E7.4-10.27.7
CR-136663

Evaluation of ERTS-1 Image Sensor Spatial Resolution in Photographic Form

(E74-10277) EVALUATION OF ERTS-1 IMAGE SENSOR SPATIAL RESOLUTION IN PHOTOGRAPHIC FORM Process Report, 1 Nov. 1973 - 1 Jan. 1974 (Arizona Univ., Tucson.) 13 p HC $3.00 CSCL 05B G3/13

N74-16026

Unclas 00277

R. L. Antos
R. A. Schowengerdt
P. N. Slater

Type I
Progress Report 8

Prepared for
NASA/ERTS Contract Number NAS 5-21849
Proposal Number 618

Principal Investigator
P. N. Slater
(UN237)

December 1973

Introduction

This report describes progress on this contract during the period 1 November 1973 to 1 January 1974. Analysis of imagery from 11/29/72 and 1/4/73 is continuing. Digitized data from microdensitometer scans of imagery taken on 4/4/73 has been received and is presently being organized into a format suitable to subsequent analysis. Work has been initiated to locate or develop a program to read the computer compatible tapes for ERTS-1 imagery from 4/4/73.

Discussion

A majority of this reporting period was devoted to continuing the analysis of imagery from 11/29/72 and 1/4/74. This analysis consisted of two phases. The first phase involved the computation of polynomial coefficients that would yield a good analytical approximation to the modulus and phase constituents of the microdensitometer scan aperture optical transfer function (OTF). The second phase analytically determined the required correction for irradiance falloff as a function of field angle ($\cos^4\phi$), for arbitrary scan lines, in the aerial photographs.

In addition, the microdensitometer scans of imagery from 4/4/73 were completed and received. The analog output (microdensitometer chart record) has been checked against data log to verify order of images scanned and establish required computer program parameters for the data organization programs previously developed. The application of these programs has been initiated to organize data in a format suitable for analysis.

A problem exists in the location of a program to read the computer compatible tapes (CCT's) from ERTS-1 imagery from 4/4/73. This is discussed along with a review of the analysis phases in the following sections of this report.

Slit Transfer Functions

A polynomial fit was applied to the sampled Optical Transfer Function (OTF) data for the microdensitometer scan apertures previously given in Progress Report #6. The resulting modulus and phase transfer functions are shown in Figures 1 - 2 and supercedes all previous aperture OTF data.

Note that the modulus is an even function of frequency so that only the even power coefficients of the polynomial approximations are significant . Similarly the phase is an odd function and thus only odd powers are used in the approximation. The approximating curves are therefore of the form:

modulus $M(f) = 1 + Cf^2 + Ef^4$

phase $P(f) = Bf + Df^3$

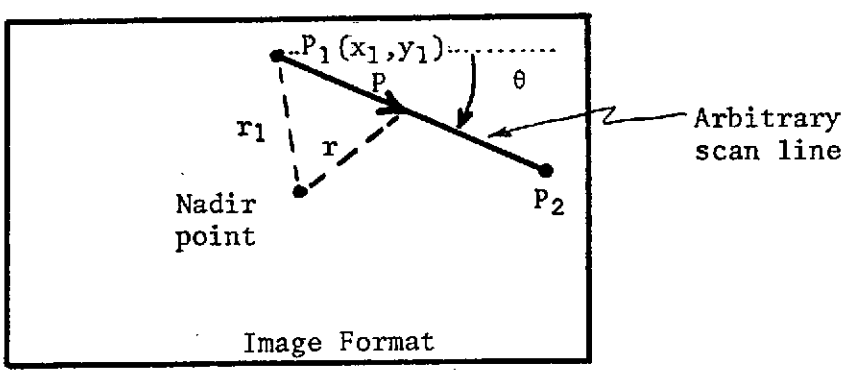
The two frequency values necessary to determine the two coefficients were chosen to give a good polynomial approximation over the entire frequency range of interest. In Fig. 2 two curves are shown for the 23.5 x 138 μm slit. Each curve used a different pair of frequency values to calculate the coefficients, giving a different polynomial approximation in each case. Also note the phase parts of the OTF's are essentially zero in the frequency range of interest.

