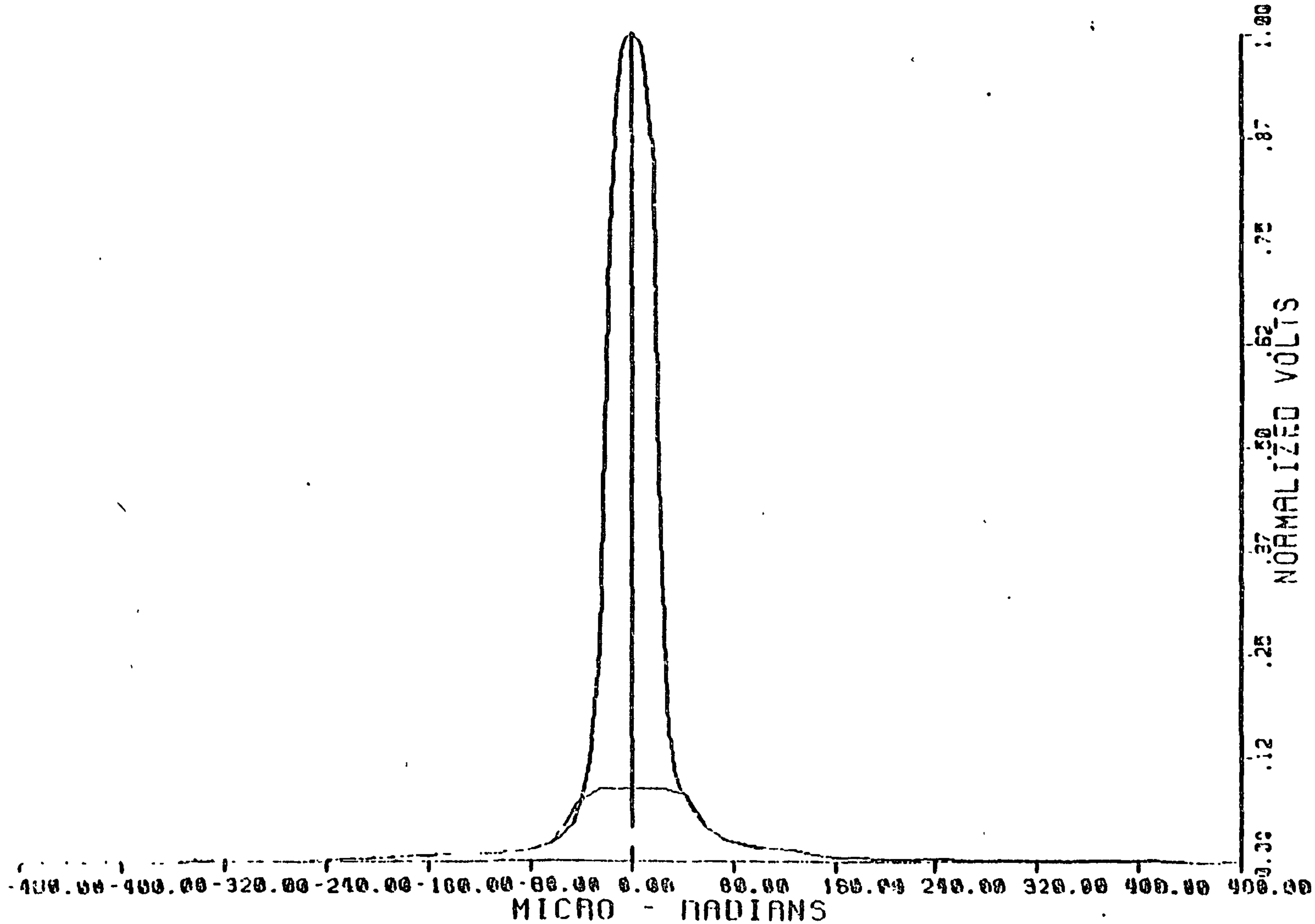

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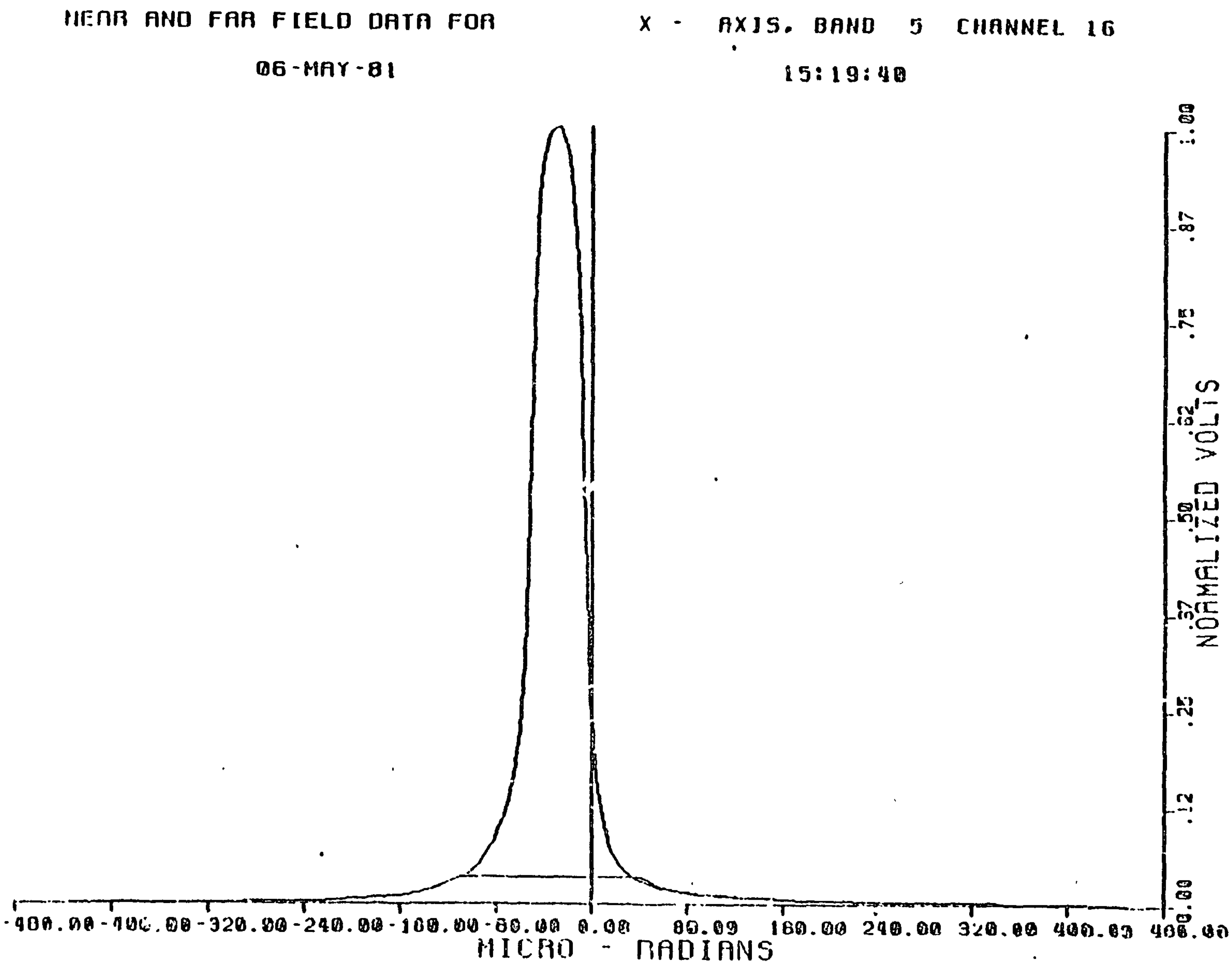

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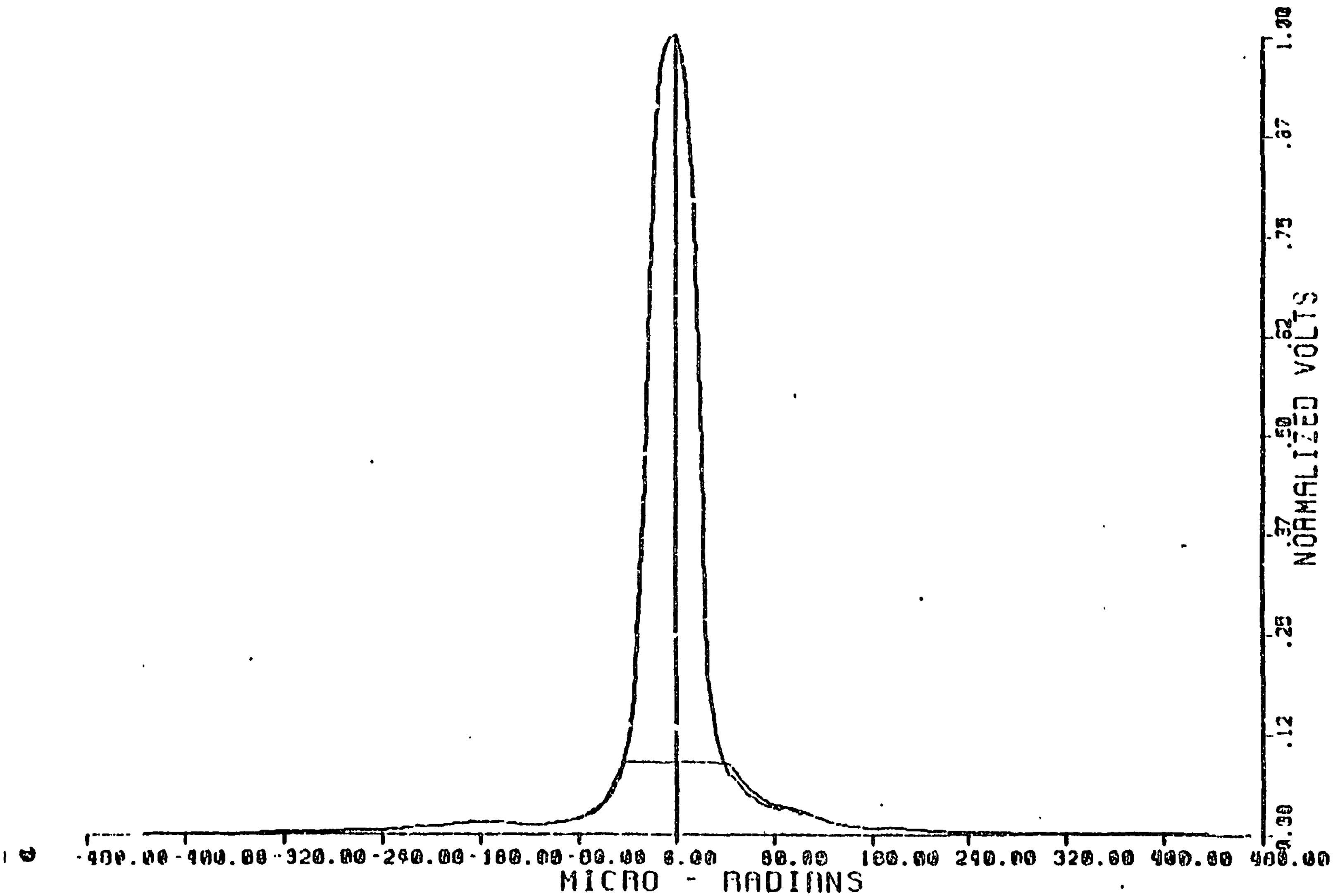

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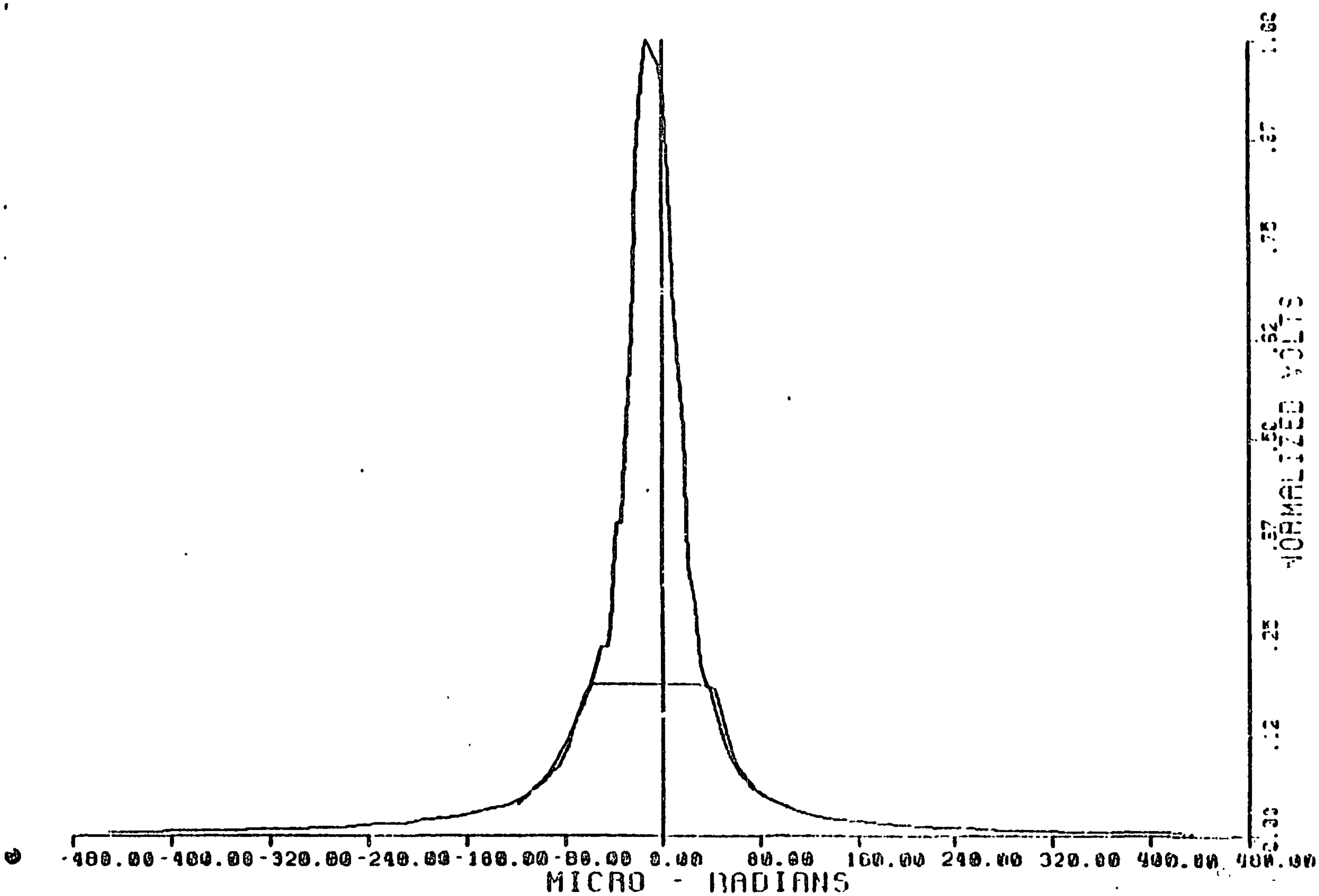

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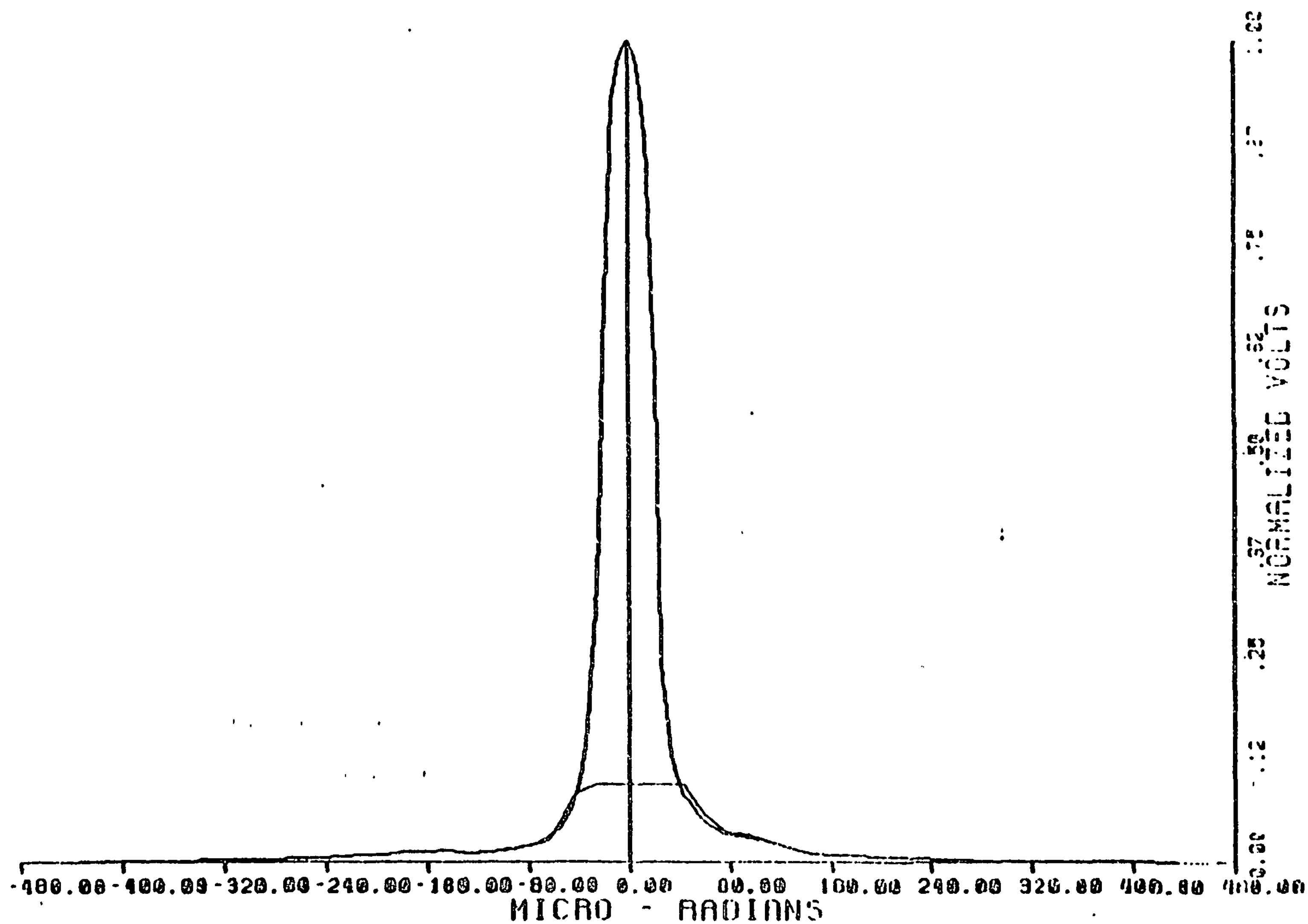

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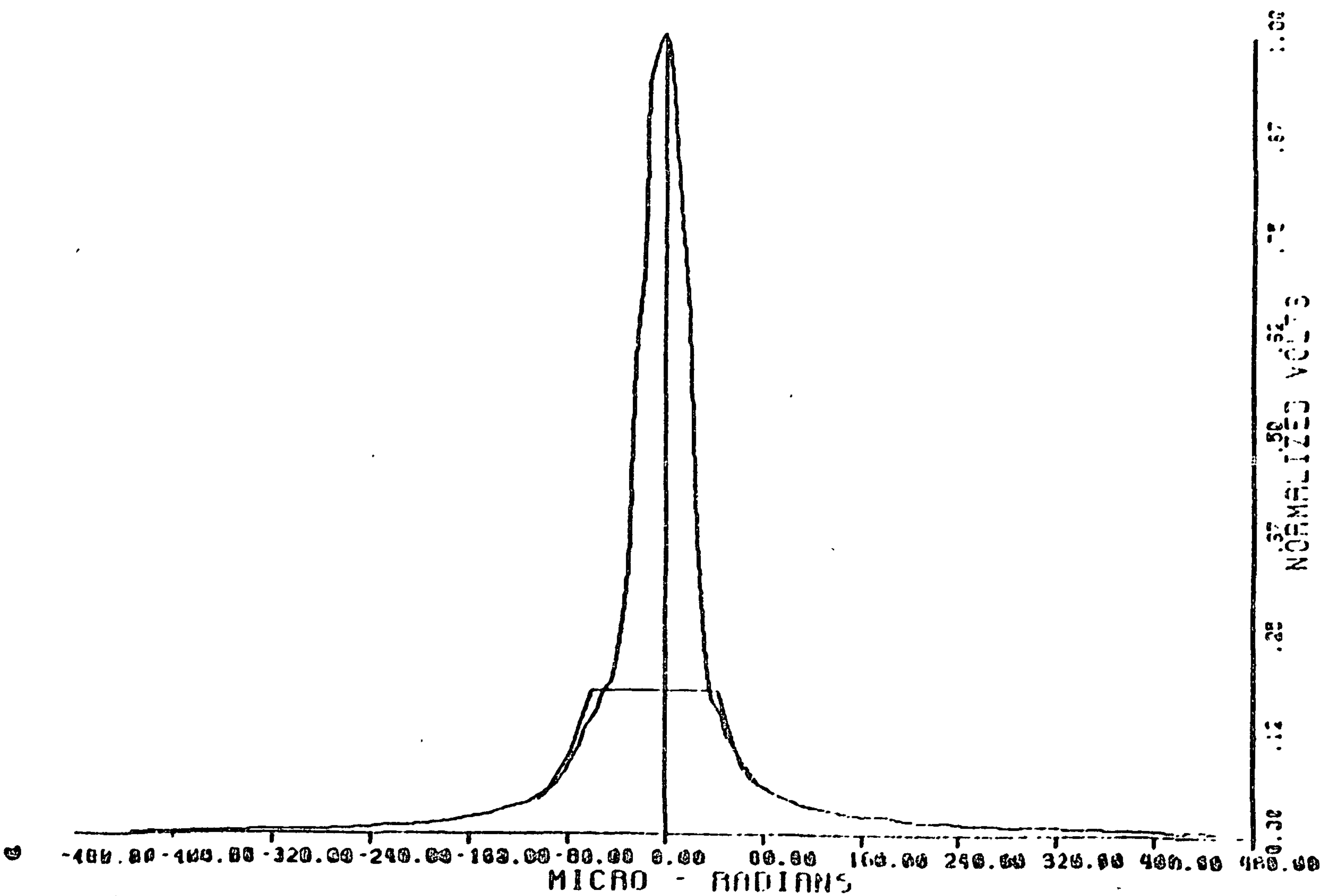

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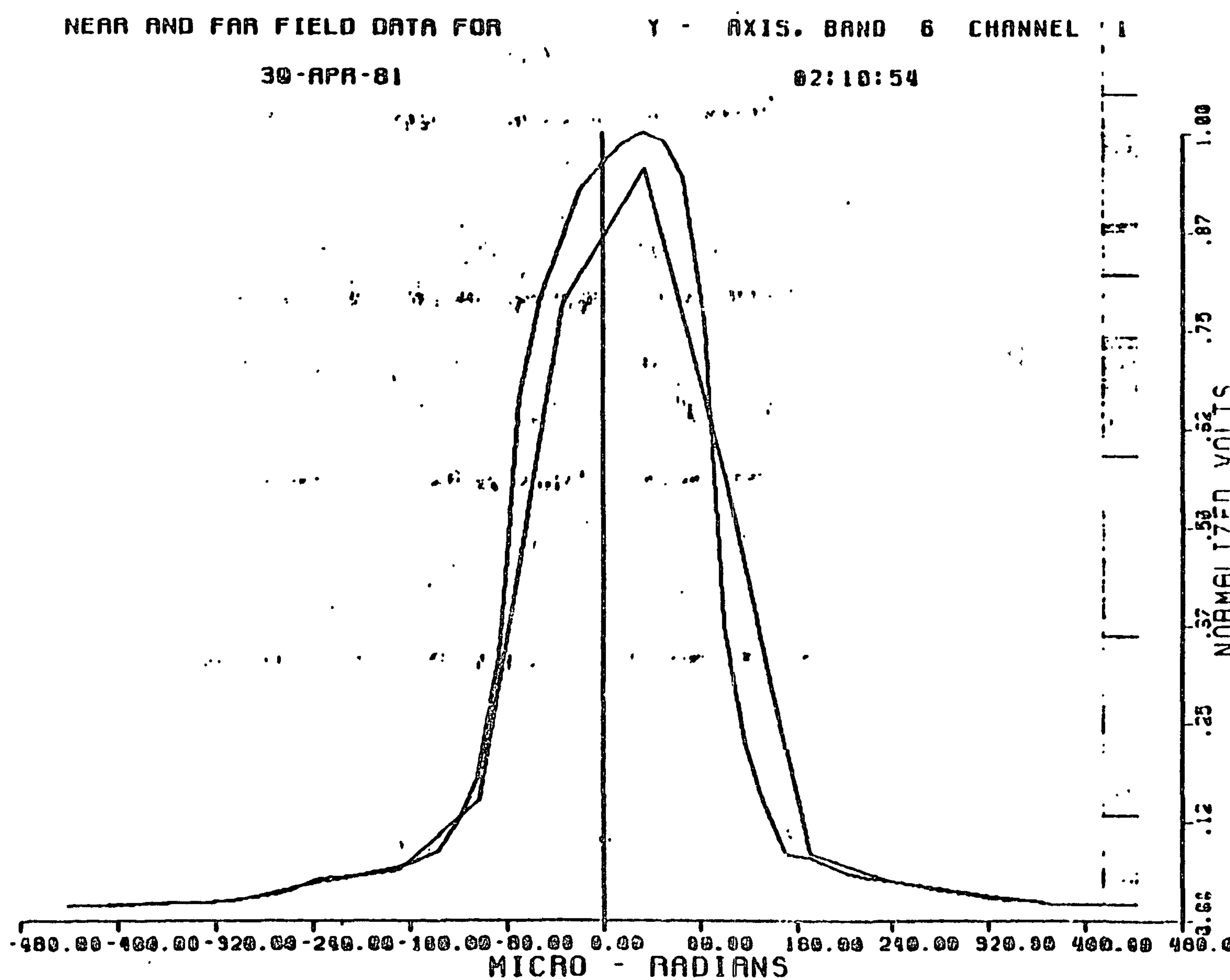

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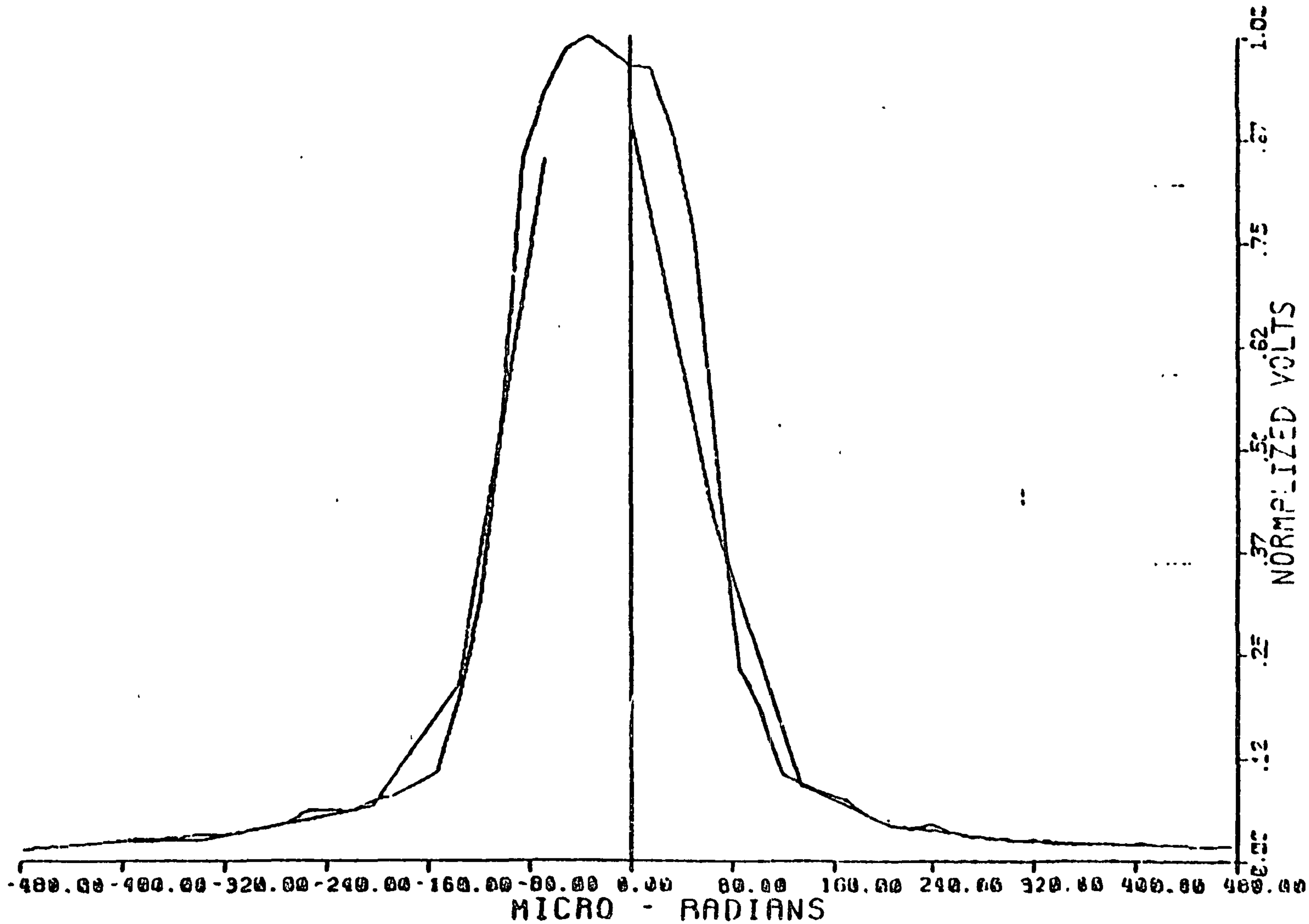
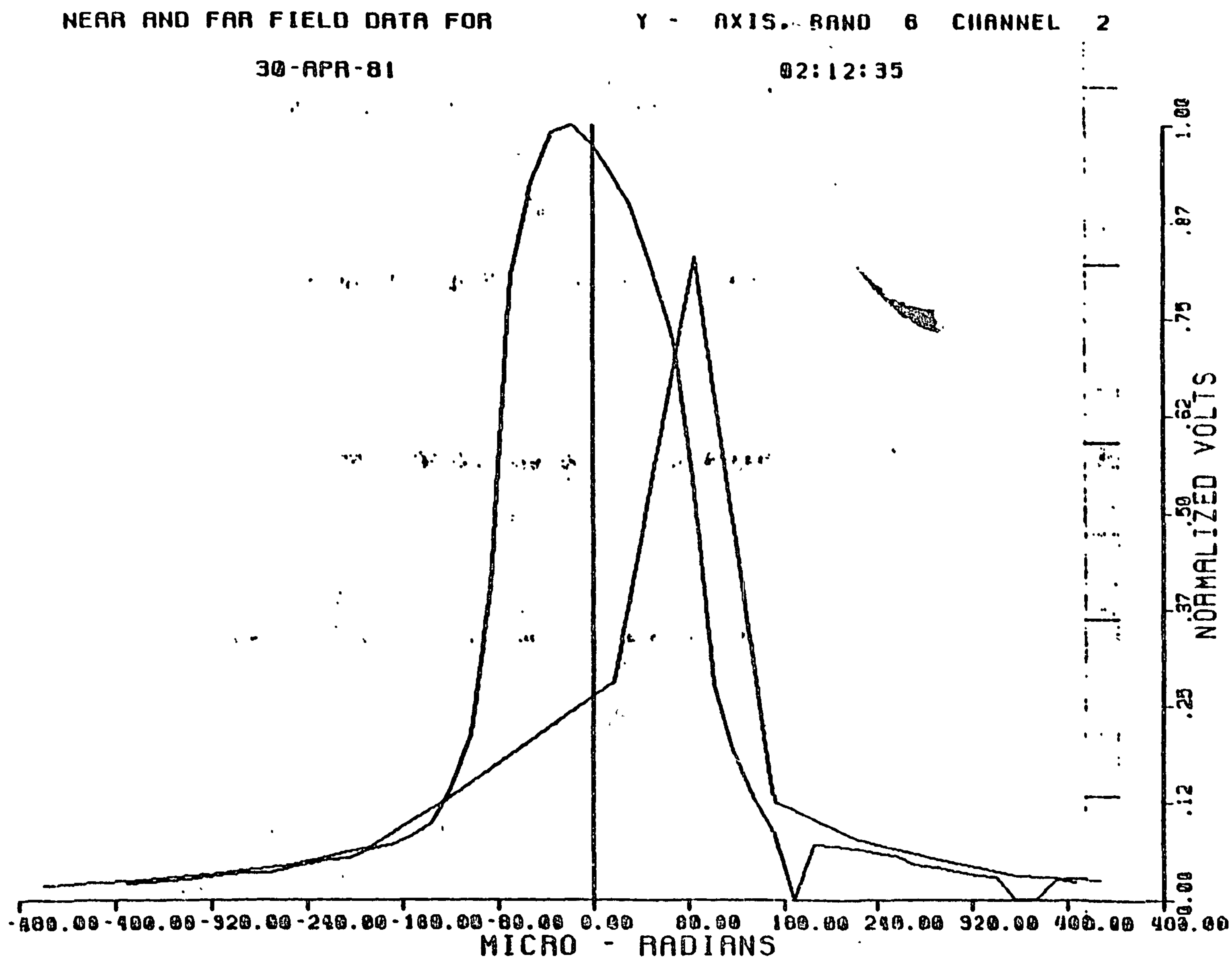
29-APR-81 20:16:12





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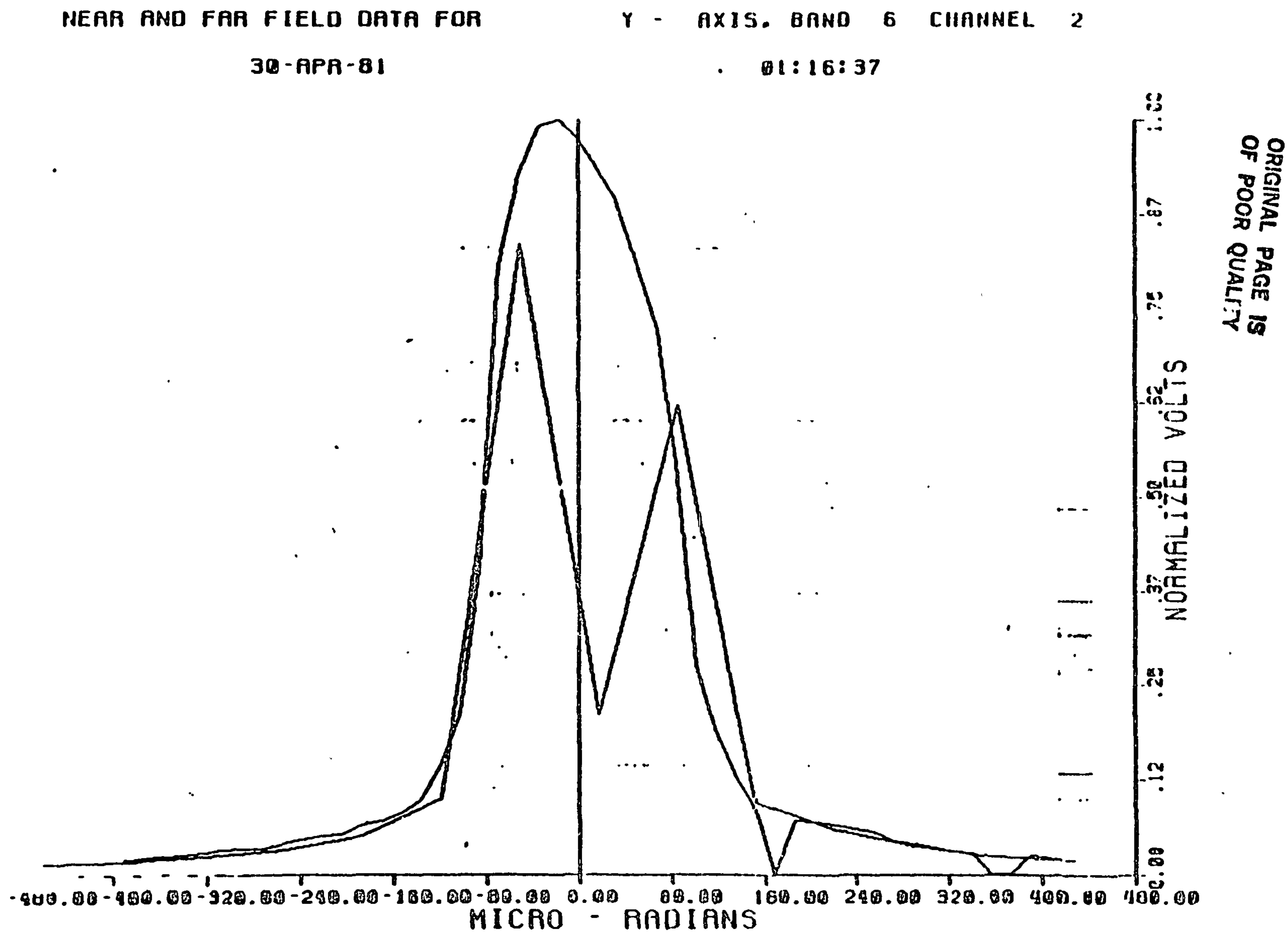
NEAR AND FAR FIELD DATA FOR Y - AXIS. BAND 6 CHANNEL 2
30-APR-81 01:16:37
MICRO - RADIANS
NORMALIZED VOLTS
-480.00 -400.00 -320.00 -240.00 -160.00 -80.00 0.00 80.00 160.00 240.00 320.00 400.00 480.00
0.00 .12 .25 .37 .50 .62 .75 .87 1.00
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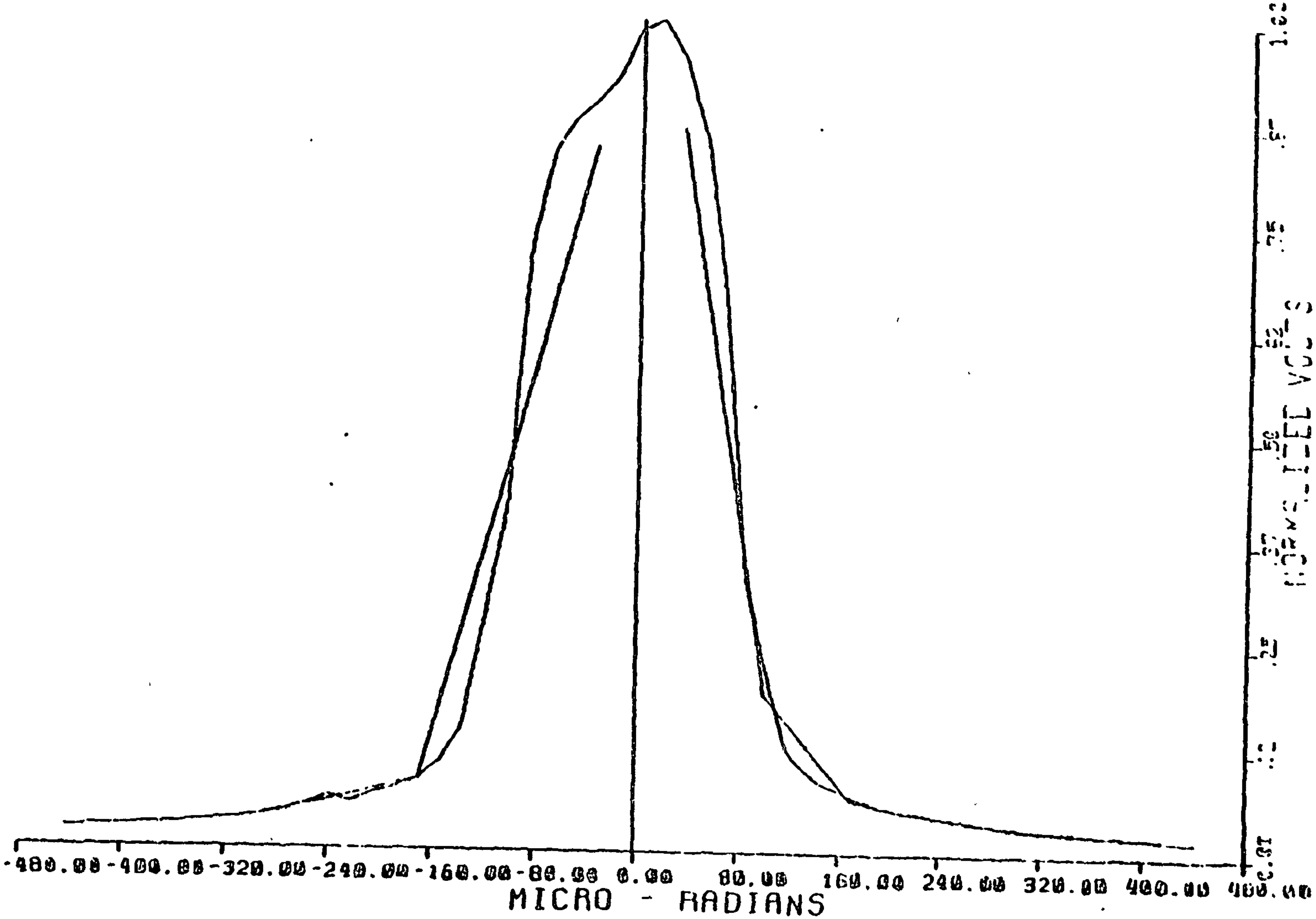
29-APR-81 20:16:19



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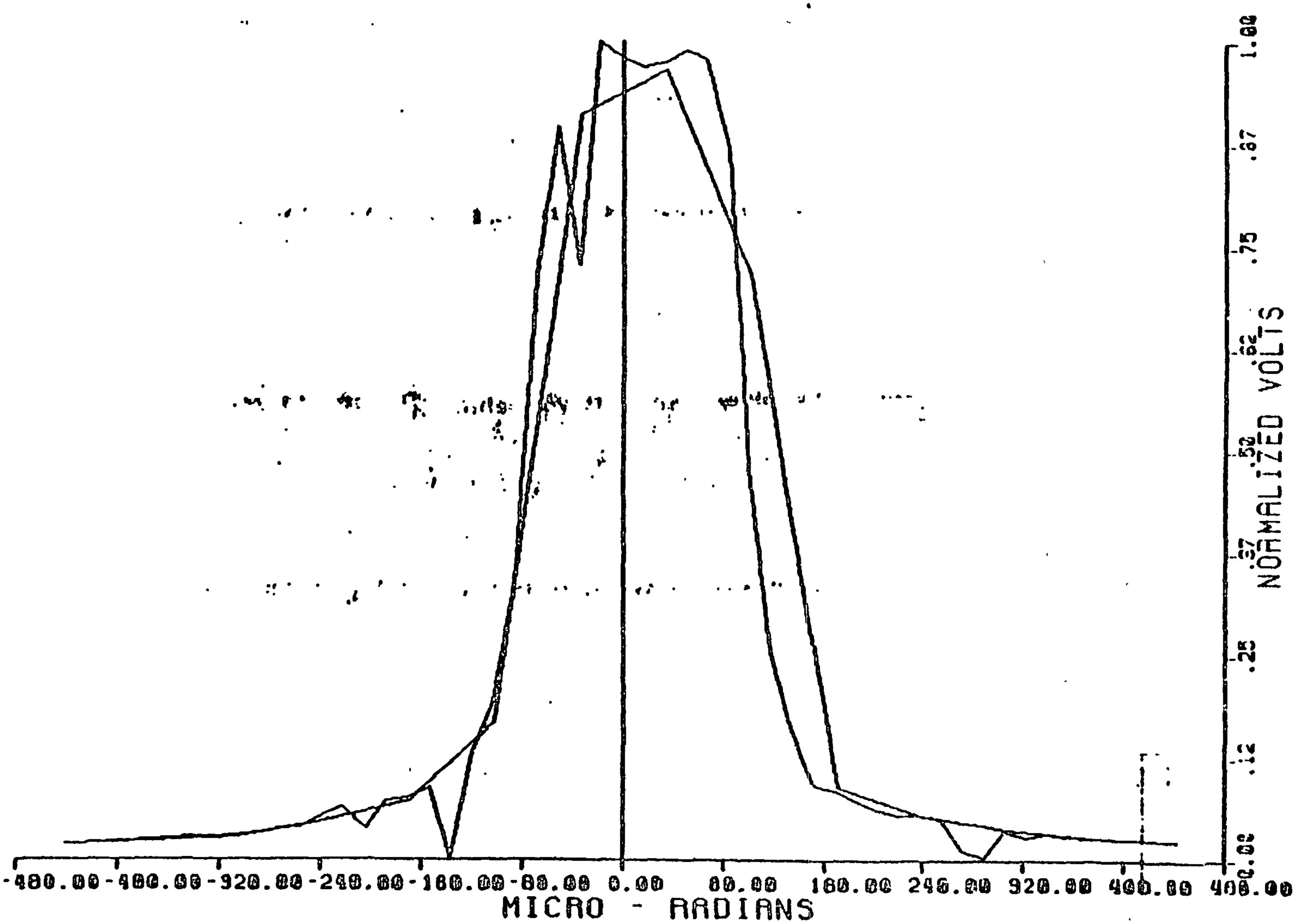

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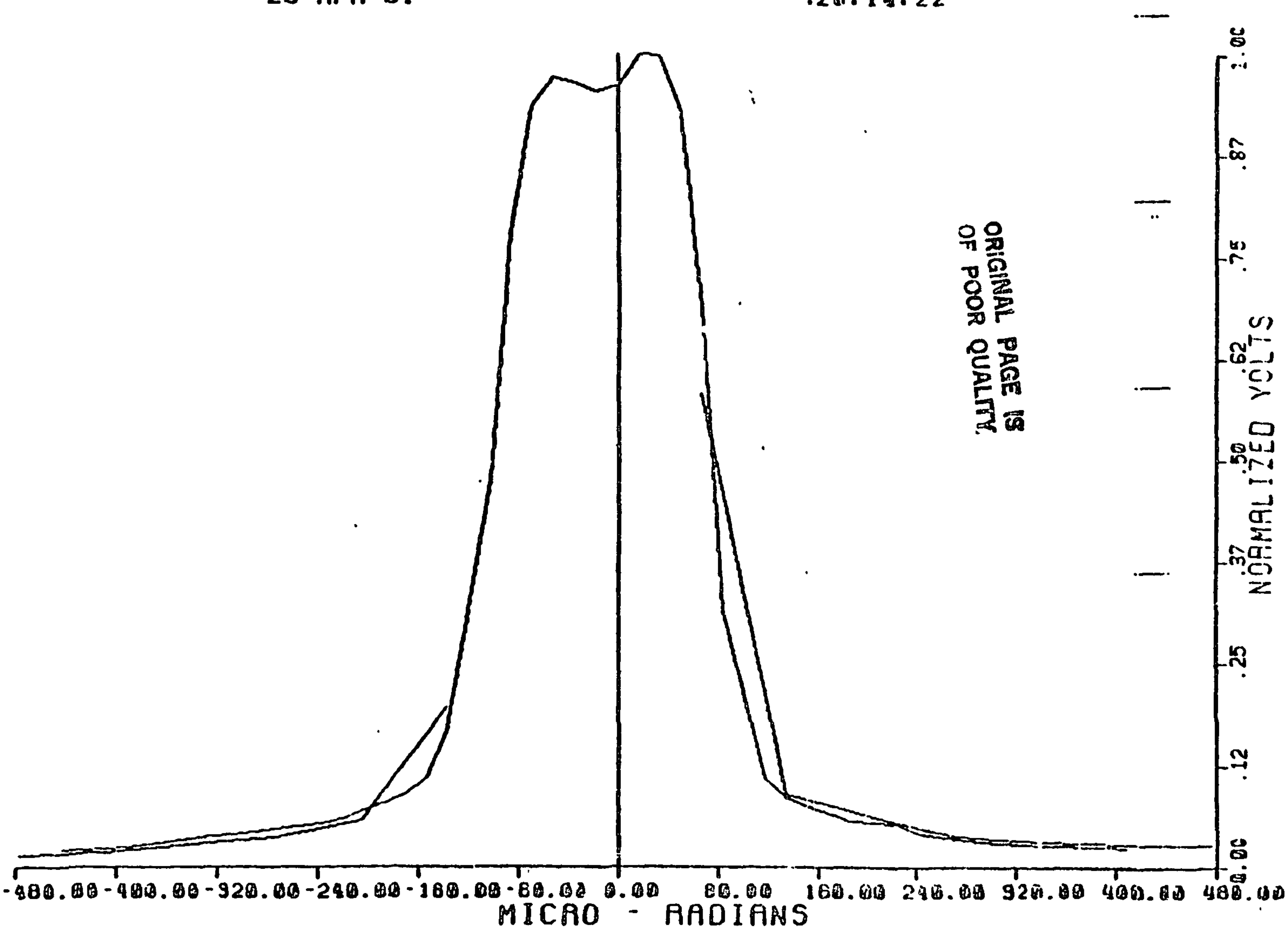
NEAR AND FAR FIELD DATA FOR X - AXIS. BAND 6 CHANNEL 3