These curves represent the correction that must be made, in frequency space, to the digitized imagery data obtained from the convolution of the microdensitometer aperture with the photographic imagery. These aperture OTF's will be divided into the Fourier transform of the digitized image data to obtain the true data spectrum. This will then be inverse Fourier transformed to obtain the true data, as described in Progress Report #6.

Cos^4 Correction

The irradiance falloff across the image plane of an aerial camera system is a function of the field angle, ϕ, and obeys the relationship $\cos^4\phi$. Since, in the U-2 imagery scans only, a large range of field angles is covered by the scan a correction must be made to the exposure values. The required correction is obtained by multiplying these exposure values by the factor $1/\cos^4\phi(P)$, where P is the image point of interest. Since our scans are at an arbitrary angle and position within the format, the following process must be followed.

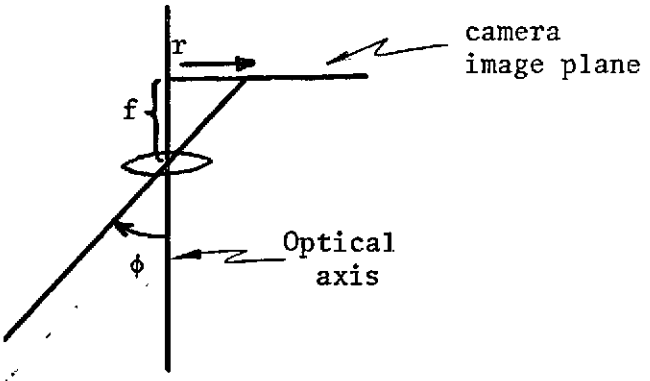
Given an arbitrary scan line in the image format, as shown below, image



position can be described in terms of P, the distance along line P_1P_2 from the point P_1. This distance then defines r, the radius from the nadir point to the position P in the image format:

$$r(P) = [P^2 + r_1^2 + 2P(x_1\cos\theta + y_1\sin\theta)]^{1/2}$$

Then, using the geometry for aerial camera system shown below,



the field angle, ϕ, can be calculated using

$$\phi = \tan^{-1}\left(\frac{r}{f}\right)$$

where f is the known focal length of the camera system.

The variation for the required correction factor, $1/\cos^4\phi$, as a function of the image position along the microdensitometer scan line is shown in figures 3 and 4 for the imagery obtained on 11/29/72 and 1/4/73. Note the significant difference in the value of the correction factor required between microdensitometer scan line 1, 2 and 3 for the imagery on 11/29/72. This is due to the fact that scan lines 1 and 2 were parallel and closely spaced while scan line 3 was at a completely different orientation and position in the image format. This same argument explains the difference between the correction required for the imagery taken on 11/29/73 and those taken on 1/4/73.

ERTS Computer Compatible Tapes (CCT's)

An initial investigation into locating a program to read the ERTS CCT's has not been successful. Several of the ERTS investigators that use ERTS CCT's were contacted during this reporting period. However, all of the programs utilized by these investigators were written for IBM computer systems and based on a 9 track tape input. The only computer system presently available for our use is a CDC 6400, with a 7 track tape input.

We are presently awaiting a list of all CDC 6400 installations from Control Data Corporation. This will be cross referenced against a list of ERTS investigators to identify those that may be able to provide the program information desired.

If our search is unsuccessful then a program will be written specifically for our purposes during a future reporting period.

Current Status of Acquired Imagery

Set	Flight Date	Aircraft (A/C) Vinten	Scanner	# Frames	ERTS-1 MSS	Microdensitometer scans
1	8/22/72 8/23/72 Arizona	✓	NA	184	✓	-
2	11/29/72 San Francisco	✓	✓*	18	✓	✓
3	1/4/73 San Francisco	✓**	✓*	51	✓	✓
4	4/4/73 San Francisco	✓	✓*	48	✓	✓
5	6/15/73 San Francisco	✓	✓	75	✓ ***	-
6	Requested for	on order	not requested		ID not available yet	-

* Scanner data not suitable for analysis because of severe geometric distortion arising from the lack of a gyrostablized platform on the A/C.