29-APR-81 .20:14:22



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NEAR AND FAR FIELD DATA FOR X - AXIS. BAND 6 CHANNEL 3

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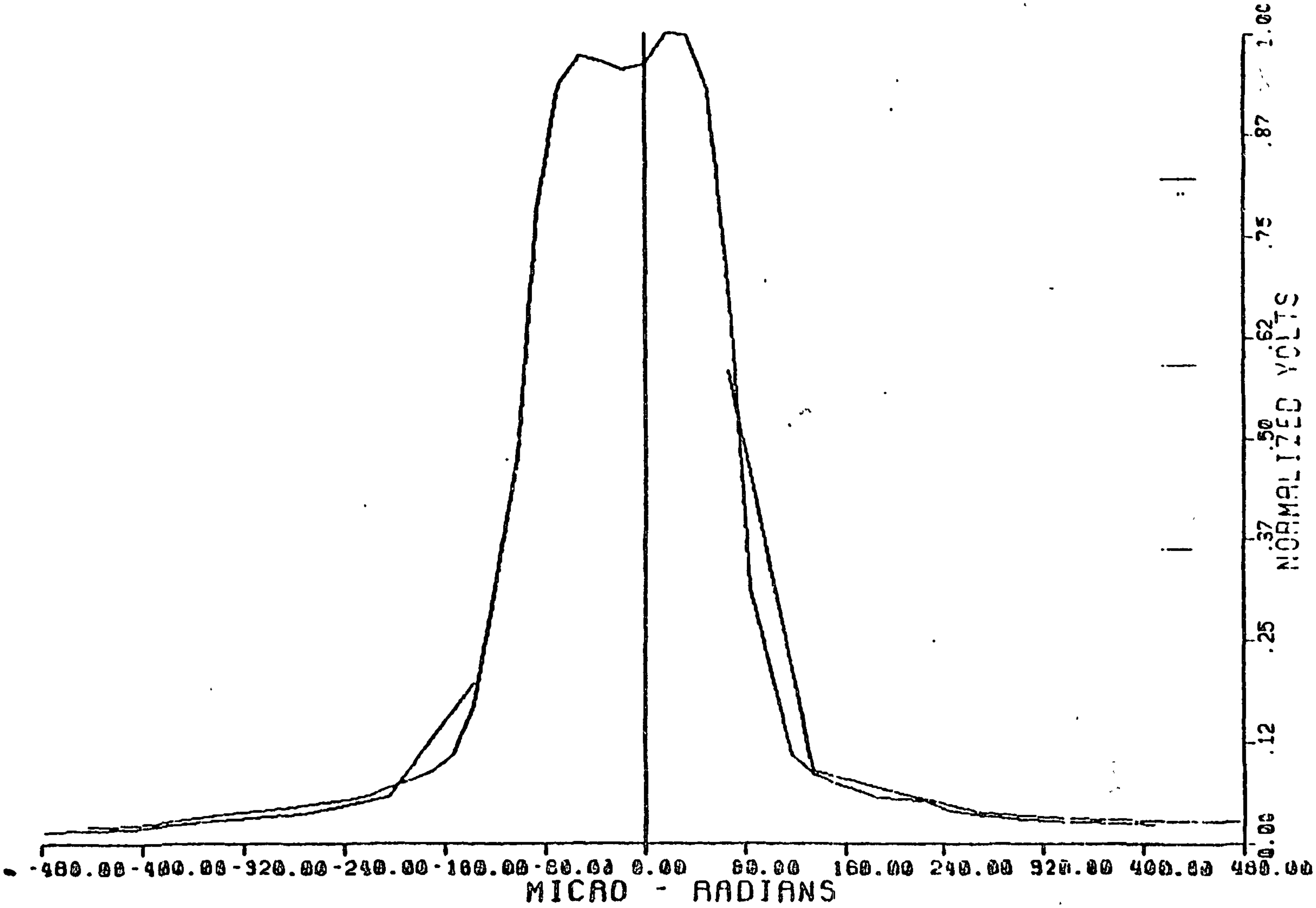

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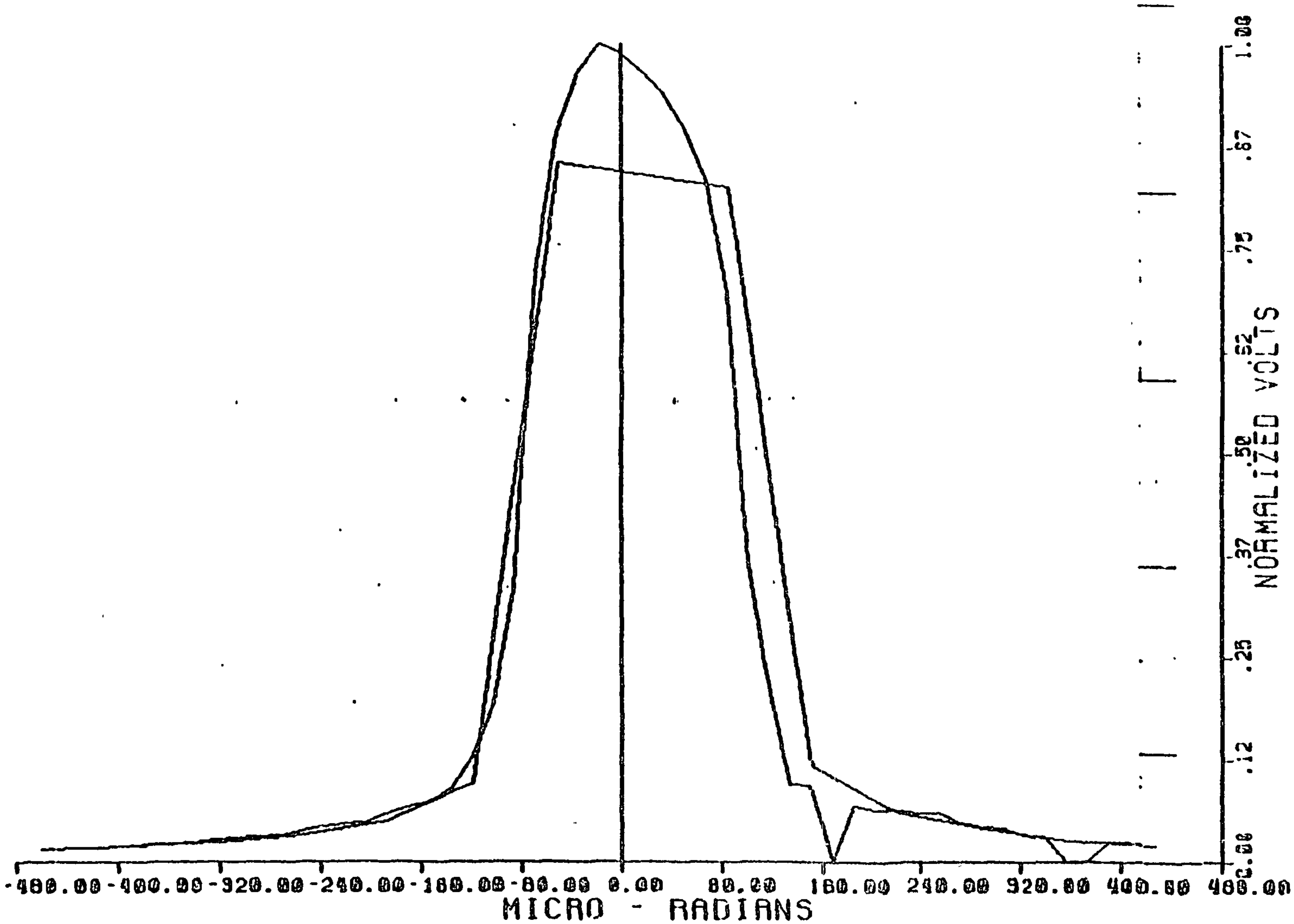

NEAR AND FAR FIELD DATA FOR X - AXIS, BAND 6 CHANNEL 4

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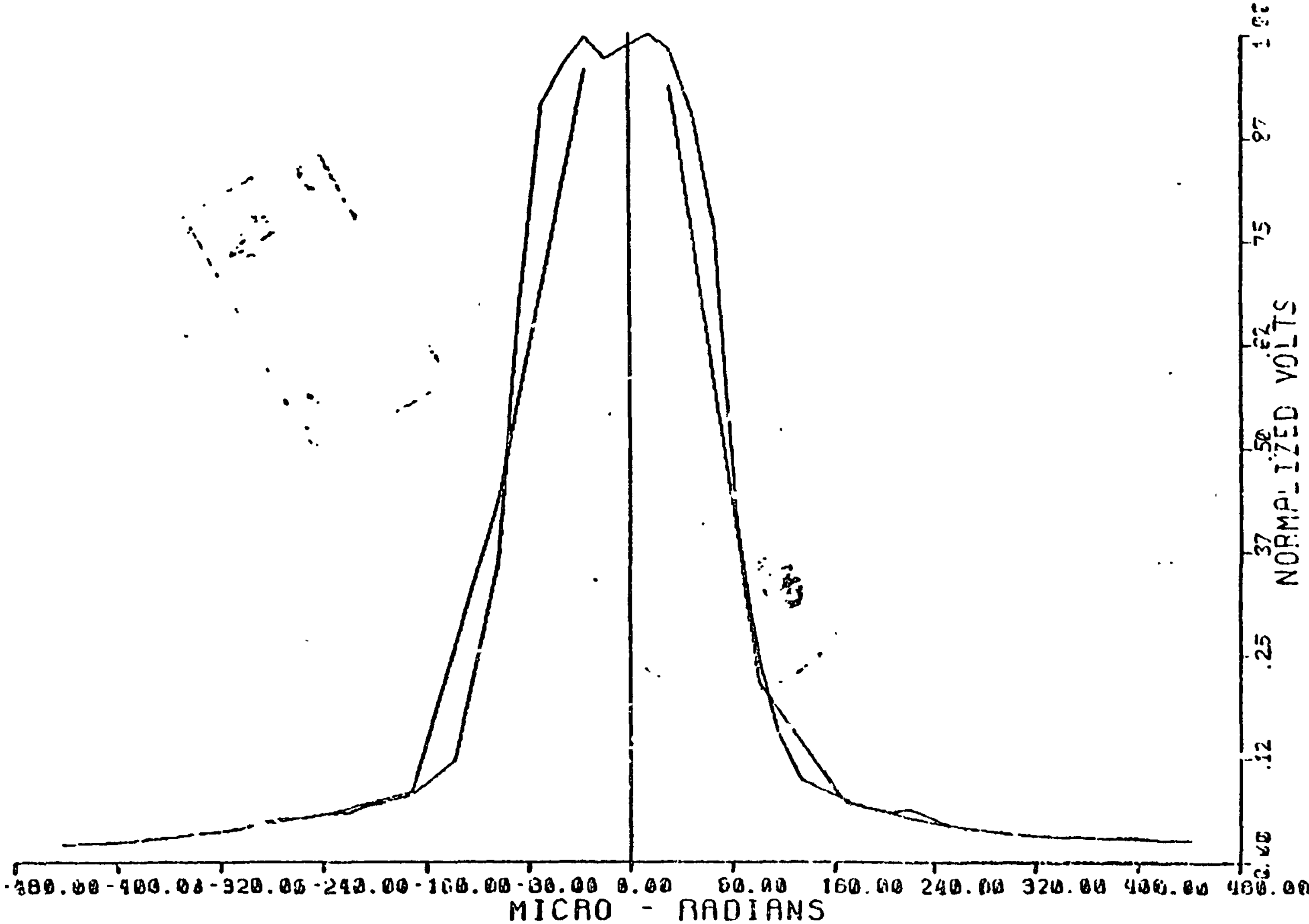

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SANTA BARBARA RESEARCH CENTER
A Subsidiary of Hughes Aircraft Company
INTERNAL MEMORANDUM

TO: J. Engel CC: Distribution DATE: 15 July 1981

REF: 2221-348
HS236-7547

FROM: J. D. Carpenter

BLDG. 774 MAIL STA. 78
EXT. 4207

SUBJECT: Special AC07 Tests

This memo describes the test results and conculsion of special tests performed in an attempt to explain the excessive "far field" radiation and "near field" channel width measured in the AC07 protoflite test. These tests are:

1. Transmission measurement of the "opaque" portion of the AC07 test reticle.

2. Special measurements of the T.M. protoflite "Far Field" and near field response.

3. Photoelectric response measurements of a typical TM silicon photodetector array.

Tests results:

1. The "far field" excessive radiation measured during the AC07 test is due primarily to the collimator reticle used during the test and is not a fault of the T.M. This conclusion is dramatically shown in the "far field" graphs included in this report.

2. No explicit cause was found for the excessive channel widths measured in the AC07 tests and subsequent special test. Average channel widths measured in the special spatial tests corresponded to the average widths measured during the AC07 test.

<u>Far Field Tests</u>

Prior to the actual special AC07 T.M. test, transmission measurements made on a spare reticle similar to the AC07 test reticle indicated that the opaque part of the reticle was not sufficiently opaque at some wavelengths. The results of this test are shown in Table I.

It would appear, at first glance, that the amount of transmission through the opaque part of the reticle is insignificant. However, when one considers that the detector is approximately 10 times wider than the slit in the reticle and is fully illuminated by the source lamp, this amount of transmission becomes more significant since its effect is multiplied by the factor of 10. This effect occurs in the far field radiation measurement over the width of the light source on the reticle, which is approximately 2 mm wide and produces a source field angle of approximately 720 μrad.

Reference: 2221-348
HS236-7547
J. Engel from J. D. Carpenter
Special AC07 Tests

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15 July 1981
2221-348

Special AC07 Tests

Actual testing of the T.M. protoflite instrument with both the spare reticle, specially masked to be completely opaque, and the AC07 test reticle proved that most of the excessive radiation was caused by the reticle. A graph of the "far field" response for each band with the "opaqued" and normal reticle is included to show the differences. The greatest change occurs in bands 2 and 3 with the least change in band 4. This result corresponds to the transmission measurements shown in Table I.

Despite this large reduction in the far field radiance with the "opaqued" reticle, the T.M. system does not pass the criterian that the detector response shall be 1% or less at 2 IFOVs away from the detector center.

It is quite obvious that some effect still exists on the "-Y" side of the even channels and the "+Y" side of the odd channels. Two probable sources for this effect are Crosstalk between channels and reflections from the spectral filter.

1. Crosstalk

   In the test arrangement the odd channels are in the "-Y" direction from the even channels. As the light is moved from the "-Y" to "+Y" direction, the light strikes the odd channels first, producing a signal in the odd channel and crosstalks to the even channel being measured. The amount of crosstalk was measured during the detector array tests with typical values ranging from 50 to 55 db down (28% to .18%) for odd to even detectors. Since the entire row of detectors are energized at the same time in the AC07 test, the amount of cross coupling is probably greater than the above values. The net effect could easily be as much as 0.3%. When an odd channel is being measured, this coupling shows up in the "+Y" direction from the channel center as in the Band 2 Channel 1 graph.

2. Multiple reflections between the shiny aluminum deposition on the detector array and the band pass filter may cause part of the excess radiation. This effect probably exists with the light source on either side of the detector, but would tend to be more pronounced when the light is towards the opposite channels since the mask in front of the detector limits the reflection area on the outside edge of the array but does not limit the reflection area between the channels. Because of this difference, reflections from the light source can reach the detector at much larger field angles in the "Y" direction of the opposite channel. The amount of the reflection is not known and no test is planned at this time to measure it.

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Near Field Tests

Data for the near field response of the T.M. was recorded for at least one channel in each of the Bands 1-4 with both the AC07 reticle and the specially "opaqued" reticle. The results of this data is very similar to the AC07 test data. The only apparent difference occurred with the "opaqued" reticle towards the Y-limits of the "near field" response curve, where the signal was reduced. Some graphs of the "near field" response are included within this report.

In addition to the complete "near field" response curves, the 50% widths of the detector response were carefully measured with as many as 100 data samples per data point to establish a high degree of accuracy. The results were nearly the same as AC07 in that the detector width measured approximately 44 microradians.

To determine the focus effects the position of the reticle slit was moved along the optical axis of the collimator on both sides of the best focus position with detector width data taken at the various positions. The detector width decreased a small amount, approximately 0.5 μrad, when the reticle was .010 to .015 inches closer to the primary. The measured channel size increased rapidly when the focus position was more than .015 indicating that the image of the slit on the detector was increasing rapidly and was larger than the detector. The results of the channel width tests are shown in Table II.

The channel width was a separate test from the graph data, usually taken just before a full run of near field-far field data. The width data was determined using 100 samples per data point with a period of about one minute. The procedure used was to establish the two 50% levels of the response curve with as few data points as possible and measure the distance between them. The width vs focus data was taken in the same manner as the previous width data except that more width measurements were made for each focus position. It would have been advantageous to have more focus measurements, but due to the limited amount of time available, only a few measurements could be made.

The special spatial tests used the same optical equipment and test method as used in the AC07 tests. The main difference was that the procedure was manually controlled and the data was handled and stored by an H.P. 9815 desk top calculator. Each data point is the average of 10 samples taken over a period of about 10 seconds of time. As can be seen from the near field graphs, the data was still noisy.

The signal intensity ratio between the far field and near field for each band and channel was established by setting the "Y" position of the source approximately 2-1/2 IFOV from the channel center and measuring the channel output signal for each of the two settings of the source intensity that was used in the AC07 test for that specific band and channel.

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Detector Width Test

To eliminate the possibility that the active (photoelectric) width of the detectors were not the same as the design width, photoelectric response tests were conducted on a typical T.M. silicon photodetector array. The widths measured corresponded to the approximate design widths and essentially eliminated the detectors as a cause for the excessive widths measured in the AC07 test. The results are shown in Table III.

The measurements were made using the spare AC07 reticle projected through a par focal microscope onto the detector with and without special masks covering the opaque area, and with and without a band #1 spectral filter. No significant difference occurred with any of the various combinations, different detectors, or the x and y directions of the detectors. The apparent width of the light slit falling on the detector was changed by changing the focal length of the objective lens on the par focal microscope. The widths projected were approximately .0004 inches and .0002 inches. The results were the same. There is no reason to believe that any of the above conditions should change the measured channel width. However, it was necessary to verify this in case something is being overlooked.

The results of all of the "near field" tests and detector measurements indicate that the image of the illuminated slit falling on the detectors in the AC07 tests is sufficiently wide as to cause the detector width measurement to be large. Whether this measurement is consistent with the measured optical performance of the T.M. has not been established.

James D. Carpenter

dz

Distribution:

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TABLE I

TRANSMISSION MEASUREMENT
FOR THE OPAQUE PORTION OF THE SLIT RETICLE

BAND	λ (μm)	T (%)
1	.45	<0.01
	.52	0.04
2	.52	0.04
	.60	0.08
3	.63	0.07
	.70	0.04
4	.76	.02
	.90	0.01
5	1.55	<0.01
	1.75	<0.01
7	2.08	<0.01
	2.35	<0.01

TABLE II

CHANNEL WIDTHS, PROTOFLITE
SPEICAL SPATIAL TEST

BAND	CHANNEL	WIDTH, μrad, SOURCE AT COLLIMATOR FOCUS (N*)	STANDARD DEVIATION	WIDTH, μrad, SOURCE INSIDE COLLIMATOR FOCUS - .010 to .015 (N*)	STANDARD DEVIATION
1	2	44.09 (5)	0.39	43.45 (4)	0.38
1	16	43.98 (2)	0.21	44.07 (2)**	0.45
2	1	43.28 (1)			
3	2	43.8 (1)			
3	16	44.23 (3)	0.12		
4	2	43.67 (3)	0.09	42.98 (3)	0.31
ALL MEASUREMENTS		43.94 (15)	0.36	43.43 (9)	0.54

Band 1 Channel 2 @ +.025, Width = 50 μrad
@ -.030, Width = 46.2 μrad

*(N) = Number of Measurements

** = One Measurement was very high (44.52) and is probably not right.

Note: All data points consist of 100 samples taken over a period of approximately one minute of time.

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TABLE III

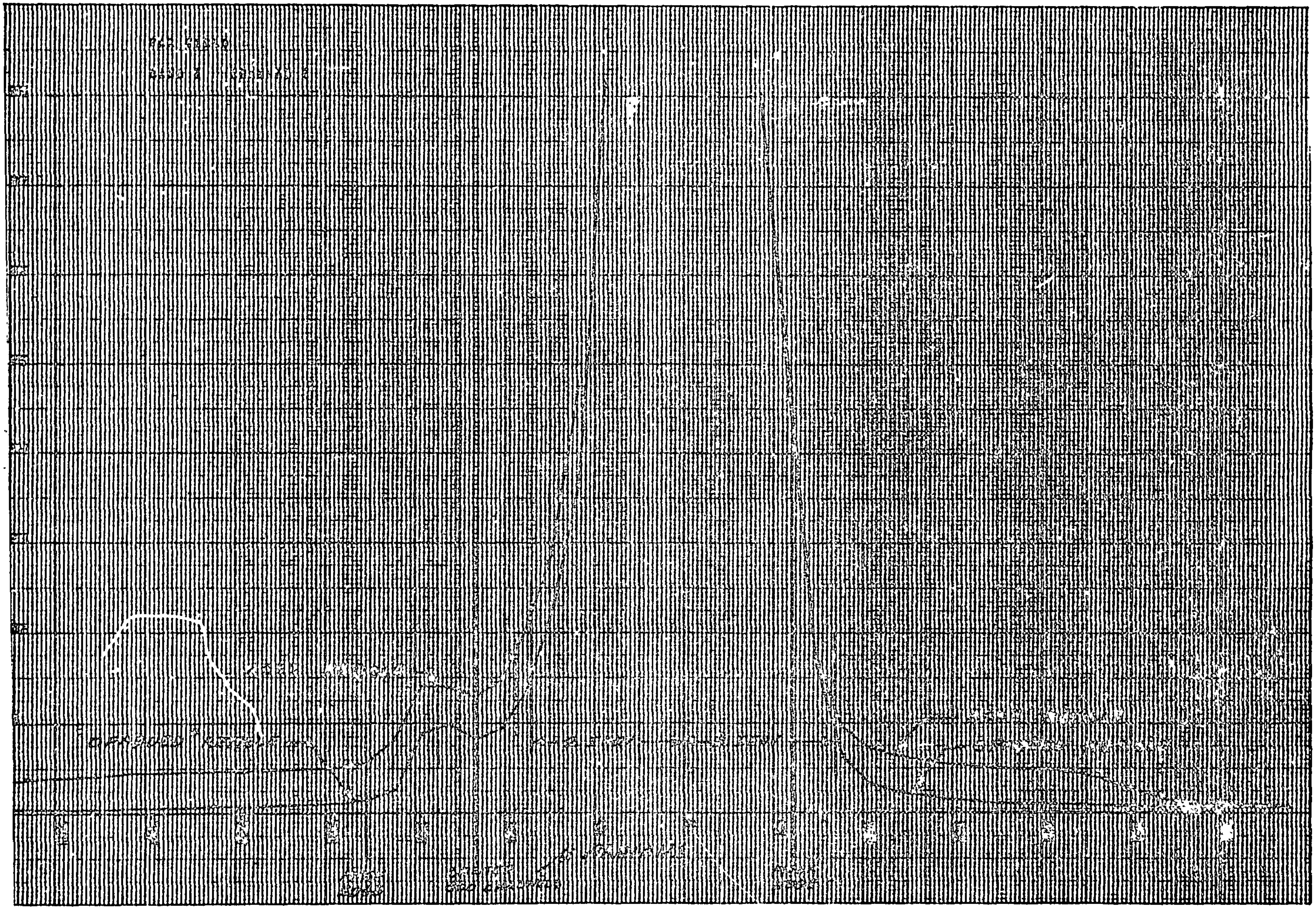
TM PHOTODETECTOR ARRAY MEASUREMENT
(PHOTOELECTRIC HALF WIDTH)

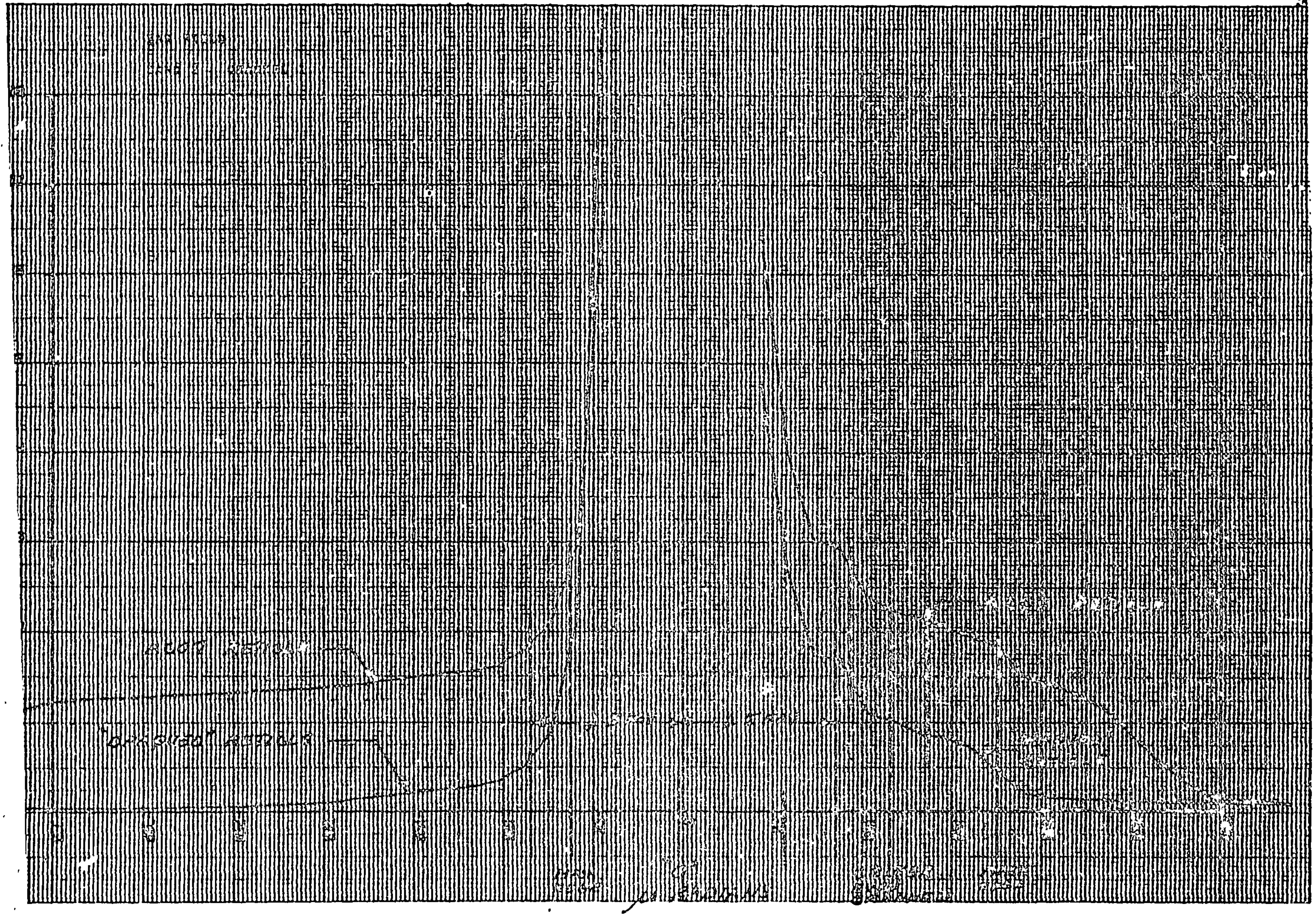
DETECTOR	AXIS	CONDITIONS**	WIDTH
1	Y	"Opaqued"	.004097
1	Y	"Opaqued," .5 N.D. Filter	.004005
1	Y	Band #1 Filter	.004115 *
1	Y	Band #1 Filter	.004109 *
1	Y	Band #1 Filter	.004117 *
1	Y	Band #1 Filter, "Opaqued"	.004078 *
1	X	.5 N.D. Filter, Opaqued	.004130
1	X	.5 N.D. Filter	.004137
1	X	Band #1 Filter	.004054
1	X	Band #1 Filter	.004087
2	X	Band #1 Filter	.004122
2	X	Band #1 Filter	.004128 *
8	Y	Band #1 Filter	.004171 *
		MEAN =	.004104
		STANDARD DEVIATION =	.000040
		DESIGN WIDTH =	.00408

* Improved Measurement Technique

** "Opaqued" means that the test reticle had a metal material placed over the dark portion of the reticle to prevent any transmission except through the slit.

A filter call out under "Conditions" means that the filter was placed in the light path to change the character of the light falling on the detector.





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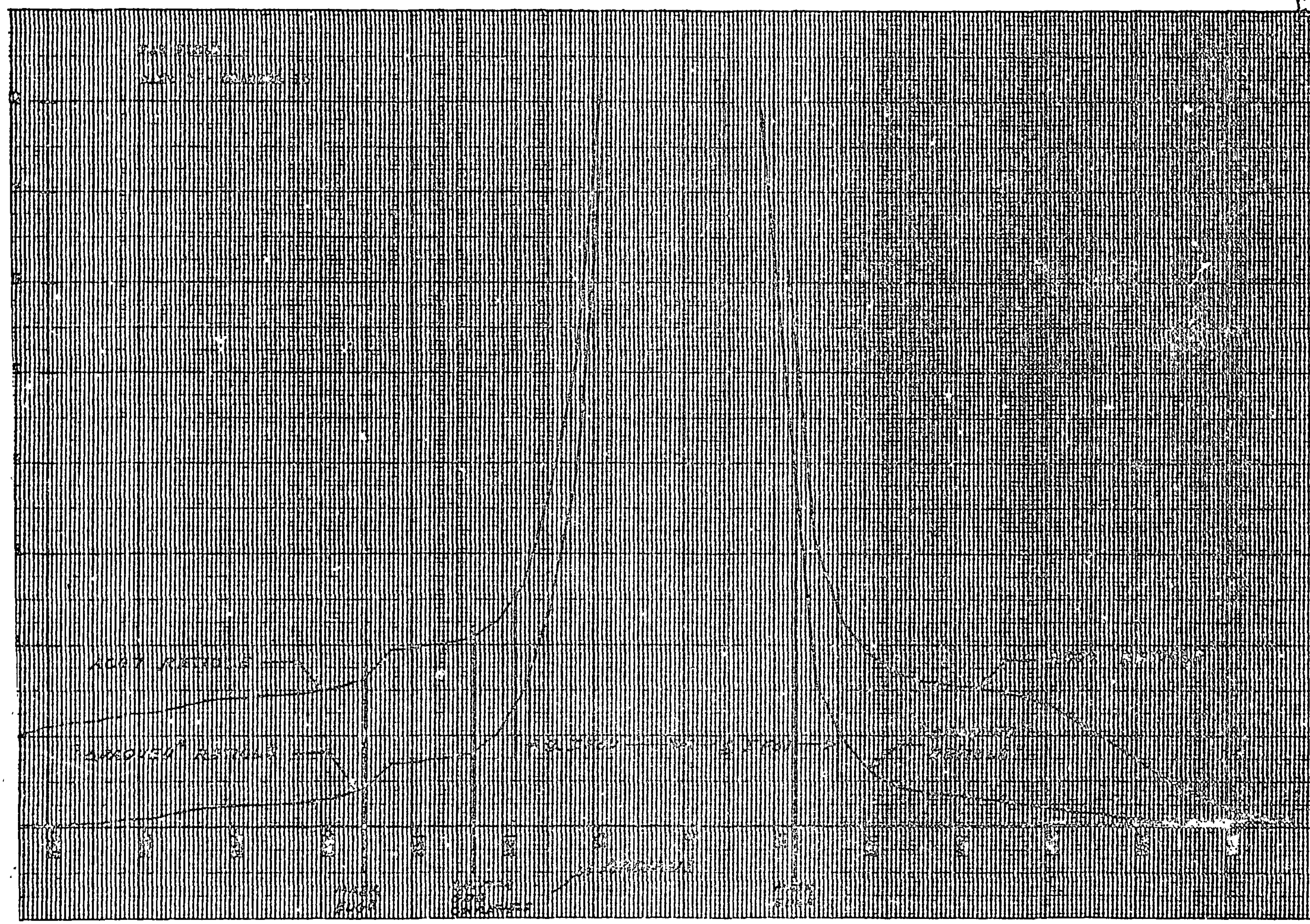

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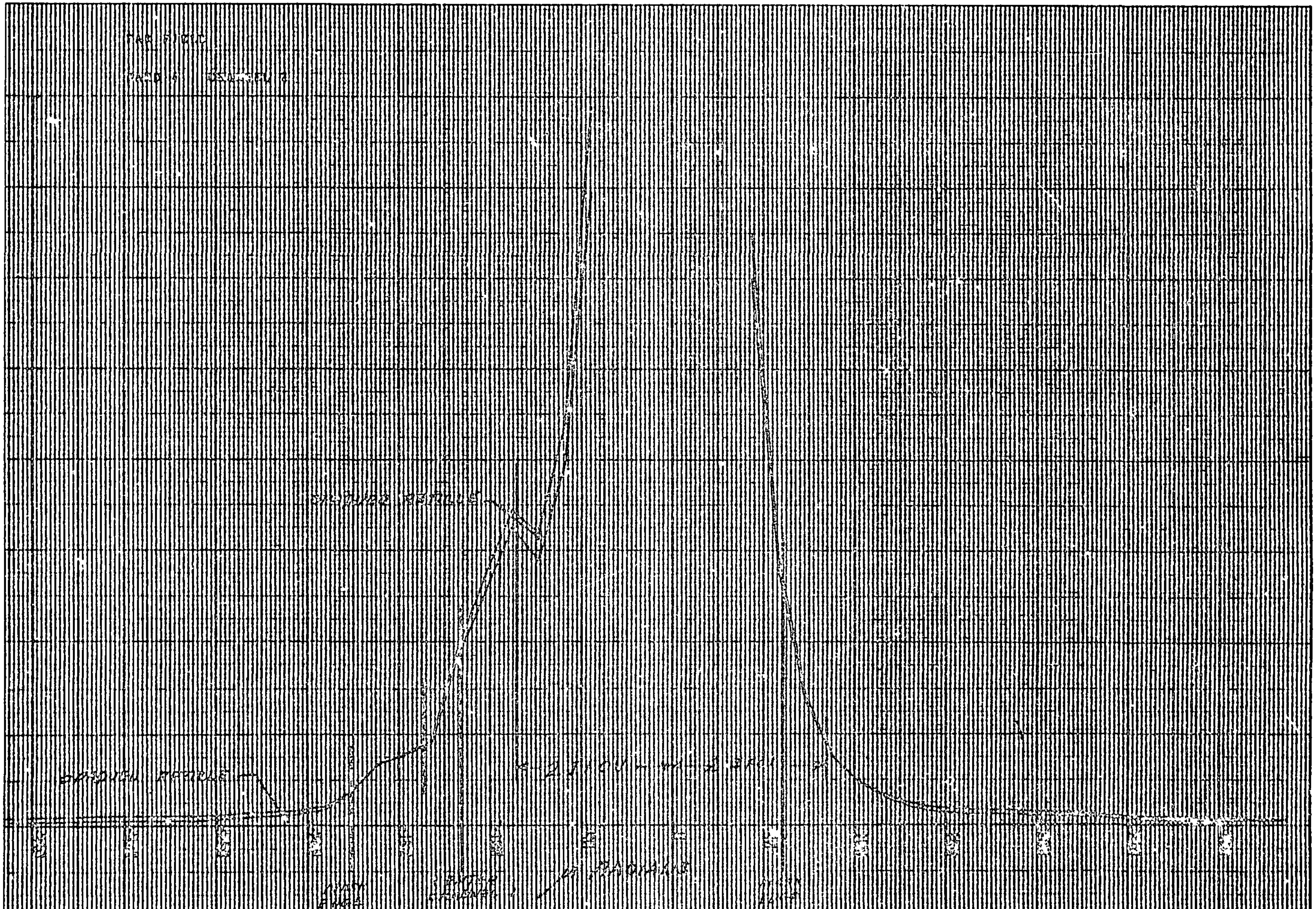

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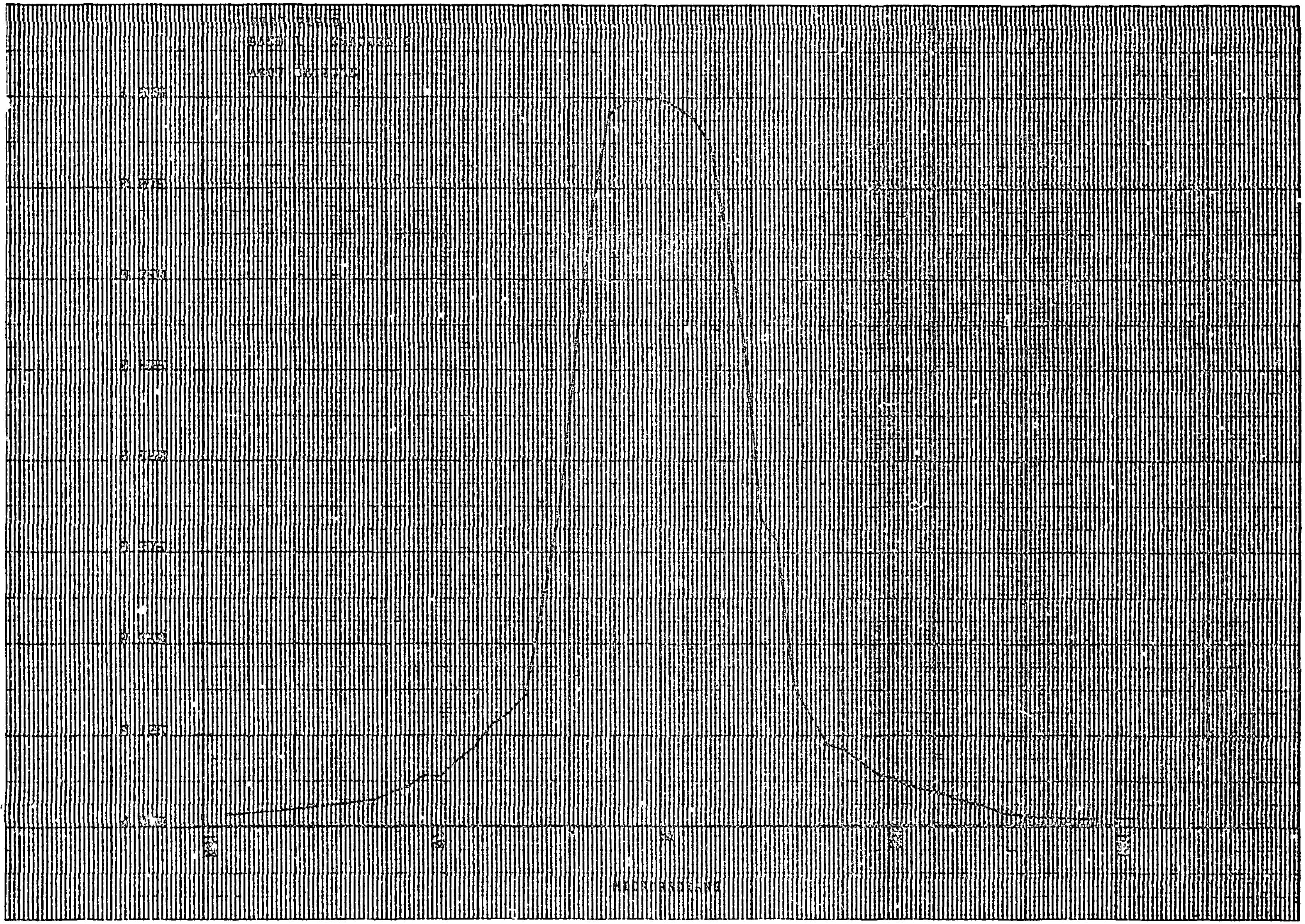

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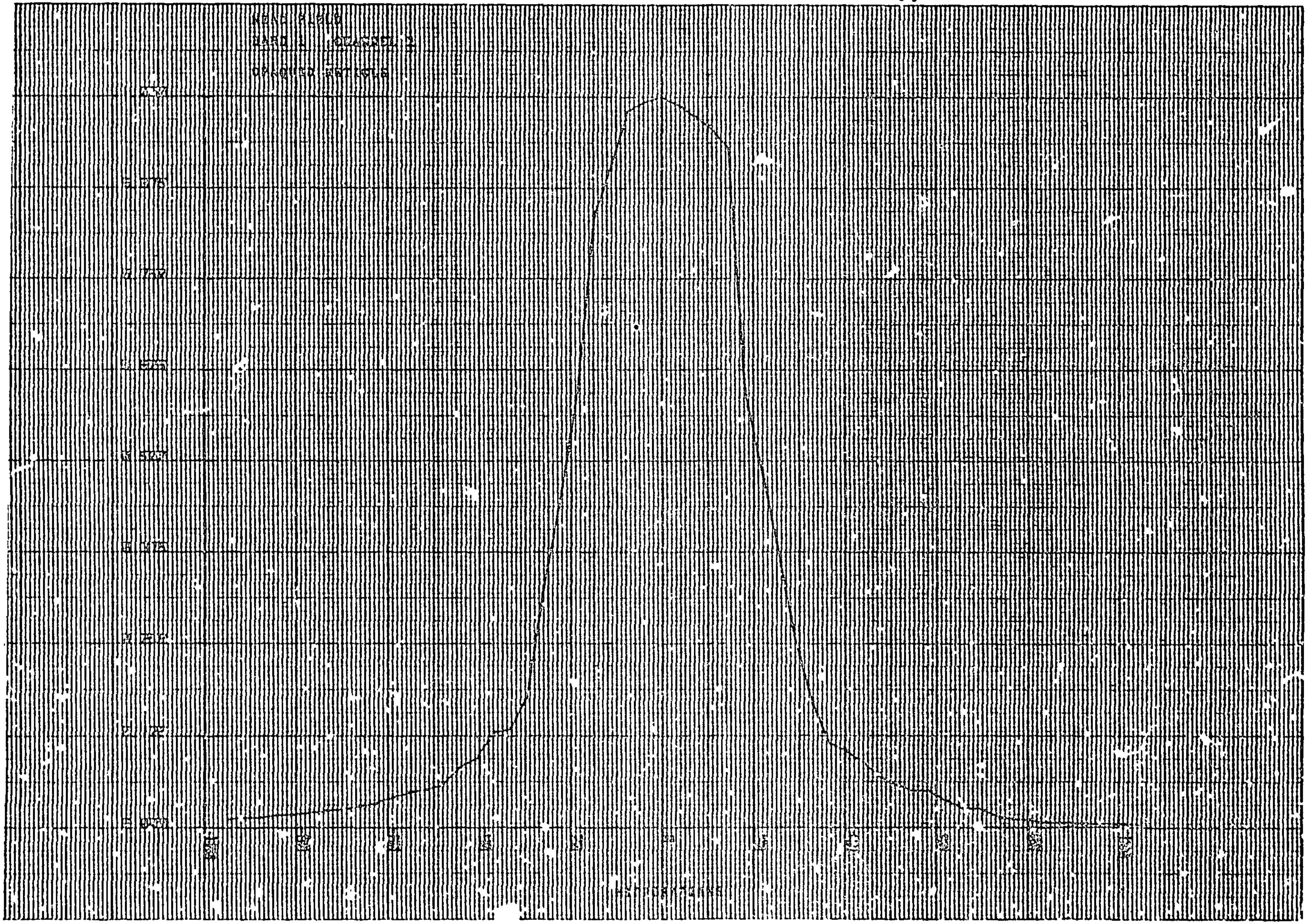

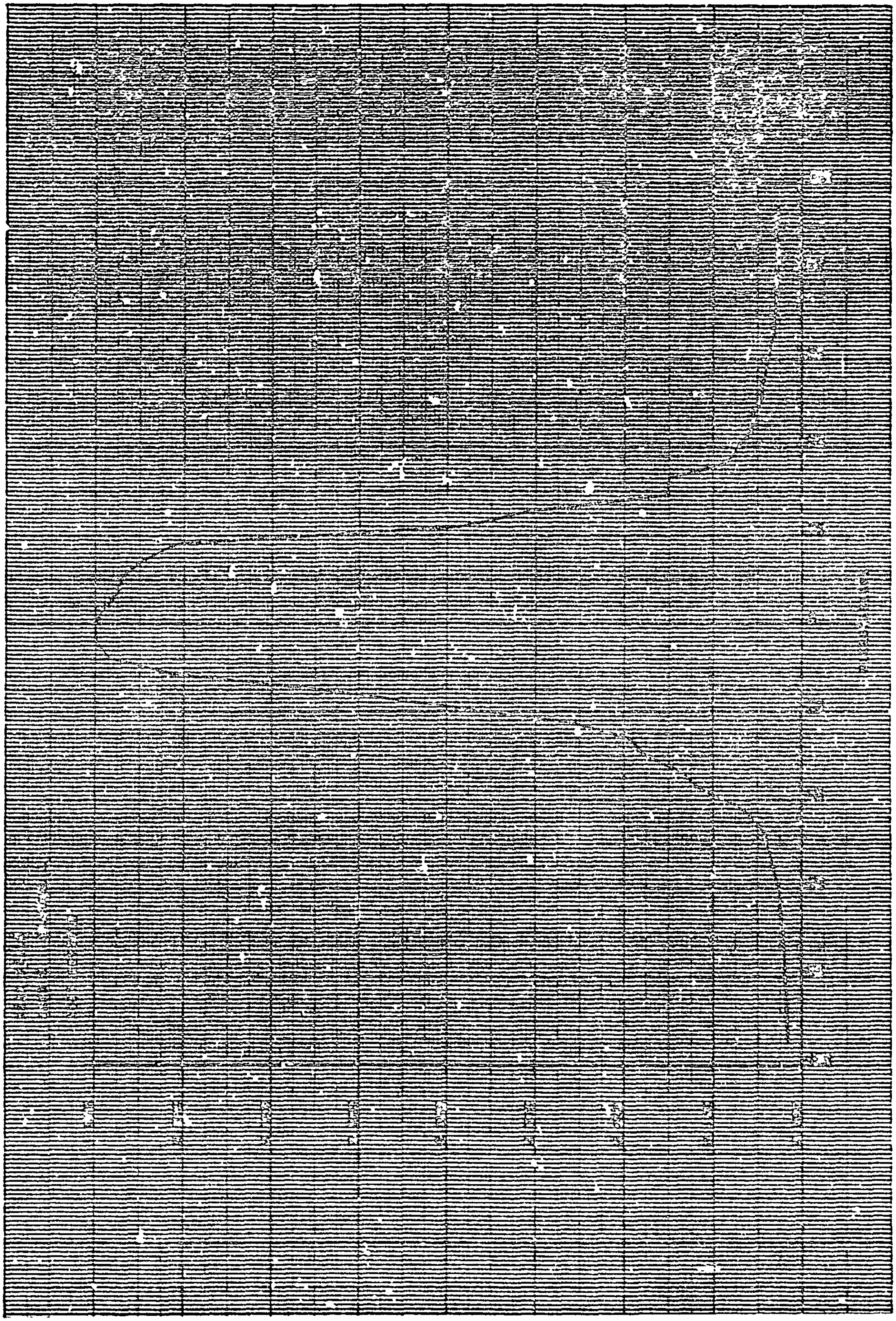

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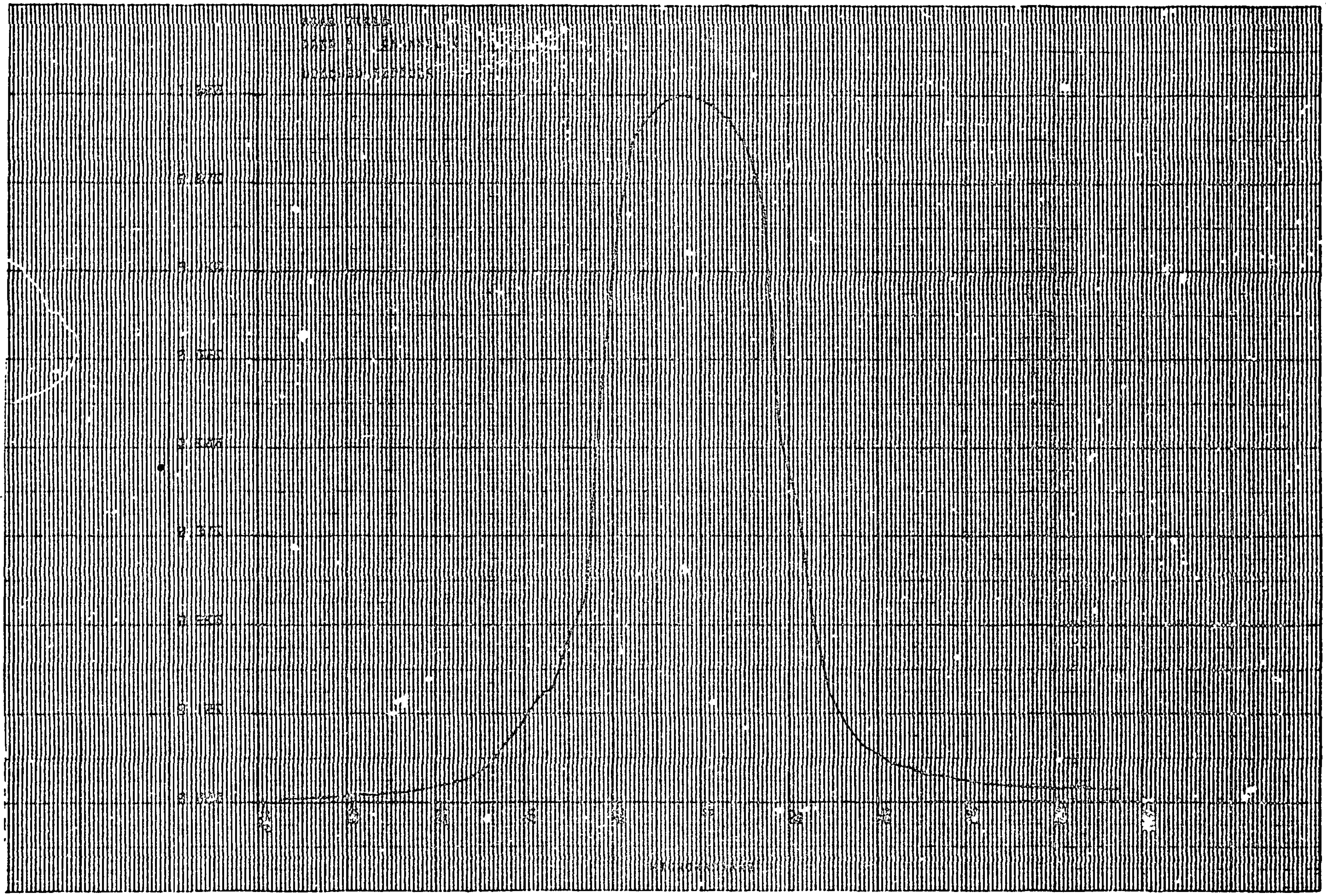

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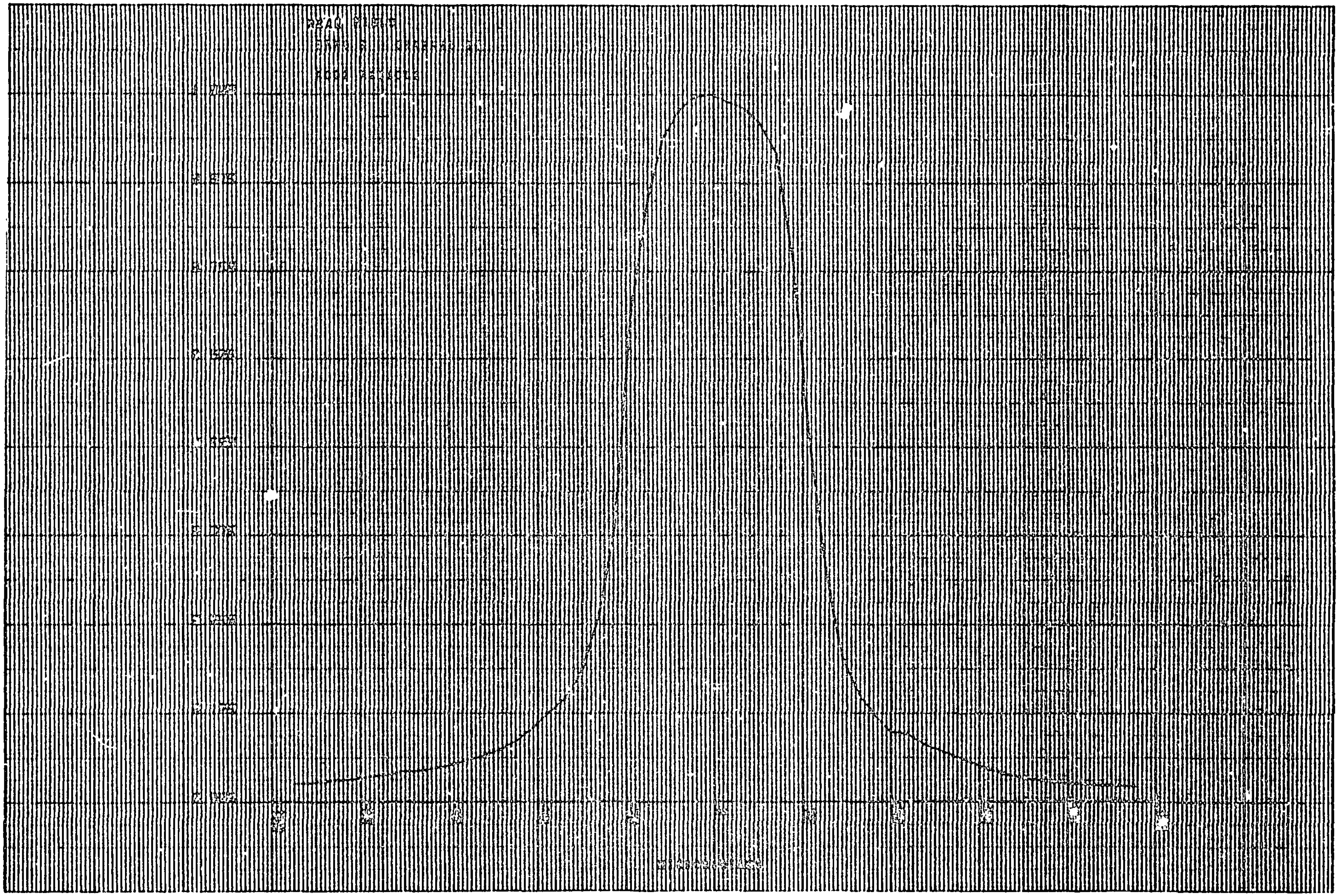

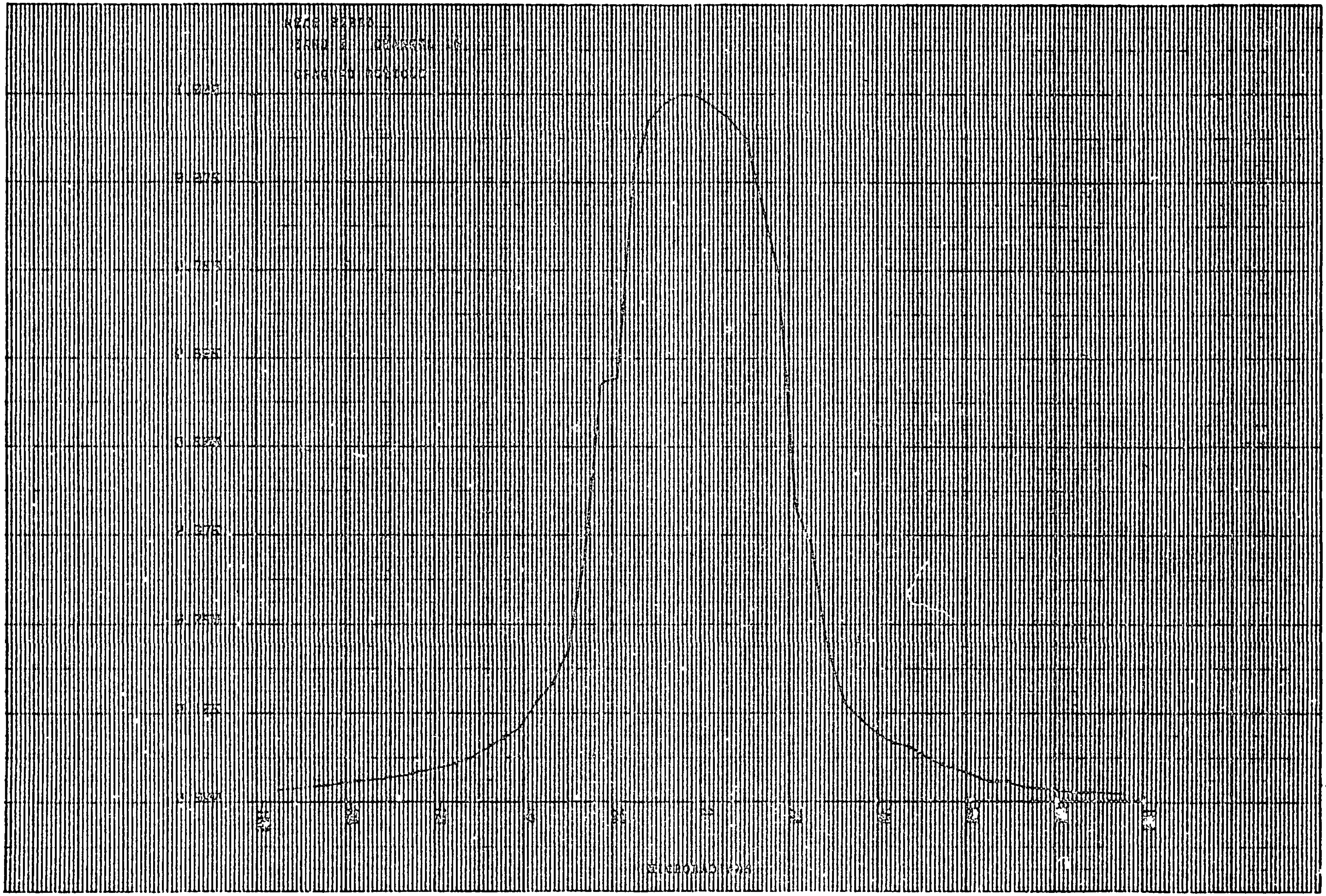

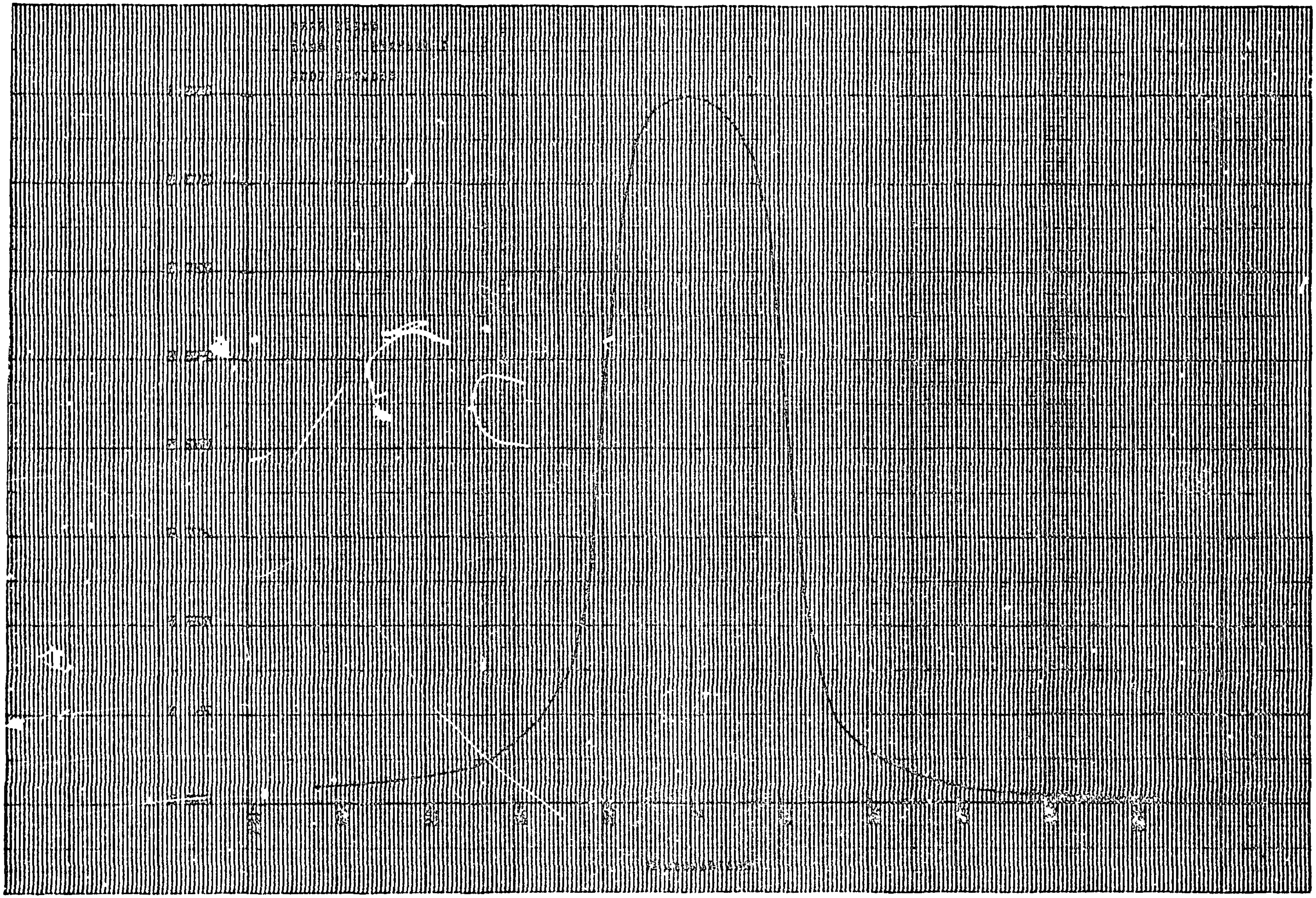

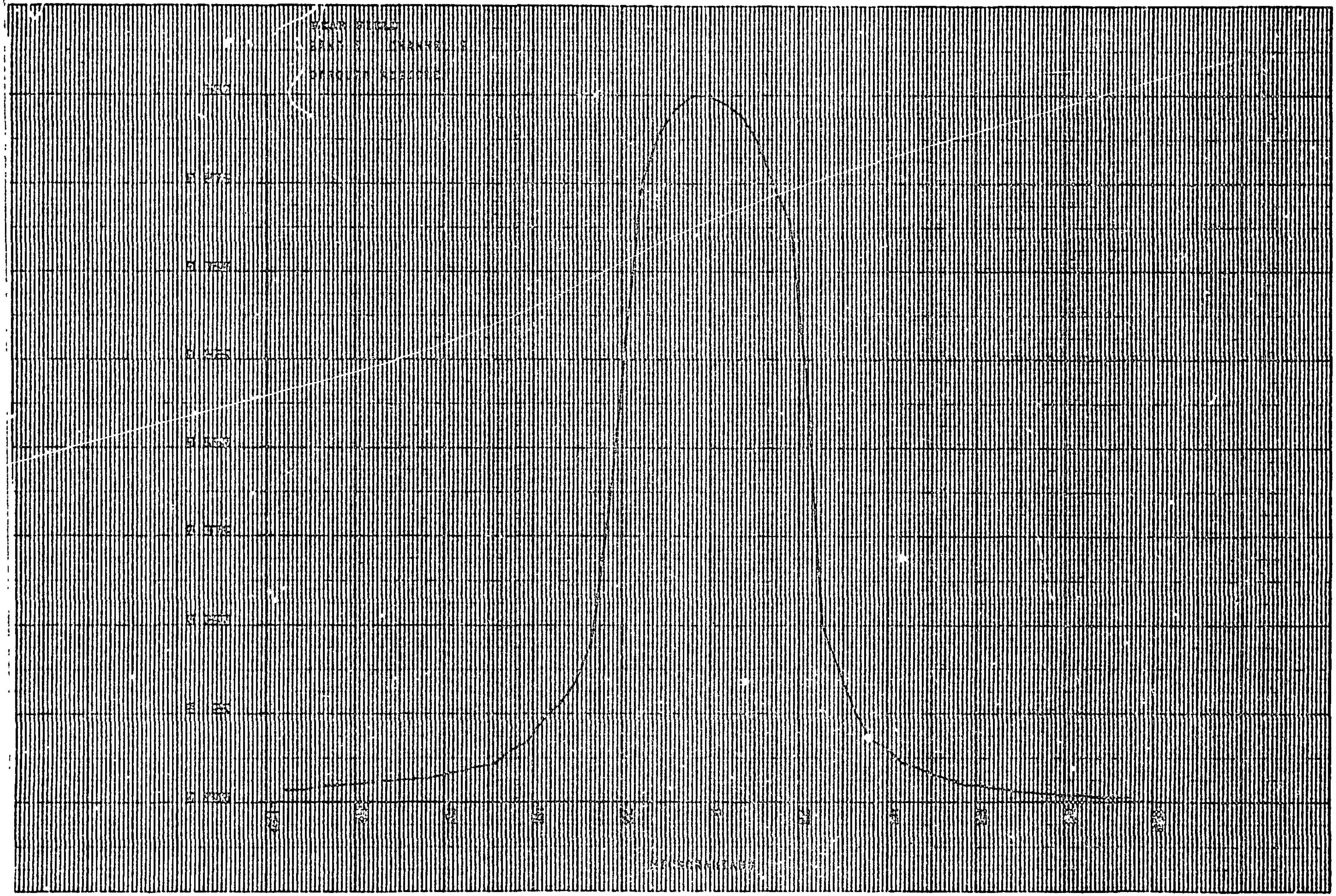

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I N T E R N A L   M E M O R A N D U M

TO: G.S. Plews   CC: Distribution

DATE: 820527
REF: HS236-8004

FROM: J.C. Campbell

SUBJECT: AC07 Optional Test Configuration-- Bands 1-5, 7 Testing

BLDG: B11 MAIL STA. 78
EXT: 6151

REFERENCE: HS236-7989 IA04 Configuration Options

INTRODUCTION:

This memo describes a possible optional test configuration, TM to BTCE, that can be used for Bands 1-5, 7 testing during the AC07 test phase to support the presently defined AC07 data collection and also to provide the TM instrument with computer controlled power turn on and thermal shutdown capability. This configuration is based on reference memo HS236-7989 and is presented here in terms of existing configuration drawings and test procedures to the extent possible.

TEST CONFIGURATION

1. Configure TM & BTCE per drawing 3533100-300-2, but with the following possible exceptions:

FUNCTION	REQUIREMENT	DWG ZONE	CABLE#
X-Y ALIGN MONTR	NOT USED	B-19	W-109
VIDEO MONITOR	DON'T CARE	E-3	W2114-2
HDRR	DON'T CARE	F-10	(see DWG)
DEMUX	DON'T CARE	G-7	(see DWG)
TM MUX TST PTS	NOT USED	G-15	VERIFY DISCONN. W5002& W5003

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2. Then refer to phase-I DWG 3533100-300-1, and make the following connections or changes:

FUNCTION	REQUIREMENT	DWG ZONE	CABLE or CONN#
B1 AOTS VIDEO	CONNECT	E/F-17	WTC30& 35
B2 AOTS VIDEO	CONNECT	E/F-17	WTC31& 36
B3 AOTS VIDEO	CONNECT	E/F-17	WTC32& 37
B4 AOTS VIDEO	CONNECT	E/F-17	WTC33& 38
B5 AOTS VIDEO	CONNECT	E/F-17	WTC-41
B7 AOTS VIDEO	CONNECT	E/F-17	WTC-42
AOTS DC RESTR	1 CONNECTION	E/F-15	W5050 to J410
AOTS TLMY	NOT USED	E/G-15	W5050(J102, J105, & J400)
AOTS VID OUT	CONNECT	F-15/17	W5035& W5036
AOTS IW COUNT	DON'T CARE	G-16	AOTS CONN B5-J5
DC RESTORE	CONNECT	E-19	W-139

3. Provide the following functions according to test procedure number TP32015-514:

   a) Install the SMACC per Appendix U: conn..t SMACC or SAMLOCK Drawer to penetration-plate connector P-10 via adapter cable # W3071. Ground the SMACC dc power return to the Collimator Ground Bus.
   b) Implement "Shutter Aside" via Appendix S, Method 3 at TM connector P45.

4. Install the BTC and CFPA Temp Sensor Converter per Appendix V of TP32015-504.

5. Bring TMT software up using TLMY stream #2.

TM COMMANDS REQUIRED:

Power the following TM functions ON:

TM COMMANDS (ALL BANDS)

TM: 001; PS1 ON
TM: 004; Thermal Shutdown Enabled
TM: 009; SME 1 ON / 2 OFF
TM: 005; MUX ON (PS1)
TM: 007; TLMY Scaling ON

The choice of this configuration is optional and is to be used at the Test Director's discretion. If its use fails to support the test adequately then the configuration shall be per phase - I DWG 3533100-300-1 as originally specified by TP32015-514.

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INTERNAL MEMORANDUM

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CDMO DATA BANK
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TO: J. L. Engel

CC. Data Bank (7)
Optics File
Distribution

DATE 2 June 1982

REF: 2221-606
HS236-8011

SUBJECT. Spatial Coverage
Band 6

FROM: J. B. Young

BLDG. B11 MAIL STA 78

EXT. 6180

A deviation/waiver (D-156) has been initiated to request that Band 6 IGFOV be calculated from component level spot scan detector measurements in lieu of measuring the IFOV of Band 6 channels using a scanned slit source per TP32015-514 Spatial Coverage Test Procedure AC07R.

For convenience a copy of TM System Specification GSFC 400.8-D-210 Spatial Coverage paragraph 3.2.3 and TM HgCdTe Band 6 Test Report (applicable pages) for array 4-29-2G-120 are attached. Data from this test report was used to generate Table I.

Table I summarizes the linear and calculated angular Band 6 IGFOV values. The telescope and relay optics geometrical and diffraction contributors to image quality will not result in any appreciable change of Band 6 IFOV. Thus the values tabulated in Table I indicate the TM FM Band 6 IFOV meets the NASA specification. In conclusions I believe the methodology proposed in the deviation/ waiver is adequate and justifiable.

J. B. Young

James B. Young

dz

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Table I. Band 6 Calculated IGFOV
Based upon detector and telescope measurements

Detector #	HW_y(inch	HW_x(inch)	Cross Scan $IGFOV_y$	Along Scan $IGFOV_x$
1	.00780		162.5 μr	
1		.00820		170.8 μr
2	.00760		158.3 μr	
2		.00824		171.7 μr
3	.00786		163.8 μr	
3		.00830		172.9 μr
4	.00800		166.7 μr	
4		.00832		173.32 μr

$$IGFOV = \text{Detector Half-Width} \div (EFL_{TM} \times \text{Relay Magnification, } M_R)$$

$$EFL = 95.995$$

$$M_R = 0.5$$

Specification is: $IFOV \leq 174.4$ μr

Accuracy of Measurement: ± 16 μr

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3.2.3 Spatial Coverage

The Instantaneous Field of View (IFOV) of each detector is swept in a direction approximately normal to the ground path of the satellite. Contiguous coverage in the along track direction is generated by appropriately timing successive cross track scans as the satellite advances along its ground track path. Scanning shall be accomplished with an object plane scan mirror technique.

The IFOV is the angle bounded by the points where the detector response to a point source is 50% of the maximum. The response to that same point source shall be less than [illegible] at angular distances equal to or greater than two IFOV's.

The cross track and along track dimensions of the IFOV's shall not exceed 42.? microradians for the first [illegible] five and seven and 174.4 microradians for the sixth. The final [illegible] shall be determined from trade-off [illegible] such as sensor signal to noise, the signal [illegible] filter, sampling rate and multiplexing techniques and ground processing.

With the scan mirror disabled, response curves for each detector IFOV shall be obtained by moving a line (slit [illegible] 10% of IFOV) source at least ±10 IFOV's in the cross track and along track directions.

All measurements shall be accurate to [illegible] five bands and [illegible] within [illegible] for the sixth band.

3.2.4 Band-to-Band Registration

A point imaged in any of the first four spectral bands shall be [illegible] to the same point in any of the other first four bands within .2 IFOV alongtrack and crosstrack. This registration error includes the effects of all synchronizing and correcting signals developed by the [illegible] that are required to process the data into an image. Similarly, [illegible] 7 shall be registered within 0.2 pixel and shall be registered [illegible] 0.2 of a band 6 IFOV and band 5 shall be registered to the [illegible] within 0.3 IFOV. These requirements shall be satisfied at [illegible] the time and apply to all points along a scan line.

3.2.5 Square Wave Response

In this specification square wave modulation response is defined as the ratio of the peak-to-peak signal modulation produced by scanning a series of high-contrast square wave targets of specified spatial frequency corresponding to half cycles of 500 meters (ground target size) for bands 1 through 5 and 7 and 2000 meters for band 6.

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TEST REPORT

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TM HgCdTe
BAND 6

ARRAY 4-29-26-120

PART NUMBER 50959

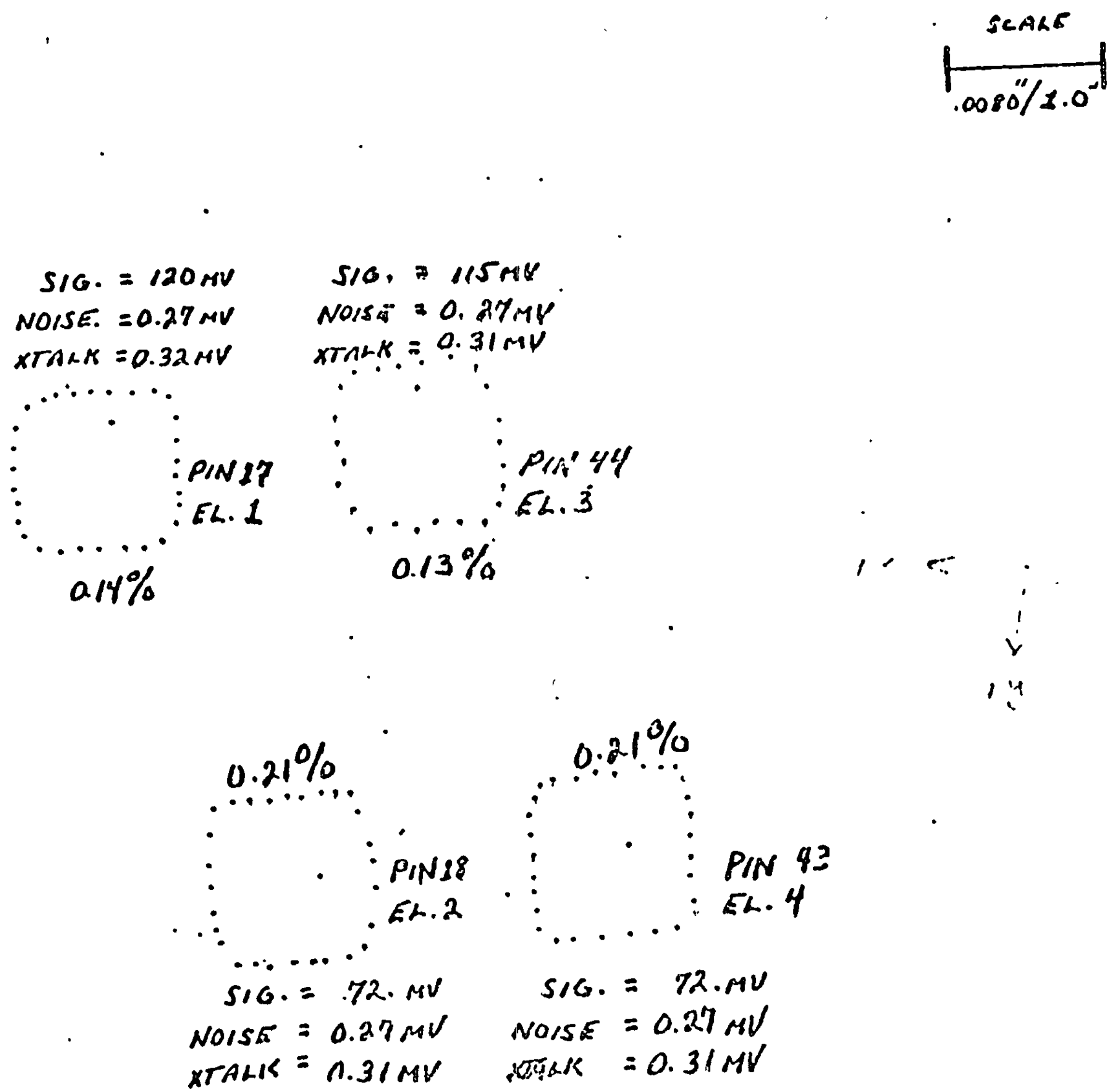
PL NUMBER 1162

PREPARED BY: [signature]
(TEST GROUP)

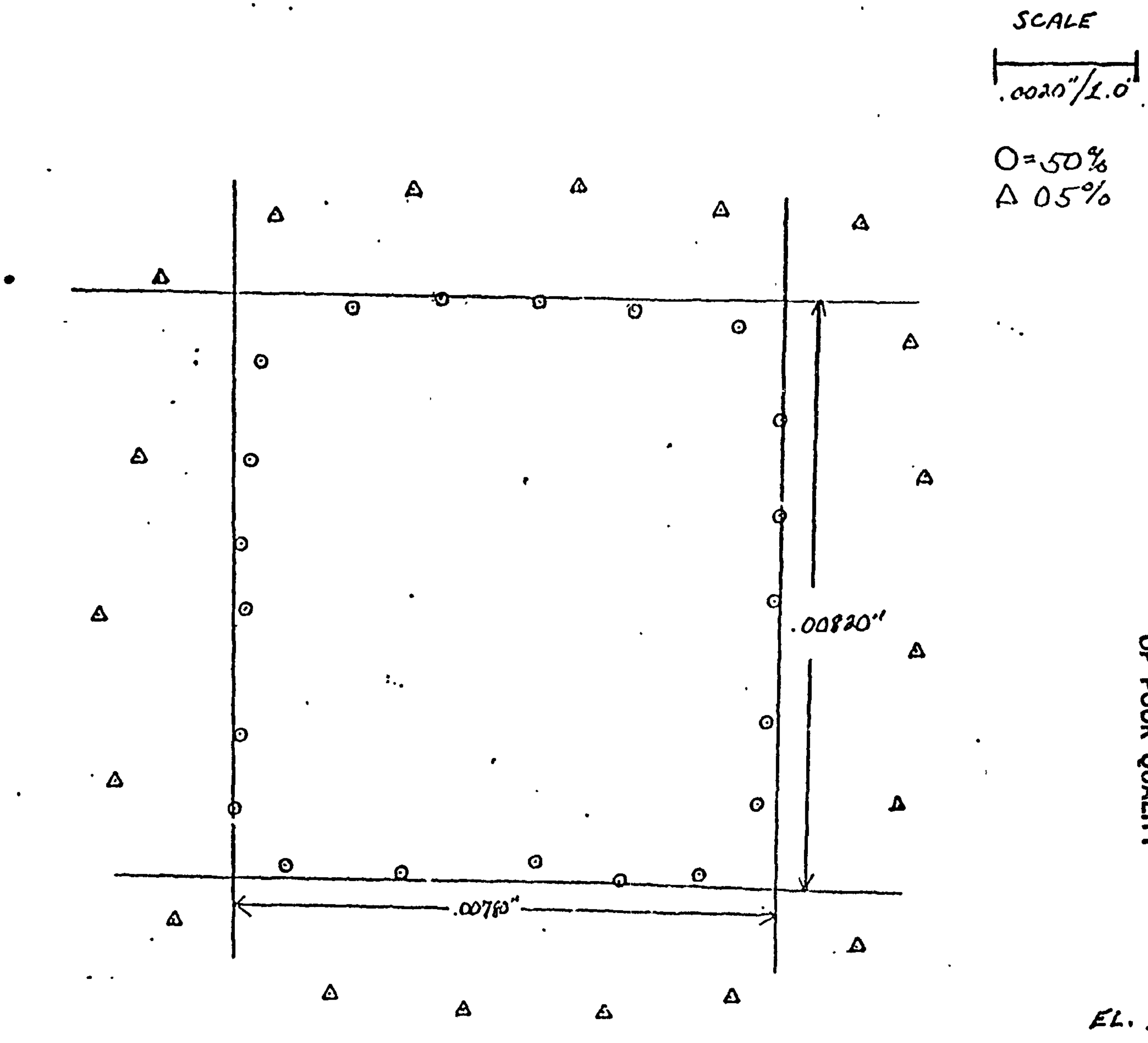
APPROVED BY: J.F. Kreider 8 Feb 79
(ENGINEERING FABRICATION)

APPROVED BY: D M Randall 2/8/79
(FPA REA)

APPROVED BY: [signature]
(SYSTEMS ANALYSIS REA)



4-29-26-120
1/10/79



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EL. 1
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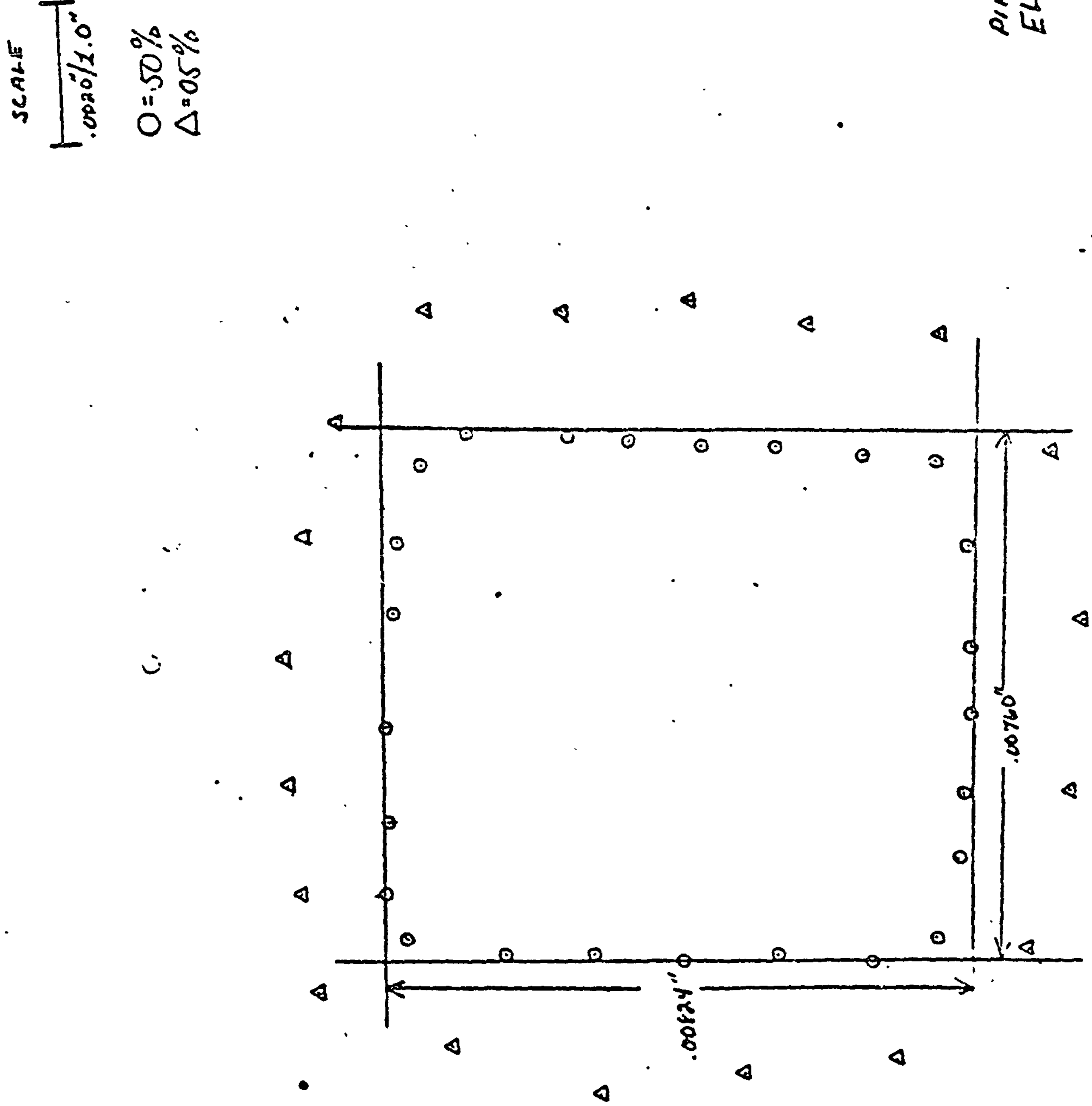

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EL.3

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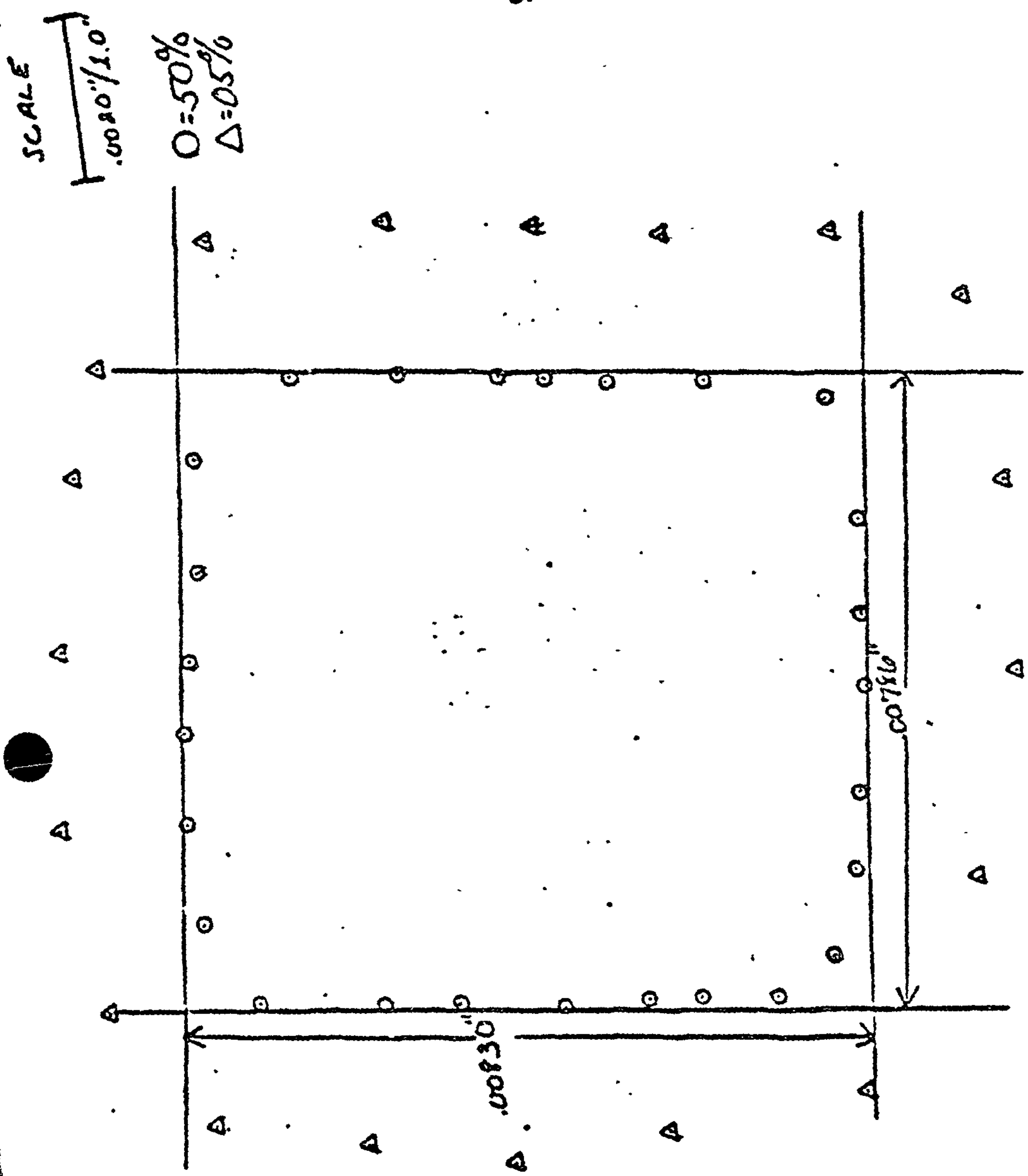

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EL. 4

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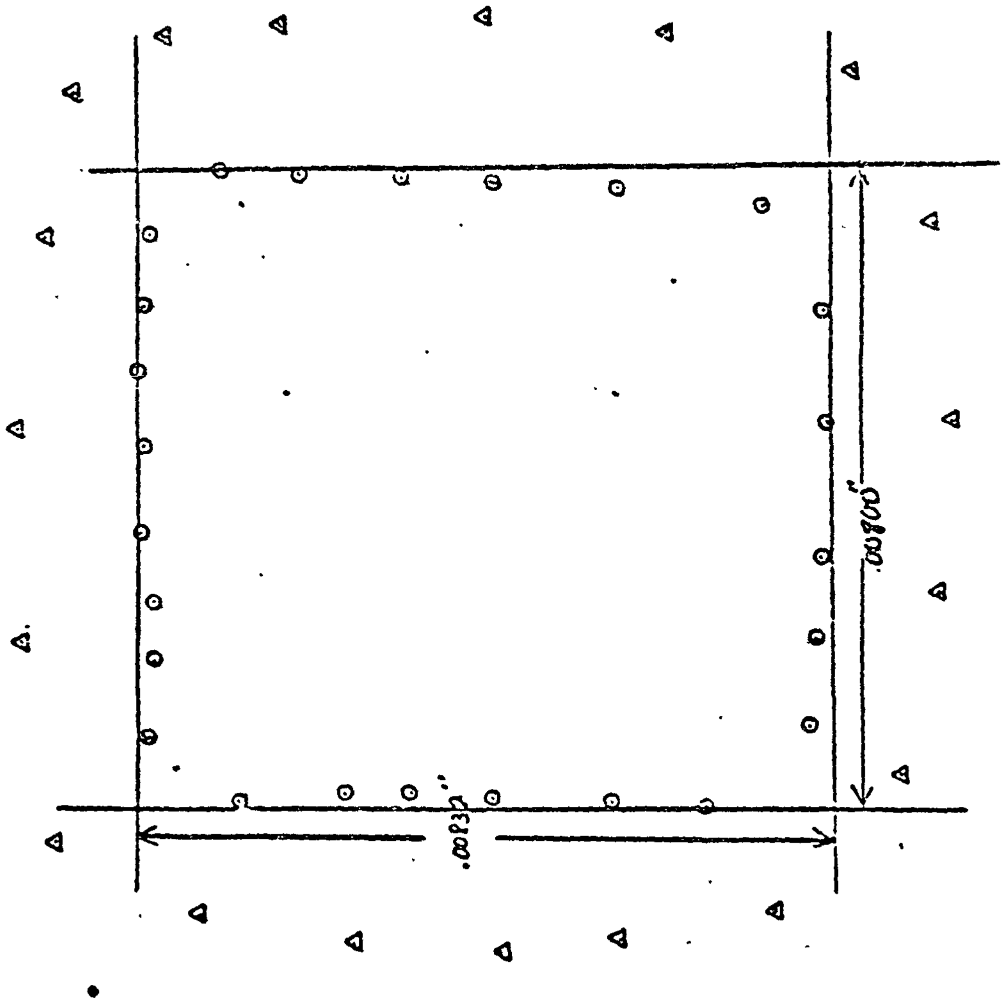

TABLE IV

TM HgCdTe Detector Array   Array No.: 4-29-2G-120

MECHANICAL INSPECTION   (See Drawing 50959

Dimension	Required	Ob-served	*	Comment
Array Height	.0205±.0010	.0207		
El. #1 width	.00816±.0001	.00818		
length	.00816±.0001	.00820		
Array width	.052 max	.051		
length	.098 max	.095		
Lead 1 to Subs. End	.001/.005	.035		
Lead 2 to Subs. End	.001/.005	.035		
Lead 3 to Subs. Side	.001/.005	.005		
Lead 4 to Subs. Side	.001/.005	.005		

Measurements by J Campbell

Date 9.27.78

VISUAL INSPECTION   (See Product Spec 16027)

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Spec. Par. & Characteristic		*	Observed & Comments
3.5.2	a. Oil, grease, contam.		
	b. Loose part.>10μ		
	c. Loose part.<10μ		
3.5.3	a. 1/3 of lead chipped		
	b. Substrate cracks		
	c. Leads lifted, peeled		
	d. Scratches on leads		
	e. Bonding pads (60%)		

*Mark here to "flag" a problem.

Examined by J. Campbell

Date 9.27.78

Elements clean. Slight PR residue on sapphire substrate.

TITLE PRODUCT SPECIFICATIONS HgCdTe ARRAY (TM)

SIZE	CODE IDENT NO	NUMBER
A	11323	
SCALE	REV	SHEET 12

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INTERNAL MEMORANDUM

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DATE 15 June 1982

TO. F. R. Phillips CC Distribution

REF: 2221-612
HS236-8027

SUBJECT. Spurious Detector Response Observed During AC07R Spatial Coverage Testing

FROM: J. C. Campbell

BLDG. B11 MAIL STA. 78

EXT. 6151

A potentially serious problem has been observed during AC07R Spatial Coverage Testing of the F-1 Model Thematic Mapper. While positioning the scanning slit/source assembly in preparation for later phase of the required testing, spurious signals of up to 10% of peak were observed on Band 1 Detectors 1 and 2. This chance observation instigated an immediate search which resulted in locating two more unwanted peaks on the Band 1 FOV skirts and a similar set in three out-of-field locations for Band 2. At that time Failure Report FR5776 "On Spurious Response in Extended Far Field Locations" was initiated and a formal troubleshooting sequence was begun. Since then, additional data has been collected for Band 4 showing the presence of four spurious peaks. Bands 5 and 7 were similarly investigated with negative results thus indicating that we are faced with a problem peculiar to the prime focal plane array.

An additional test was undertaken to roughly locate the source of spurious radiation with respect to the collimator beam. This was accomplished by masking the telescope aperture, one half of its area at a time. The mask when inserted over top or bottom halves, cut the magnitude of the beam in half. Inserted over the +Y half of the aperture, it reduced the beam to 80% of maximum. Inserted over the -Y half of the aperture, the mask produced no change in signal level. The spurious radiation thus passes thru the +Y half of the telescope aperture.

The initial supposition was that the observed effects might be due to light reaching the detectors thru the filters after multiple reflections in the TM optical system and/or in the collimator and test equipment. Subsequent investigations show that the light leakage is due to unfiltered light and, therefore, cannot be entering thru any normal optical path. This was demonstrated by inserting various spare TM filters into the optical beam near the collimator source and observing the effect on the spurious signals. The evidence is as follows:

1) Looking at a Band 2 Detector 2 spurious signal, a supplemental Band 2 filter attenuates the spurious peak by about 90%.

Spurious Detector Response...

2) Looking at a Band 4 Detector 2 spurious signal, a supplemental Band 4 filter attenuates the signal by about 70%. When clear glass was used instead of the filter, the signal dropped by 10%.

3) Looking at Band 1 Detector 2, a supplemental Band 1 filter causes all spurious signals to disappear. Insertion of a Band 4 filter attenuates the Band 1 signal by about 70%; the same as for Band 4.

Current speculation is that the observed effects may be due to radiation reaching sensitive areas of the detector array other than thru the attached filters. Such abnormal paths could be thru the sides of the detector substrates or by reflections from gold plated detector lead wires. The precise geometry of such effects is not presently understood. Dick Cline and Dave Randall will be consulted concerning array geometry with respect to possible light paths.

Further investigation is planned and may include:

1) Replacing the current tungsten filament slit/source with an integrating sphere and slit with filtering that more nearly represent the sunlit earth source.

2) Try a different slit size (currently 0.1 IFOV). A larger slit might increase the wanted signal without increasing the spurious radiation.

3) A more detailed survey of the aperture masking may be performed.

4) Use more reasonable values of source current to more nearly simulate actual TM radiation inputs. In order to observe the spurious effects, lamp currents were increased by up to 50%.

Since the last paragraph above was written, items 1 and 2 of the further investigation have been completed. The additional test results are as follows:

1) The ribbon filament lamp was replaced with the 6 inch SIS that is normally used on collimator number 3. The primary purpose of this change was to try to level out the spectral radiance from the source to prevent Bands 1 and 2 (and 3 to some extent) from being overexposed to longer wavelength radiation in the Band 4 region.

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Spurious Detector Response...

a) Looking at the B1D8 signal (100%) first, it was found necessary to use 100 Hz filter on the output. The 100% response (SIS @ 7.65A) was 360 mv(rms). The spurious signal amounted to less than 1 mv on a noise floor of ~1.8 mv(rms).

b) A check of B2D8 gave:

100% response ≅ 380 mv(rms) @ + .0074" (Y-pos.)
noise + spurious ≅ 1.2 mv + 0.4 mv @ + .0694" (Y-pos.)
noise + spurious ≅ 1.2 mv + 0.2 mv @ - .0576" (y-pos.)

c) A check of B4D8 gave:

100% response ≅ 360 mv(rms) @ -.2216" (Y-pos.)
The spurious response could not be found so it was decided to use a Lock-In Amplifier. Using a PAR 186-A and processing the unfiltered signal from the Tustin input gave the following data:

100% response = 0.64 V dc (on 500 mv scale) @ -.2194" (Y-pos.)

Spurious response signals appeared to reside at coordinates -.1736" and -.1536". The signals were out-of-phase with the 100% signal and were on the order of 0.3 and 0.4 V (rms) on a 2 mv scale. This gives a suppression ratio on the order of 1000:1.

2) Changing the slit width from 1/10 IFOV to ~ 1 IFOV (5 mils at the collimator focal plane) and still looking at B4D8 gave the following results:

new 100% response = 1.00 V dc (on 500 mv scale) @ -.2810" (Y-pos.)
spurious response ≃ 0.2 V dc (on 2 mv scale) @ -.2340" (Y-pos.)
spurious response ≃ 0.3 V dc (on 2 mv scale) @ -.3130" (Y-pos.)
spurious response ≃ 0.8 V dc (on 2 mv scale) @ -.3450 (Y-pos.)

Positioning the slit at B4D8's spurious response zone (-.3450) and checking each detector's signal level gave even detector spurious response signals in the range 1.5 to 1.7 mv (rms) and odd detector response signals in the range 0.3 to 0.8 mv (rms).

A similar check on B1D1 using the expanded slit gave a 100 mv signal at the band center with a largest spurious peak of 3 mv at a displacement of -.0600 (Y-pos.). Even channel B1D2 gave a spurious peak of about ½ this magnitude and a further check of B1D5 gave 5 mv.

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3) In addition, a detailed point by point scan was made for B4D8 over the range -.3600" (Y-pos.) to -.2100 (Y-pos.) in increments of .0020". The spurious response signals showed up as expected at the locations indicated above.

John C. Campbell

John C. Campbell

dz

Distribution:

W. Adams	B11/39
L. Altman	B11/39
D. Brandshaft	B11/40
C. Cardona	B11/102
J. Engel	B11/101
G. Gritt	B12/90
C. Kent	B11/78
J. Lansing	B11/40
L. Long	B11/79
W. Nichols	B2/36
W. O'Donnell	B11/78
L. O'Connell	B11/39
G. Plews	B11/101
T. Sciacca	B12/90
D. Young	B12/AF
J. Young	B11/78
Data Bank (5)	B11/59
Optics File	

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SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

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TO: Distribution

CC: TM DMO (6)

DATE: 15 June 1982

REF: HS236-8031

SUBJECT: Investigation of AC07R Test Failure

FROM: F. R. Phillips

BLDG. B11 MAIL STA. 79

EXT. 6132

Subject test failure revealed that Bands 1 and 2 show secondary peaks in sensitivity well away from the nominal channel centers.

A meeting was held on Monday, 14 June 1982, to determine what actions should be taken to resolve this failure. In attendance were:

D. Adams, D. Brandshaft, J. Campbell, C. Kent, L. O'Connell, A. Perline, F. Phillips, G. Plews, D. Randall, and T. Sciacca.

The following actions and assignees were agreed to by the conferees:

Action	Assignee
1. Document results of tests to date.	J. Campbell
2. Conduct special test - rerun tests using two different aperture masks.	G. Plews
3. Review Protoflight BL-16 and BL-17 test results to determine if same condition existed.	D. Brandshaft
4. Review PFPA construction sources.	D. Cline (?)/ D. Randall

The conferees will meet at 8 a.m. on Tuesday, 15 June, in Bldg B11, Room A-711, to review the results/status of the action items listed above.

FR Phillips

F. R. Phillips, Manager
Thematic Mapper Program

IO/FRP/lbg

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INTERNAL MEMORANDUM

TO	Distribution	CC TM DMO (6)	DATE 15 June 1982
			REF HS236-8031
SUBJECT	Investigation of AC07R Test Failure		FROM F. R. Phillips
			BLDG. B11 MAIL STA 79
			EXT 0132

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TO: F. R. Phillips CC: Distribution

DATE 15 June 1982

REF: 2221-612
HS236-8027

SUBJECT Spurious Detector Response Observed During AC07R Spatial Coverage Testing

FROM: J. C. Campbell

BLDG. B11 MAIL STA. 78

EXT. 6151

A potentially serious problem has been observed during AC07R Spatial Coverage Testing of the F-1 Model Thematic Mapper. While positioning the scanning slit/source assembly in preparation for later phase of the required testing, spurious signals of up to 10% of peak were observed on Band 1 Detectors 1 and 2. This chance observation instigated an immediate search which resulted in locating two more unwanted peaks on the Band 1 FOV skirts and a similar set in three out-of-field locations for Band 2. At that time Failure Report FR5776 "On Spurious Response in Extended Far Field Locations" was initiated and a formal troubleshooting sequence was begun. Since then, additional data has been collected for Band 4 showing the presence of four spurious peaks. Bands 5 and 7 were similarly investigated with negative results thus indicating that we are faced with a problem peculiar to the prime focal plane array.

An additional test was undertaken to roughly locate the source of spurious radiation with respect to the collimator beam. This was accomplished by masking the telescope aperture, one half of its area at a time. The mask when inserted over top or bottom halves, cut the magnitude of the beam in half. Inserted over the +Y half of the aperture, it reduced the beam to 80% of maximum. Inserted over the -Y half of the aperture, the mask produced no change in signal level. The spurious radiation thus passes thru the +Y half of the telescope aperture.

The initial supposition was that the observed effects might be due to light reaching the detectors thru the filters after multiple reflections in the TM optical system and/or in the collimator and test equipment. Subsequent investigations show that the light leakage is due to unfiltered light and, therefore, cannot be entering thru any normal optical path. This was demonstrated by inserting various spare TM filters into the optical beam near the collimator source and observing the effect on the spurious signals. The evidence is as follows:

1) Looking at a Band 2 Detector 2 spurious signal, a supplemental Band 2 filter attenuates the spurious peak by about 90%.

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15 June 1982
2221-612
HS236-8027

Spurious Detector Response...

2) Looking at a Band 4 Detector 2 spurious signal, a supplemental Band 4 filter attenuates the signal by about 70%. When clear glass was used instead of the filter, the signal dropped by 10%.

3) Looking at Band 1 Detector 2, a supplemental Band 1 filter causes all spurious signals to disappear. Insertion of a Band 4 filter attenuates the Band 1 signal by about 70%; the same as for Band 4.

Current speculation is that the observed effects may be due to radiation reaching sensitive areas of the detector array other than thru the attached filters. Such abnormal paths could be thru the sides of the detector substrates or by reflections from gold plated detector lead wires. The precise geometry of such effects is not presently understood. Dick Cline and Dave Randall will be consulted concerning array geometry with respect to possible light paths.

Further investigation is planned and may include:

1) Replacing the current tungsten filament slit/source with an integrating sphere and slit with filtering that more nearly represent the sunlit earth source.

2) Try a different slit size (currently 0.1 IFOV). A larger slit might increase the wanted signal without increasing the spurious radiation.

3) A more detailed survey of the aperture masking may be performed.

4) Use more reasonable values of source current to more nearly simulate actual TM radiation inputs. In order to observe the spurious effects, lamp currents were increased by up to 50%.

Since the last paragraph above was written, items 1 and 2 of the further investigation have been completed. The additional test results are as follows:

1) The ribbon filament lamp was replaced with the 6 inch SIS that is normally used on collimator number 3. The primary purpose of this change was to try to level out the spectral radiance from the source to prevent Bands 1 and 2 (and 3 to some extent) from being overexposed to longer wavelength radiation in the Band 4 region.

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Spurious Detector Response...

a) Looking at the B1D8 signal (100%) first, it was found necessary to use a 100 Hz filter on the output. The 100% response (SIS @ 7.65A) was 360 mv(rms). The spurious signal amounted to less than 1 mv on a noise floor of ~1.8 mv(rms).

b) A check of B2D8 gave:

100% response ≅ 380 mv(rms) @ + .0074" (Y-pos.)
noise + spurious ≅ 1.2 mv + 0.4 mv @ + .0694" (Y-pos.)
noise + spurious ≅ 1.2 mv + 0.2 mv @ - .0576" (y-pos.)

c) A check of B4D8 gave:

100% response ≅ 360 mv(rms) @ -.2216" (Y-pos.)
The spurious response could not be found so it was decided to use a Lock-In Amplifier. Using a PAR 186-A and processing the unfiltered signal from the Tustin input gave the following data:

100% response = 0.64 V dc (on 500 mv scale) @ -.2194" (Y-pos.

Spurious response signals appeared to reside at coordinates -.1736" and -.1536". The signals were out-of-phase with the 100% signal and were on the order of 0.3 and 0.4 V (rms) on a 2 mv scale. This gives a suppression ratio on the order of 1000:1.

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Positioning the slit at B4D8's spurious response zone (-.3450) and checking each detector's signal level gave even detector spurious response signals in the range 1.5 to 1.7 mv (rms) and odd detector response signals in the range 0.3 to 0.8 mv (rms).

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15 June 1982
2221-612
HS236-8027

Spurious Detector Response...

3) In addition, a detailed point by point scan was made for B4D3 over the range -.3600" (Y-pos.) to -.2100 (Y-pos.) in increments of .0020". The spurious response signals showed up as expected at the locations indicated above.

John C. Campbell

John C. Campbell

dz

Distribution:	W. Adams	B11/39
	L. Altman	B11/39
	D. Brandshaft	B11/40
	C. Cardona	B11/102
	J. Engel	B11/101
	G. Gritt	B12/90
	C. Kent	B11/78
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	W. Nichols	B7/36
	W. O'Donnell	B11/78
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	Data Bank (5)	B11/59
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INTERNAL MEMORANDUM

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TO Distribution

CC TM DMO (6)

DATE 15 June 1982

REF HS236-8031

SUBJECT Investigation of AC07R Test Failure

FROM F. R. Phillips

BLDG B11 MAIL STA 79

EXT 6132

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FR Phillips

F. R. Phillips, Manager
Thematic Mapper Program

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SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

TO Distribution CC. TM DMO (6) DATE 15 June 1982

REF HS236-8031

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BLDG B11 MAIL STA 79

EXT 6132

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F. R. Phillips, Manager
Thematic Mapper Program

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Appendix 3.2.10

BL10 TEST Reference Documentation

SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

TO: Distribution CC: G. Hyde

DATE: ~~10 April 1981~~ 25 June 1982

REF: HS236-7398-1

FROM: J. Lansing
W. Shockency

BLDG. 774 MAIL STA. 79
EXT. 4351

SUBJECT: BL-10 Clarifications (Revised)

REF: HS236-6666, Test Requirements for BL-10, Radiometric Calibration of Bd. 6, 29 April 1980.

I. Introduction

The purpose of this IDC is to clarify the method of determining L_{EFF} (effective radiance shown in Appendix B* in referenced ICD, and to call out more explicit definition of the end points of the detectors transfer characteristics. Since the issuance of the initial IDC, more quantitative measurements have been made on both the throughput of the entire TM instrument and the External Calibrator.

II. Spectral Response

Table C-1 of Appendix BB depicts the normalized response of the TM (from radiance input to the aperture to output of the Bd. 6 detectors) for the 3 expected temperature states of the CFPA, 90°, 95° and 105°K.

The L_{EFF} in Eq. 3 of Appendix BB is first applied to determine the TM response to an IDEAL BB. Once this is determined for a given IDEAL BB within the specified range of the TM (L_{EFF} 260°K to L_{EFF} 320°K), the External Calibrator BB (either the REF_{BB} or MTF_{BB}) equivalent radiance is determined by applying equations A, 2, and 3.

To clarify this process, the expressions relating L_{EFF} for an IDEAL BB, MTF_{BB}, and REF_{BB} are given in Appendix BB, also. It is recommended that tables be constructed for L_{EFF} (IDEAL BB) and L_{EFF} (MTF and REF_{BB}) which will be useful in determining CALIBRATOR BB temperature commands for desired L_{EFF} (IDEAL BB).

* This Appendix is superseded by the attached Appendix BB.

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III. External Calibrator

The expressions in Appendix BB have been modified to show the appropriate transfer characteristic of the REF_{BB} and MTF_{BB}. Note that the REF and MTF L_{EFF} transfer equations are different in that the optical paths are different.

IV. Graphical TM Detector Model

The attached graph, Figure I, of Appendix BB is a model of a typical detector expected transfer curve. The purpose of the figure is to show how points on the curve are to be determined--by calculation, measurements, or by derivation (a combination of measurements and calculations). The end points on this curve which will be determined by temperature commands of the External Calibrator BB's represent specified equivalent SCENE temperatures. These temperatures are used as the boundary extremes throughout all testing in BL-10; therefore, any place in the BL-10 (HS236-6666) document end point commands are called out, the temperatures of MTF_{BB} = 251.3°K* and REF_{BB} = 323.8°K* are to be used.

V. NETD Calculations

A. In reference document, pg. 16a, change to

Temp.°K	∂L/∂T(MW/Cm²-SR-°K) @ CFPA = 90°K-105°K	
300	0.0137	.0131
320	0.0164	.0151
	PROTOFLIGHT	FLIGHT 1

B. In Ref., pg. 16e, change to

1) ρ_m = 0.85, 2) ρ_R = 0.89, 3) ε = 0.995

C. In Ref., pg. 17f, - eliminate (f)

D. In Ref., pg. 19, NETD

L_{EFF} = effective radiance for IDEAL BB

$\partial L_{EFF}/\partial T$ = data base values

* Note the command temperatures to the External Calibrator BB's have been determined by applying the process described in I-III.

APPENDIX BB

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A. Radiance/Temperature Relations

Several data reduction processes require conversions relating radiance and temperature from various thermal sources within the TM, Ideal BB, and External Calibrator. The following expression is to be used:

$$L = \frac{1.19096\ 10^4}{\lambda^5\ (\mathrm{EXP}\ \frac{1.43879\ 10^4}{\lambda T} - 1)} \quad (Eq. A)$$

~~(Eq A)~~

L = spectral radiance in Watts/cm^2 - sr - μm

λ = μm wavelength

T = temperature, °K

B. Radiance Calibration Determinations from External Calibrator

The spectral radiance, L_{EFF}, which is proportional to the TM multiplexer output is basically a function of two elements. One element is the radiance from the Calibrator or an Ideal BB, and the other is the effective transfer characteristics of the TM components.

The first element may be expressed by the following equation:

$$L_{CALIB/BB} = \rho_{CALIB}\epsilon_{BB}L_{T_1BB} + (1 - \rho_{CALIB}\epsilon_{BB})\ L_{T_2M} \quad (Eq\ 1)$$

ρ_{CALIB} = 0.89 for Ref_{BB}, 0.85 for MTF_{BB}

ϵ_{BB} = 0.995

L_{T_1BB} = Radiance of BB at Ti from (EqA)

L_{CALIB} = radiance out of CALIB

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APPENDIX BB (Cont'd)

L_{T_2M} = radiance of the calibrator mirrors (composite) as function of their temp., ~~T_2 = (T_{26} + T_{27} + T_{28})~~

$T_2 = \frac{2T_{250} + 2T_{251} + T_{253}}{5}$ where subscripts are parameter numbers.

The second element has been determined by measuring the thruput of the TM instrument and is depicted in the following table:

PROTOFLIGHT

Table C-1 TM Thruput for Bd 6

				(2) FLIGHT 1 (ALL CFPA TEMPS.)	
λ(μm)	CFPA (90°K)	CFPA (95°K)	CFPA (105°K)	DET. 1,3	DET. 2,4
10.2	.0306	.0306	.0306	.028	.029
10.4	.409	.409	.409	.323	.329
10.6	.836	.836	.836	.752	.778
10.8	.919	.919	.891	.784	.841
11.0	.998	.998	.838	.881	.975
11.2	.876	.876	.596	.899	.955
11.4	.907	.803	.367	.969	.988
11.6	.891	.685	.247	.939	.921
11.8	.721	.437	.166	.954	.977
12.0	.437	.260	.114	.914	.978
12.2	.262	.164	.09	.884	.955
12.4	.094	.067	.003	.545	.594
12.6	.006	.004	--	.042	.046
12.8	.0008	.0006	--	.008	.009

The effective spectral radiance, L_{EFF}, is calculated from the following:

$$L_{EFF} = \frac{\Sigma(1) \quad (2)\ \Delta\lambda}{\Sigma(2) \quad \Delta\lambda} \quad \text{☆} \qquad \text{(Eq. 3)}$$

$\Delta\lambda$ = 0.2μ (from 10.2 to 12.8μm)

☆ see following page for alternate equation

, 250, 251, & 253

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APPENDIX BB (Cont'd)

The calculations for (1) in this equation use the actual measured temperatures, T_2, of the mirrors in the calibrator.

Take weighted average of calibrator mirror temperatures using telemetry parameter numbers ~~24, 26, and 27.~~ This is required in the data reduction, printouts, and plots wherever L_{EFF} is called out for either the MTF or REF blackbody.

The above effective radiance takes into account the actual spectral shape of the TM transmission and detector responsivity. This effective radiance can be translated to scene temperature by substituting an IDEAL BB for the (Eq. 1) and finding the temperature of the BB which gives the same effective radiance as the calibrator. Conversely, particular temperatures of interest can be substituted to find effective radiance.

ALTERNATE EQUATION

$$L_{EFF} = K_1/(\exp(K_2/T - 1) \qquad \text{(Eq. 4)}$$

or conversely,

$$T = K_2/\ln(K_1/L_{EFF} + 1) \qquad \text{(Eq. 5)}$$

where

CFPA Temperature		Protoflight	Flight 1 ☆ Det. 1,3	Det. 2,4
90K	K_1 =	67.162	60.844	60.708
	K_2 =	1284.3	1260.77	1260.35
95K	K_1 =	69.527	same as 90K	
	K_2 =	1293.1		
105K	K_1 =	74.571	same as 90K	
	K_2 =	1311.1		

☆ Using average values, K_1 = 60.776, K_2 = 1260.56, gives results within 0.05% for F1.

TM RESPONSE TO IDEAL BB

$$L_{EFF_{BB}}^{(TM)} = \frac{\sum_{\lambda_1}^{\lambda_2} (1)\ (2)\ \Delta\lambda}{\sum_{\lambda_1}^{\lambda_2} (2)\ \Delta\lambda}$$

where (1) $L_{BB,TEMP} = \dfrac{1.19096 \times 10^{4}}{\lambda^{5} \left(EXP \dfrac{1.43879 \times 10^{4}}{\lambda T} - 1\right)}$

in watts/cm^{2}sr μm, λ = μm, T240 to 340°K

in 5°K(INC)

$\Delta\lambda = 0.2\mu m$

(2) (See Attached Table) and calculate for

TM @ 90°K, L_{EFF} μm 5°K(INC) for 240 to 340°K

95°K

105°K

TM RESPONSE TO REFBB/CALIB.

$$L_{EFF,\ CALIB}^{(TM)} = \frac{\sum_{\lambda_1}^{\lambda_2} (1)\quad (2)\quad \Delta\lambda}{\sum_{\lambda_1}^{\lambda_2} (2)\quad \Delta\lambda}$$

(2) See Attached Table @ TM (90°K)

(1) $L_{CALIB/REF_{BB}} = (0.995)\ (.89)\ L_{BB_{T_C}} \left(\begin{matrix}10.2\\12.8\end{matrix}\mu\right) + [1 - .995(.89)] L_{T_2 M}$

$$L_{\substack{M\\T_2=297}}\left(\begin{matrix}10.2\\12.8\end{matrix}\right)$$ (OR T_2 IN APPENDIX BB)

Calculate (1) for T_c = 325, 320, 315,
300°K, 322.7

TM RESPONSE TO MTF_{BB}/CALIB

In Above Process, Replace (1) by Following:

(1) $L_{CALIB/MTF_{BB}} = (0.995)\ (.85)\ L_{T_{MTF}} \left(\begin{matrix}10.2\\12.8\end{matrix}\right) + [1 - .995(.85)] L_{T_2 M}$

$$L_{\substack{T_2=297\\M}}\left(\begin{matrix}10.2\\12.8\end{matrix}\right)$$ (OR T_2 IN APPENDIX BB)

Calculate (1) for T_{MTF} = 240, 247, 260, 300,
315, 251, 325, 320,
255, 297, 305

$$L_{EFF\ CALIB}^{TM} = \frac{\sum_{\lambda_1}^{\lambda_2} (1)\ (2)\ \Delta\lambda}{\sum_{\lambda_1}^{\lambda_2} (2)\ \Delta\lambda}$$

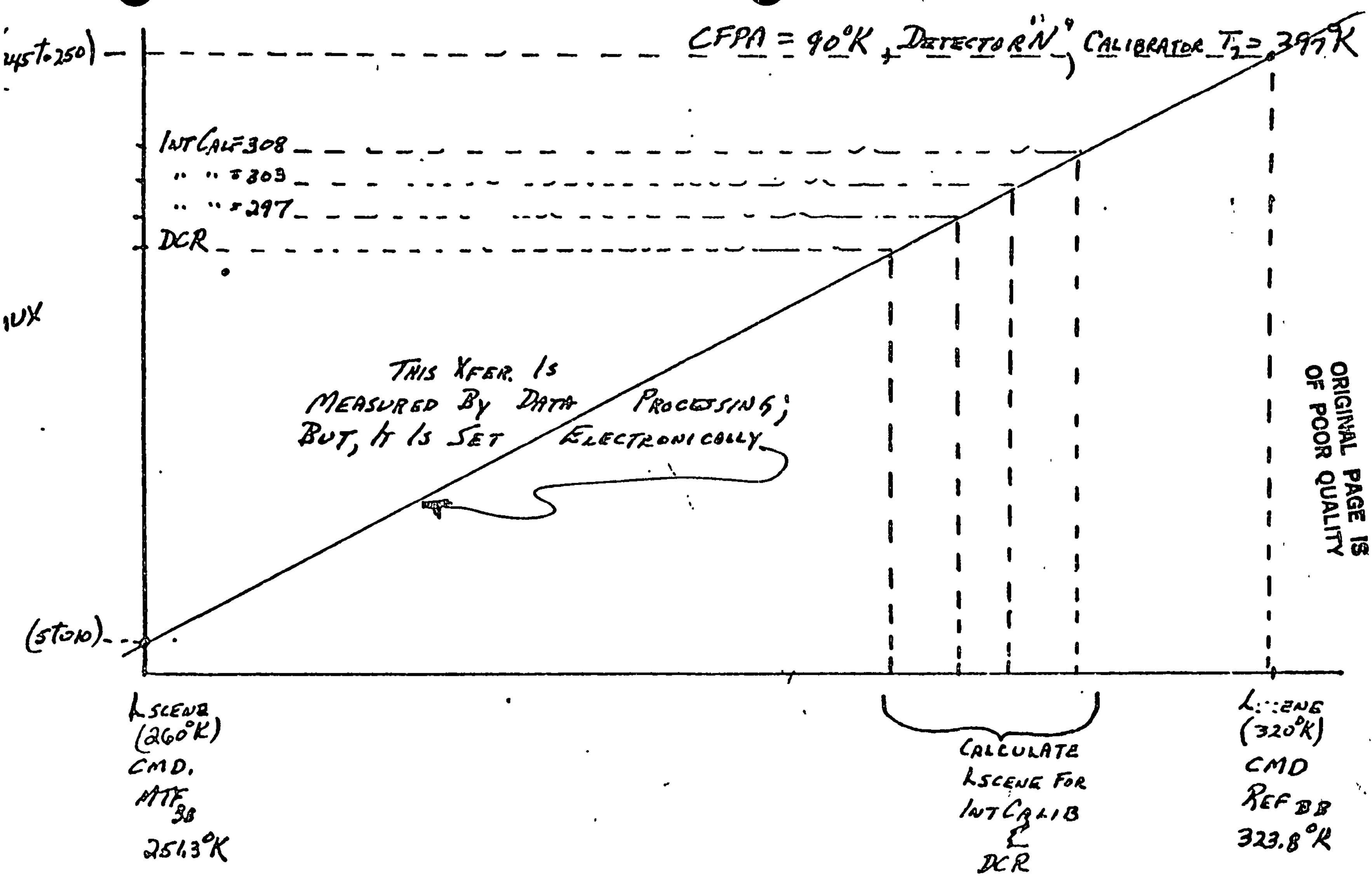

FIG I. — L_{EFF} [RESPONSE OF TM TO SCENE (IDEAL BB)] - CALCULATED
" " " TO EXT. CALIB - DERIVED/MEASURE
" " " INT CALIB./DCR - " "

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INTERNAL MEMORANDUM

TO: Distribution J

CC: L. Linstrom (GSFC)
O. Weinstein (GSFC)

DATE: June 3, 1982

REF: HS236-8013
SED 111

SUBJECT: A Band 6 Calibration Problem

FROM: J. Lansing

BLDG. B11 MAIL STA. 40

EXT. 6261

A recasting of the equations governing band 6 performance has led to a novel means of assessing the quality of the band 6 calibration data, which data now appear less promising.

The TM gain is defined as

$$G = \frac{Q_{sc2} - Q_{sc1}}{L_{sc2} - L_{sc1}} \qquad (1)$$

where Q = output signal, counts
L = radiance, mW/cm^2-sr
sc1, sc2 designate two scene elements

If TM band 6 views a scene giving exactly the same signal as obtained from the shutter, the scene radiance (L_{esh}) will conform to the following equation;

$$L_{esh}\,\rho_t + L_t V_t (1-\rho_t) = L_{sh} V_{sh} \qquad (2)$$

where ρ = reflectance
V = view factor relative to scene view factor
e designates scene equivalent
sh designates shutter
t designates telescope

Equation (2) is based on the fact that the detector's view of the shutter is replaced by a combination of the scene and a number of internal telescope parts when the shutter is aside. Lumping all these as "telescope" is a simplification which does not affect the present argument. Detailed consideration of the parts is shown in HS236-7434.

A similar equation can be written for the internal blackbody:

$$L_{ebb}\rho_t + L_t V_t (1-\rho_t) = L_{bb} V_{bb} \rho_{shm} + L_{sh}(V_{sh} - V_{bb}) + L_{sh} V_{bb} (1-\rho_{shm}) \qquad (3)$$

where
bb designates internal blackbody
shm designates shutter mirror

The first term on the right of equation (3) is the blackbody radiance reflected toward the detector, the second term is the amount of shutter radiance from areas beyond the mirror, and the third term is the radiance emitted by the mirror.

Making substitutions in equation (1)

$$G = \frac{Q_{bb} - Q_{sh}}{L_{ebb} - L_{esh}} \tag{4}$$

Solving equation (2) for L_{esh} and (3) for L_{ebb} and substituting in (4) gives

$$G = \frac{Q_{bb} - Q_{sh}}{(L_{bb} - L_{sh}) V_{bb} \rho_{shm} / \rho_t}$$

Setting this equal to equation (1) gives

$$V_{bb} \rho_{shm} / \rho_t = \frac{Q_{bb} - Q_{sh}}{L_{bb} - L_{sh}} \cdot \frac{L_{sc2} - L_{sc1}}{Q_{sc2} - Q_{sc1}}$$

The left hand side of this equation should be constant, although V_{bb} might be slightly different from one channel to another. All of the quantities on the right hand side are available as a set at a number of times in the El Segundo thermal vacuum test, where the two scenes are presented by the external calibrator, using the reference and MTF blackbodies. An attempt was made to determine the constant by using all sets wherein the internal blackbody was at its maximum temperature and the external blackbodies had at least 30°C temperature difference. Both of these conditions aid accuracy.

The results are shown in Table 1. Some variation would be expected because of noise and the size of quantization steps in the several quantities used in the calculation. The effect of these on the constant is estimated at 1.5% to 2%. Substantially larger effects are apparent, for example the difference between channels 1 and 4 which goes from 1% on day 259 to about 10% on day 266. The cooler was heated up for outgassing between days 262 and 266, but this should not affect the constant term.

The shifts in values mean that the calibration of this band is not amenable to the treatment recently attempted, which was a search for correlation of signals with various telescope temperatures.

The influence of telescope temperatures is obscured, as can be shown by solving the equations for scene radiance in terms of internal blackbody and shutter quantities, starting with the gain written as

Day	Time	$V_{bb}\rho_{shm}/\rho_t$		Ch 4/Ch 1
		Ch. 1	Ch. 4	%
259	10:08	1.372	1.386	1
259	10:54	1.343	1.353	1
259	11:27	1.366	1.381	1
262	10:39	1.434	1.441	0.5
266	02:46	1.296	1.404	8
266	07:50	1.323	1.434	8
266	12:45	1.308	1.447	11
266	18:13	1.280	1.421	11
266	22:55	1.329	1.451	9

Table 1 $V_{bb}\rho_{shm}/\rho_t$ calculated from protoflight thermal vacuum test

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$$G = \frac{Q_{sc} - Q_{sh}}{L_{sc} - L_{esh}} \quad (7)$$

Substituting from (2) and (5) gives

$$L_{sc} = (Q_{sc} - Q_{sh}) \left(\frac{L_{bb} - L_{sh}}{Q_{bb} - Q_{sh}}\right) V_{bb}\rho_{shm}/\rho_t + L_{sh}V_{sh}/\rho_t - L_t V_t (1/\rho_t - 1) \quad (8)$$

from which it is observed that variation in $V_{bb}\rho_{shm}/\rho_t$ interferes with observation of effects from the last term, which contains telescope temperature effects.

The source of the variation in $V_{bb}\rho_{shm}/\rho_t$ is not known, but suspicion falls on V_{bb} because reflectance (ρ) variations of this sort are unlikely. V_{bb} is a function of the geometry of blackbody viewing by the detectors via the shutter mirror. This conceivably can be affected by the optical masks in the path, which are the edges of two openings in a small enclosure mounted at the mirror. This part is designed to prevent stray reflections which might interfere when the detector should be viewing the shutter. The part is small and mounted on the end of the moving shutter, suggesting the possibility of error due to small location shifts which could vignette the channels differently. Such shifts might, for example, be caused by changing sets in the flex pivots.

It should be emphasized that the preceding paragraph is very conjuctural.

To use the band 6 data to best advantage in view of this problem, it appears that absolute calibration could be based on average response to the internal calibrator over all four channels. Then the channel-to-channel balance might best be based on relative gains between channels as determined in thermal vacuum testing combined with a study of channel differences when viewing uniform scenes.

J. Lansing

Appendix 3.2.12

BL16/17 Test Reference Documentation

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SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

TO: J. Engel

CC: A. Gardner
R. Hummer

DATE: 12-3-79

REF: HS236-6514

FROM: J. B. Young (3)

SUBJECT: An Alternative MTF Approach - Phased Knife Edge

BLDG. MAIL STA.
EXT.

INTRODUCTION

Many concerns have been expressed on the adequate measurement of MTF for the TM program. In part these concerns are based upon past program problems, especially MSS. In addition a number of possible problems were raised in HS236-5917 "TM Square Wave Response Evaluation" dated 24 August 1978. One area that was not noted in the referenced memo is the fact that the TM calibrator optical system has appreciable field curvature. This field curvature introduces a variable MTF across the usable calibrator field angle.

The phased knife edge approach was initially generated because of the field curvature effect. The intent was to devise a reticle pattern that would cover a significantly smaller calibrator field angle than the current P/N 73209 Reticle, Modulation Bands 1-5,7. The resultant reticle pattern is depicted in SBRC Drawing #76770 Reticle, Phased Knife Edge Modulation Bands 1-5,7.

PHASED KNIFE EDGE PATTERN

Figure 1 illustrates the basic concept being employed. Adjacent leading knife edges (KE) have 0.1 IFOV phase shift. This is equivalent to saying the distance between two adjacent leading KE is (2n + 0.1) 0.007225 inch, where n is an integer and 0.007225n is the width of a space. The phase relationship assume the TM MUX samples once per dwell time.

Table I shows the relationship between n, reticle extent, and calibrator- field curvature. Drawing #76770 has been drawn for n=5 and 8. A part with n=5 should be capable of measuring optical and nominal electrical MTF. If here are major electrical effects, e.g., excessive overshoot, it may be necessary to have n=8.

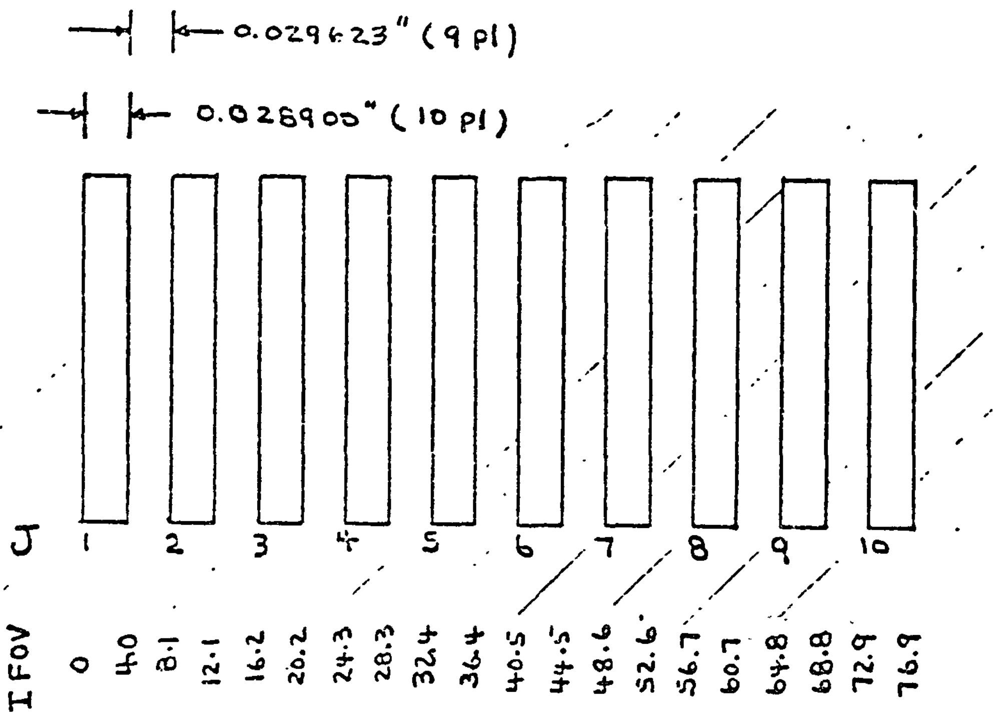

FIG. 1 PHASED KNIFE EDGE RETICLE

TABLE I

RELATIONSHIP BETWEEN n, RETICLE EXTENT(Δy), FIELD ANGLE($\theta_{1/2}$), FOCAL SURFACE CURVATURE SAG(Δz)

n	Δy* (inch)	$\theta_{1/2}$ (mr)	Δz (inch)
4	0.5556	1.6	0.003
5	0.6929	2.0	0.006
6	0.8302	2.4	0.010
7	0.9674	2.8	0.013
8	1.1047	3.2	0.018
9	1.2420	3.65	0.023
10	1.3793	4.1	0.029

*$\Delta y = [10n + 9(n + 0.1)](170)(42.5\times10^{-6})$

PHASED KNIFE EDGE USAGE

Figure 2 is a graphical representation of the phased KE reticle. It is folded for convenience. Note that each leading KE is numbered J=1,2,3,...9. Data samples (major frames-MF) are also numbered, e.g., MF≃3100-3180. There are 6320 major frames per channel per scan line. Thus, Figure 2 represents a segment of a scan line near its center. Two cases (I and II) with different phasing between KE and MF sampling are graphical illustrated in Figure 2. The knife edge response (KER) half intensity points occur at major frames MF_I=3118 and MF_{II}=3167 for cases I and II, respectively.

By inspection of Figure 2 we can readily see that the data stream must be rearranged to construct the desired KER. Table II has been constructed from visual examination of Figure 2.

For convenience the angle ϕ is made zero at the half intensity point and units of ϕ are in terms of IFOV. This convention is arbitrary and others may be deemed more suitable. Table II has been made for ±1.5 IFOV. This range could be as great as ± 2.0 IFOV for n=4. If n were made greater larger angular regions can be covered.

KER CONSTRUCTION ALGORITHM

The desired KER can be constructed using the following method.

1. Search through data stream, locate maximum and minimum signals.

2. Calculate half intensity point by 1/2 (Max-Min) + Min.

3. Search through data stream and locate major frame that has signal closest to half intensity point (use only leading edge). This gives MF_I=3118 and MF_{II}=3167

4. Note leading edge (J) at which half intensity occurs. For cases I & II

$$J_I = 3$$

$$J_{II} = 9$$

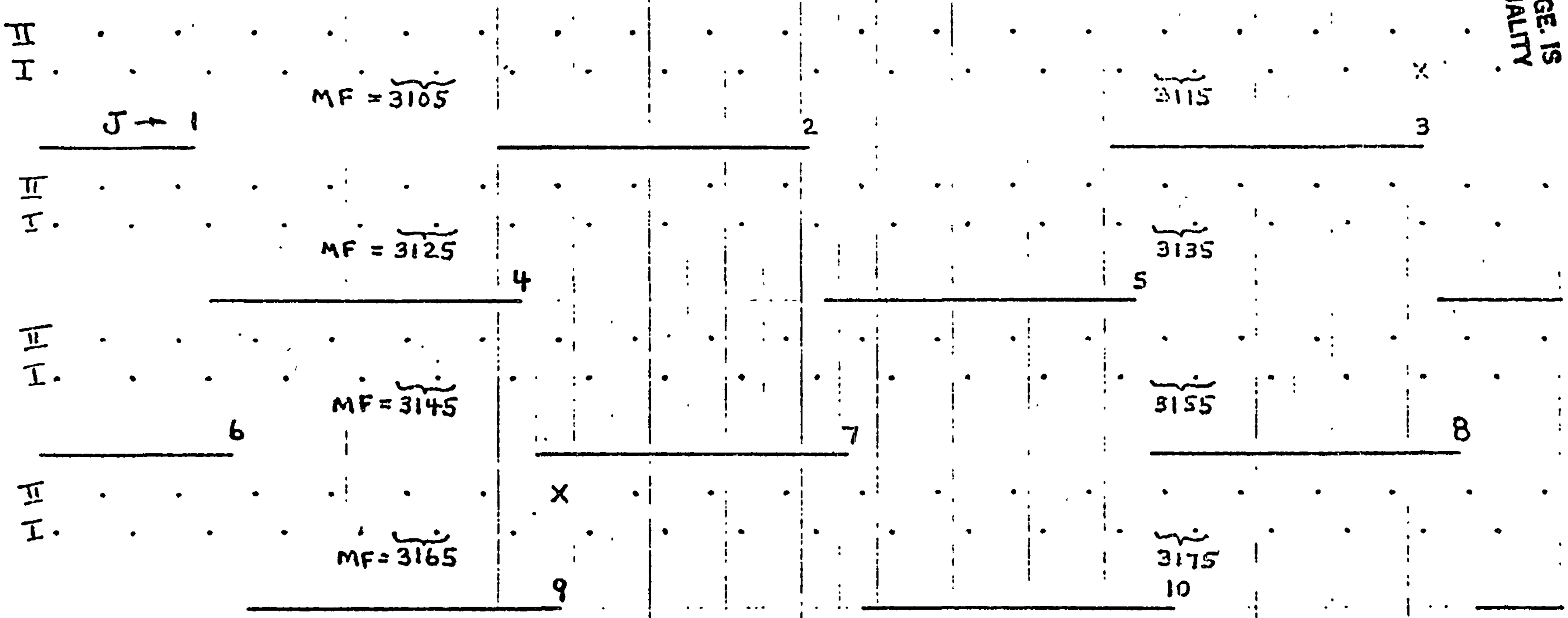

FIG. 2 PHASED KE RETICLE WITH CASES I & II MF/KE PHASING

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TABLE II

KER CONSTRUCTION FOR CASE I and II

ϕ (IFOV)	MF Case I	MF Case II
-1.5	3157	3125
-1.4	3149	3117
-1.3	3141	3109
-1.2	3133	3101
-1.1	3125	3174
-1.0	3117	3166
-0.9	3109	3158
-0.8	3101	3150
-0.7	3174	3142
-0.6	3166	3134
-0.5	3158	3126
-0.4	3150	3118
-0.3	3142	3110
-0.2	3134	3102
-0.1	3126	3175
0	3118	3167
0.1	3110	3159
0.2	3102	3151
0.3	3175	3143
0.4	3167	3135
0.5	3159	3127
0.6	3151	3119
0.7	3143	3111
0.8	3135	3103
0.9	3127	3176
1.0	3119	3168
1.1	3111	3160
1.2	3103	3152
1.3	3176	3144
1.4	3168	3136
1.5	3160	3128

5. The following algorithm is for our cases where n=4 IFOV

   use MF=MF(1/2) - 10(2n)ϕ

   if MF(1/2)-(J-1)2n-2<MF<MF(1/2)+(10-J)2n+2

   use MF=MF(1/2)-10(2n)ϕ+10(2n+0.1)

   if MF<MF(1/2)-(J-1)2n-2 when

   MF=MF(1/2)-10(2n)ϕ

   Use MF=MF(1/2)-10(2n)ϕ-10(2n+0.1)

   if MF>MF(1/2)+(10-J)2n+2 when

   MF = MF(1/2) - 10(2n)ϕ

The above algorithms satisfy cases I and II. It is not known if the algorithms are completely general.

After the KER has been generated it can be converted to MTF by differentiating the KER and taking the Fourier Transform of the resultant line spread function (LSF)

$$LSF(y) = \frac{\partial KER}{\partial y}$$

$$MTF(f_s) = \frac{\left[(\Sigma LSF(y)\sin 2\pi f_s y \Delta y)^2 + (\Sigma LSF(y)\cos 2\pi f_s y\Delta y)^2\right]^{1/2}}{\Sigma LSF(y)\Delta y}$$

CONCLUSION

A phased knife edge reticle pattern has been described that will permit KER data to be obtained at the TM-TM calibrator configuration with scan mirror operating. Algorithms have been developed to permit KER construction via computer data reduction. The linear extent of the phased knife edge (DWG. #76770) is significantly smaller than the current MTF patterns (DWG.#73209) and thus the deleterious effect of the TM calibrator field curvature is reduced.

J. B. Young
J. B. Young

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SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

TO: J. Engel

CC: A. Gardner
R. Hummer

DATE: 12-10-79

REF: HS236-6514-1

FROM: J. B. Young

SUBJECT: An Alternative MTF Approach - Phased Knife Edge - Addendum

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Ref: HS236-6514 entitled "An Alternative MTF Approach - Phased Knife Edge

The methodology described in the referenced memo for KER Construction Algorithm was not general enough. In fact it did not cover all aspects of Cases I and II. A more complete method is given below.

KER CONSTRUCTION ALGORITHM

The desired KER can be constructed using the following sequence.

1. Search through the data stream, locate maximum and minimum signals.

2. Calculate the half intensity point S(1/2) which is equal to S(1/2) = 0.5 (Max-Min) + Min.

3. Search through the data stream and locate major frame (MF) that has its signal closest to half intensity point, S(1/2). (Use only leading edge) From Figure 2, referenced memo, we have $MF_I = 3118$ and $MF_{II} = 3167$.

4. Note leading edge (J) at which half intensity signals occur. For cases I and II

$$J_I(1/2) = 3, \quad J_{II}(1/2) = 9.$$

5. A KER function is desired. This function consists of an ordered set of signals S(i) with the corresponding associated angles $\phi(i)$. By "ordered set" is meant as $\phi(i)$ becomes more positive S(i) becomes greater.

6. The data stream (MF) must be rearranged to achieve this KER function. Thus, we need to have the following data set

$$MF(i), \phi(i), S(i)$$

Where MF is a major frame number.

7. Determine the maximum and minimum major frame within this data set. These values will depend upon the location of the half intensity signal major frame, MF(1/2).

$$MF(Min) = MF(1/2) - (J(1/2)-1)(2n+0.1) - 0.5n$$

$$MF(max) = MF(1/2) - (10-J(1/2)(2n+0.1) + 0.5n$$

Now all signals, S(i), used in the KER function must have associated major frames, MF(i), such that

$$MF(min) \leq MF(i) \leq MF(max)$$

8. The phased knife edge pattern cycle extent is given by $2n + 0.1$.

9. The relationship between MF(i) and $\phi(i)$ is

$$MF(i) = MF(1/2) + \frac{\partial n}{\partial \phi} \frac{\partial(MF)}{\partial n} \phi(i)$$

$$MF(i) = MF(1/2) - 10(2n)\phi(i).$$

10. Additional selection rules are:

If $MF(i) < MF(min)$, calculate

$MF'(i) = MF(i) + 10(2n + 0.1)$. If

$MF'(i) \geq MF(min)$, use it. If

$MF'(i) < MF(min)$ calculate

$MF''(i) = MF'(i) + 10\ (2n+0.1)$. If

$MF''(i) \geq MF(min)$, use it. If

$MF''(i) < MF(min)$ continue the same type sequence.

11. If $MF(i) > MF(max)$ calculate

$MF'(i) = MF(i)-10(2n+0.1)$. If

$MF'(i) \leq MF(max)$, use it. If

$MF'(i) > MF(max)$ calculate

$MF''(i) = MF'(i)-10(2n+0.1)$. If

$MF''(i) \leq MF(max)$, use it. If

$MF''(i) > MF(max)$ continue the same type sequence.

12. It is emphasized that the relationship

$$MF(min) \leq \left\{ \begin{array}{l} MF(i) \\ \text{or } MF'(i) \\ \text{or } MF''(i) \\ \text{or etc} \end{array} \right\} \leq MF(max)$$

must be satisfied.

I believe the above Algorithm to be general. However exhaustive checks have not been made.

G. B. Young

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INTERNAL MEMORANDUM

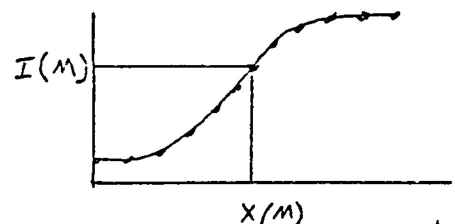
): R. Cline   CC: DATE: 5-21-79

REF: HS236-6242

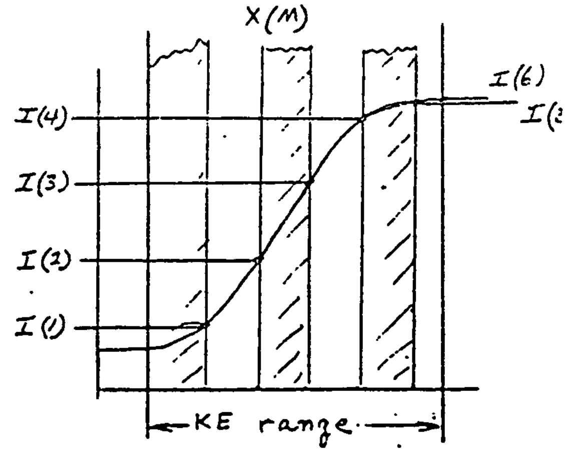
UBJECT. Square Wave Response From Edge Function   FROM: P. Thurlow

BLDG.   MAIL STA.
EXT.

It is desired to obtain square wave response (SWR) of various TM - associated optical systems. SWR can be computed directly from measured knife edge (KE) data, without going through intermediate steps of line - spread - function, MTF, etc., by using the following numerical integration method--



(1) Assume a data file containing N knife edge response values, I (M), at knife locations, X(M). (The X(M) need not be equally spaced, and I(M) (Maximum) need not be normalized to 1.0)



(2) For a single spatial frequency, ν, superpose a sufficient number of SWR bars across the KE function to cover the KE range from minimum to maximum KE.

(3) Find the unobscured area of the associated line spread function by taking differences of KE intercept values at the bar edges for each of the unobscured areas of the KE function. Sum those differences, calling the sum $S_1(\nu)$. In the illustration-

$$S_1(\nu) = (I(2) - I(1)) + (I(4) - I(3)) + (I(6) - I(5))$$

In general, KE data points will not correspond with intercept locations, and a linear interpolation would be appropriate to obtain KE function values at intercepts.

(4) Analytically, shift the bar pattern 0.01 cycle of spatial frequency (right or left). Repeat step (3), finding $S_2(\nu)$.

Continue, shifting bars in the same direction by .01 cycle increments, covering one complete cycle of bar pattern, and generating $S_1(\nu)$ ......$S_{100}(\nu)$.

(5) Find $S(\nu)$ maximum and $S(\nu)$ minimum values out of the 100 $S(\nu)$ set.

(6) Compute SWR $= \dfrac{S(\nu)\ max - S(\nu)\ min}{S(\nu)\ max + S(\nu)\ min}$

(7) Repeat steps (2) thru (6) for other spatial frequencies of interest.

(8) Store and print a table of SWR (ν) VS. (ν)

(ν)	SWR (ν)
....	....
....	....

Since computations are executed at memory speed, the overall run time, for bar patterns $\approx$1 to 100 bars per KE range, should not be excessive.

Paul Thurlow

Paul Thurlow

Distribution:

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SANTA BARBARA RESEARCH CENTER
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INTERNAL MEMORANDUM

TO: J. Young

CC: R. Cline
J. Engel
Optics File

DATE: 5 June 1981

REF: 2221.310
HS-236-7483

FROM: P. Thurlow

SUBJECT: SWR for T.M. Engineering Model Detectors After Deconvolution of Calibrator Blur

BLDG. 774 MAIL STA. 78
EXT. 4267

An attachment shows preliminary SWR values for Band 1-5, 7 of T.M. Engineering Model detectors. The SWR per band are averaged over those detectors which appeared to be operable and produced a reasonable clustering of SWR values. The degree of clustering obtained is indicated by the associated sigma values.

To obtain true SWR for the EM, spot broadening introduced by the calibrator must be accounted for in some way. If we were dealing with MTF instead of SWR, the procedure would be to divide combined EM-calibrator MTF by the 30 meter bar, calibrator measured MTF of 0.88. This would elevate the EM MTF by a factor of 1/.88 or 1.136.

In the case of deconvolving SWR numbers, we do not have such a simple rule available and will resort to blur size analysis to produce a SWR enhancement factor comparable to the MTF enhancement factor. One might expect the SWR factor to be larger than the MTF factor by reason of the steeper slope of SWR versus blur size as compared to a lower MTF slope value.

<u>Blur Size and SWR Analysis</u>

(1) Compute Calibrator Blur Diameter, β:

Use a 30 meter bar calibrator MTF = 0.88. From Smith, figure 13.51, p.405, MTF = 0.88 at a (ν)(β) product of about 0.30, where ν= spatial freq. in cycles/rad and β = blur diameter in radians. A more accurate value of νβ is obtained using Smith, eq. 11.43, p.320:

$$MTF(\nu) = \frac{2J_1(\pi\beta\nu)}{\pi\beta\nu} \quad ; \quad J_1 = \text{1st order Bessel Function}$$

By trial:

$$MTF(.90) = \frac{2J_1(.90)}{.90} = \frac{2 \times .4059}{.90} = .9020$$

$$MTF(1.00) = \frac{2J_1(1.00)}{1.00} = \frac{2 \times .4401}{1.0} = .8802$$

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The .8802 MTF should be close enough to avoid further extrapolation measures. Therefore:

$$\pi\beta\nu = 1.00 \qquad \beta\nu = 1/\pi = .3183$$

@ 30 meter bar; $\nu = 11{,}765$ cycles/radian

$$\beta = \frac{.3183}{\nu} = \frac{.3183}{11{,}765} = 27.05\ \mu\text{rad calibrator blur}$$

(2) Compute blur $\delta_{EM/CAL}$ for the EM-calibrator combination, using a rough value of $\overline{SWR}$ = 0.270 from the attached set of BL-16 measurements:

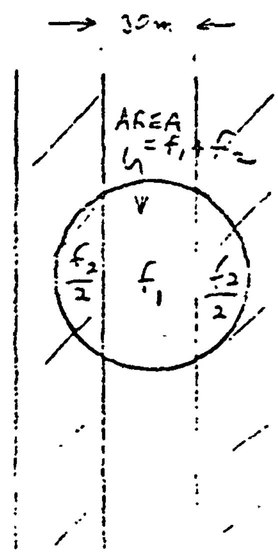
$$SWR \equiv \frac{S_{max} - S_{min}}{S_{max} + S_{min}} = .270 = \frac{S_{max}/S_{min} - 1}{S_{max}/S_{min} + 1}$$

$$S_{max}/S_{min} = 1.740$$

If spot fractional area f_1 is exposed at Smax, and f_2 is exposed at Smin:

$$\frac{S_{max}}{S_{min}} = \frac{f_1}{f_2} = \frac{A - f_2}{f_2} = \frac{A}{f_2} - 1 = 1.740$$

$$\frac{A}{f_2} = 2.740$$



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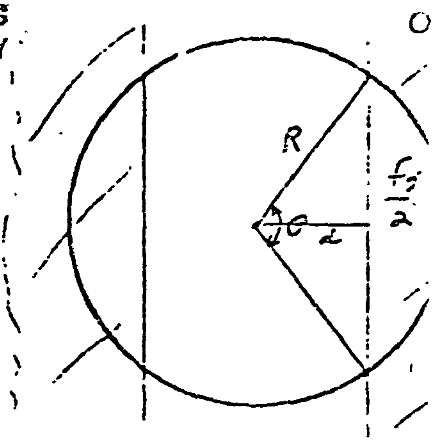

The segment area, $f_{2/2}$ is:

$$f_2/2 = R^2/2\,(\theta - \sin\theta)$$

$$\therefore\ A/f_2 = \frac{\pi R^2}{R^2(\theta - \sin\theta)} = \frac{\pi}{\theta - \sin\theta} = 2.740$$

$$\therefore\ \theta - \sin\theta = \frac{\pi}{2.740} = 1.146$$

The θ value will be about 115°.
To find θ exactly, bracket 115°, and interpolate:

$$@\ \theta = 110°:\ \theta - \sin\theta = 1.919 - .9397 = 0.979$$

$$@\ \theta = 120°:\ \theta - \sin\theta = 2.094 - .8660 = 1.228$$

Interpolating: $\theta(1.146) = 110° + 15°\left(\frac{0.167}{0.249}\right) = 116.71°$

Now, solving for the blur diameter: β = 2R

$$\frac{d}{R} = \cos\frac{\theta}{2} = \cos 58.355° = .5246$$

$$R = \frac{d}{\cos(\frac{\theta}{2})} = \frac{\beta A R/2}{\cos(\theta/2)} = \frac{21.25\,\mu rad}{.5246} = 40.51\,\mu rad$$

$$\boxed{\therefore\quad \beta = 2R = 81.02\ \mu\text{rad blur for EM/CAL}}$$

(3) De-convolve calibrator blur from combined blur to get EM blur. This involves an assumption that the blurs combine as RSS, which is reasonable, but perhaps should be verified in detail. Using that assumption:

$$\beta_{C-EM} = \sqrt{\beta_{EM}^2 + \beta_C^2}$$

$$\beta_{EM} = \sqrt{\beta_{EM-C}^2 - \beta_C^2} = \sqrt{(81.02)^2 - (27.05)^2} = 76.37\,\mu rad$$

$$\therefore\ R_{EM} = \frac{\beta_{EM}}{2} = 38.18\,\mu rad$$

(4) Find obscuration area and SWR for EM blur:

$$\cos^{-1}\frac{\theta}{2} = \cos^{-1}\frac{d}{R_{EM}} = \cos^{-1}\frac{21.25}{38.18} = .5566;\quad \frac{\theta}{2} = 56.17^{\circ}$$

$$\theta - \sin\theta = 1.961 - .925 = 1.036$$

$$A/f_2 = \pi/(\theta - \sin\theta) = \pi/1.036 = 3.032$$

$$\frac{S_{max}}{S_{min}} = \frac{f_1}{f_2} = \frac{f}{f_2} - 1 = 2.032$$

$$SWR_{EM} = \frac{(S_{max}/S_{min}) - 1}{(S_{max}/S_{min}) + 1} = \frac{1.032}{3.032} = 0.3403$$

Conclusion

From the above, it would appear that the SWR enhancement ratio by calibrator blur deconvolution should be the order of .34/.27 or $\approx$ 1.26.

Applying this factor to measured $SWR_{EM/CAL}$:

		SWR Before Calibrator Deconvolution	SWR After Calibrator Deconvolutic
Band:	1	.2801	.3529
	2	.2718	.3425
	3	.2388	.3008
	4	.3014	.3797
	5	.2439	.3073
	7	.2927	.3688

P. Thurlow

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ENGINEERING MODEL SQUARE WAVE RESPONSE

SUMMARY OF RESULTS TO 2 JUNE 1981

BAND 1	$\overline{SWR}$ @ 30 METER BAR	σ SWR
16 Averageable Detectors	0.2801	0.0168
BAND 2		
16 Averageable Detectors	0.2718	0.0214
BAND 3		
11 Averageable Detectors	0.2388	0.0243
BAND 4		
14 Averageable Detectors	0.3014	0.0212
BAND 5		
2 Averageable Detectors	0.2439	0.0029
BAND 6		
(TBD) Averageable Detectors	(TBD)	(TBD)
BAND 7		
5 Averageable Detectors	0.2927	0.0439

END

DATE

FILMED

AUG 8 1983