** Band 001 (green) malfunction, no imagery.

***ERTS-1 imagery of San Francisco was not acquired on 6/15/73. Therefore imagery from the previous (5/28/73) and following (7/3/73) cycles and from the adjacent 6/14/73 pass have been acquired.

Current Status of Analysis

Calibration, matching, and scaling are in progress for the data from 11/29/72 and 1/4/73 and all of the data is at the stage of generating OTF's. CCT's of ERTS-1 image # 1255-18183 (4/4/73) have been received. This data will be compared to the system corrected MSS photographic product to determine the amount of image degradation introduced in the EBR-photographic steps.

Acknowledgements

Mead Technology Laboratories (Dayton, Ohio), an Industrial Associate of the Optical Sciences Center, is performing the microdensitometer scanning for this contract.

ERTS Frames Studied

Data Set	Frame #'s	Bands
11/29/72	1129-18181	4, 5, 6
1/4/73	1165-18173,-18175	5, 6

Figure 1: Modulus and Phase of Microdensitometer Optical Transfer Functions

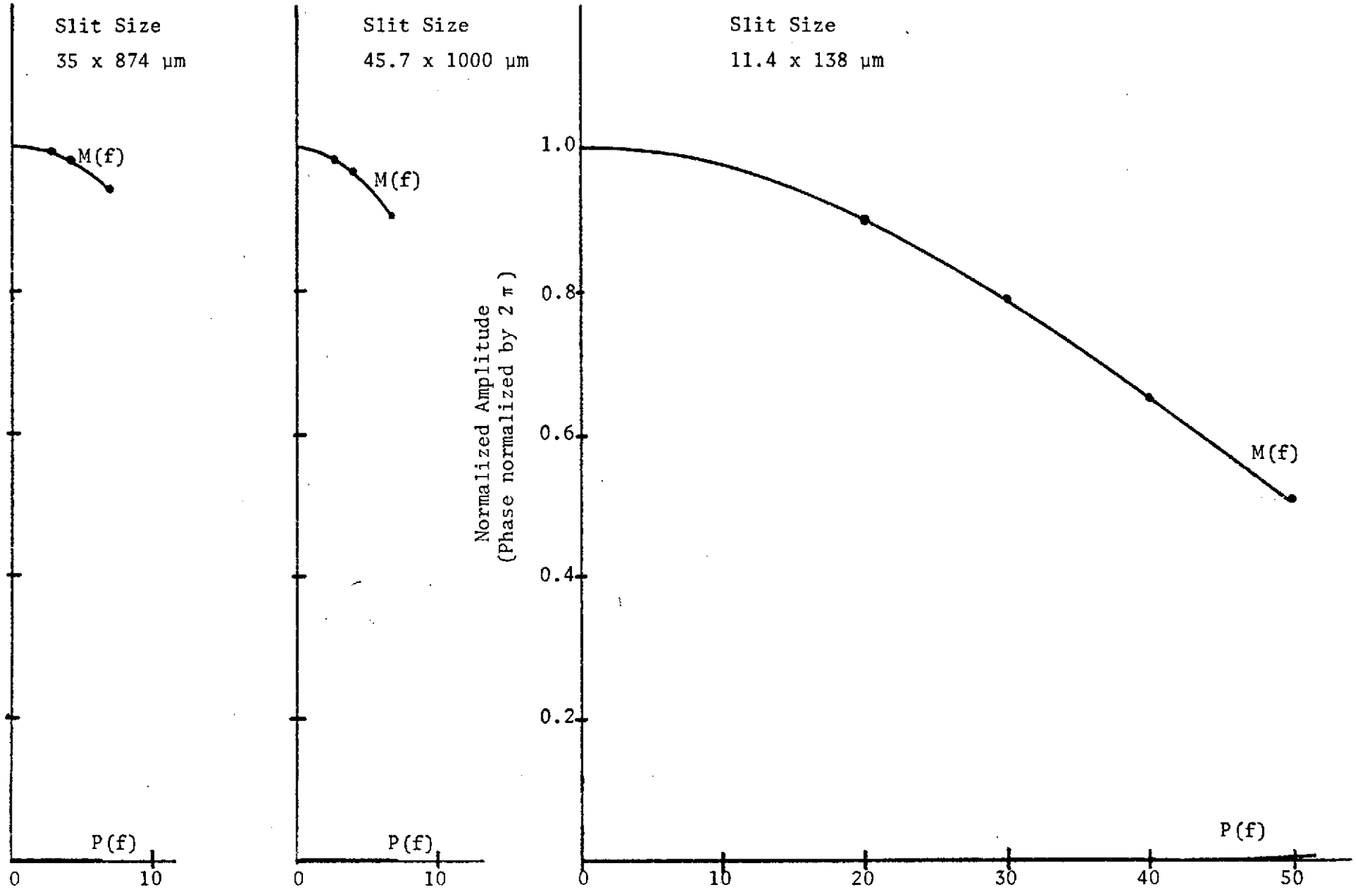


Figure 4: Correction Factor vs. Image Position

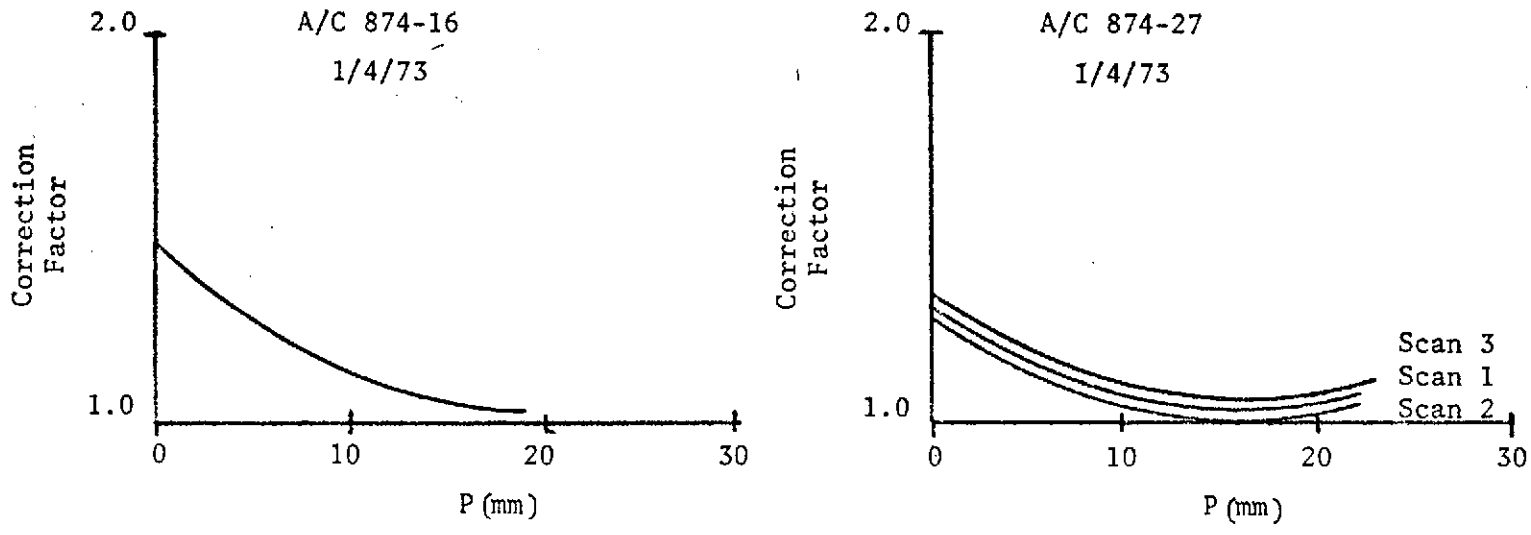


Figure 2: Modulus and Phase of Microdensitometer Optical Transfer Functions

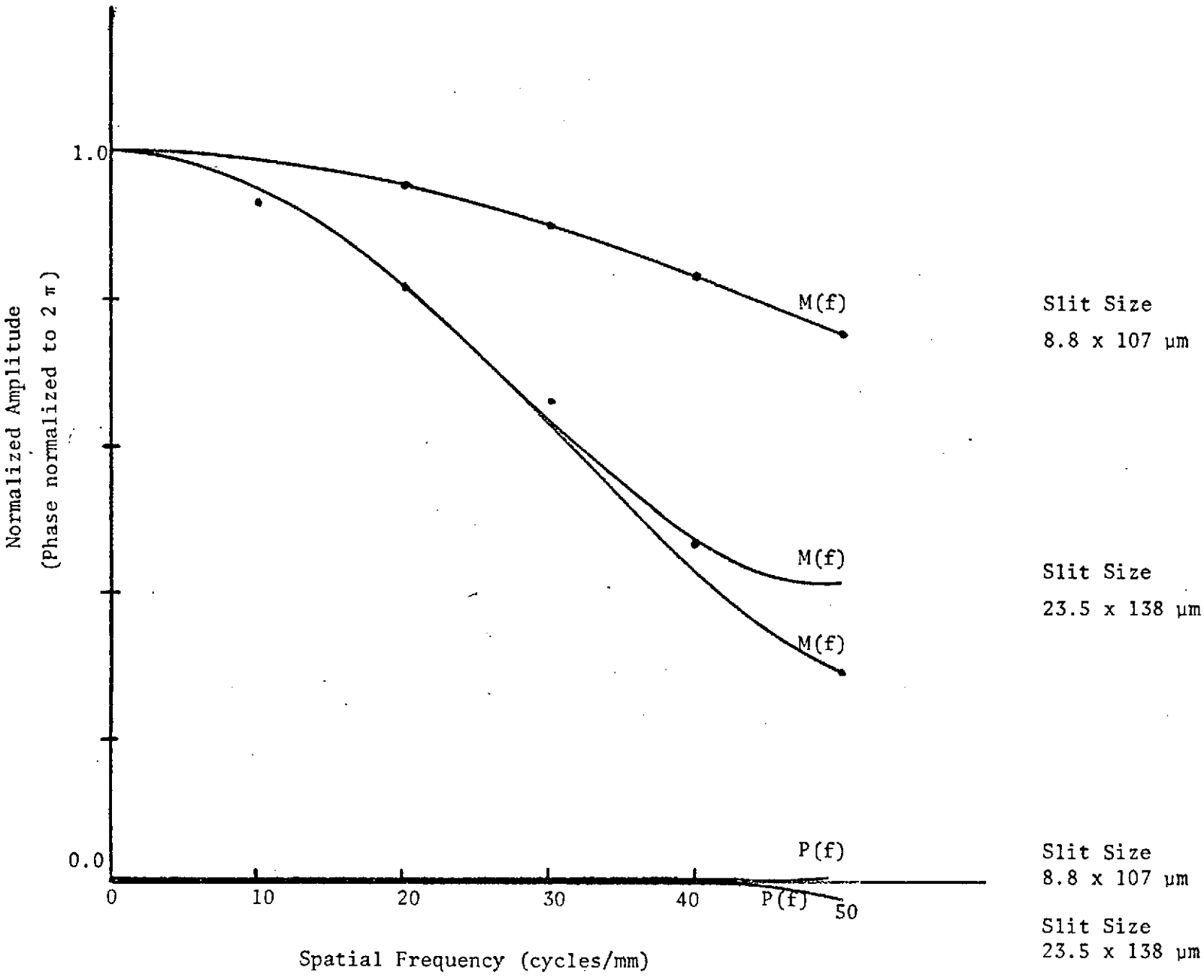
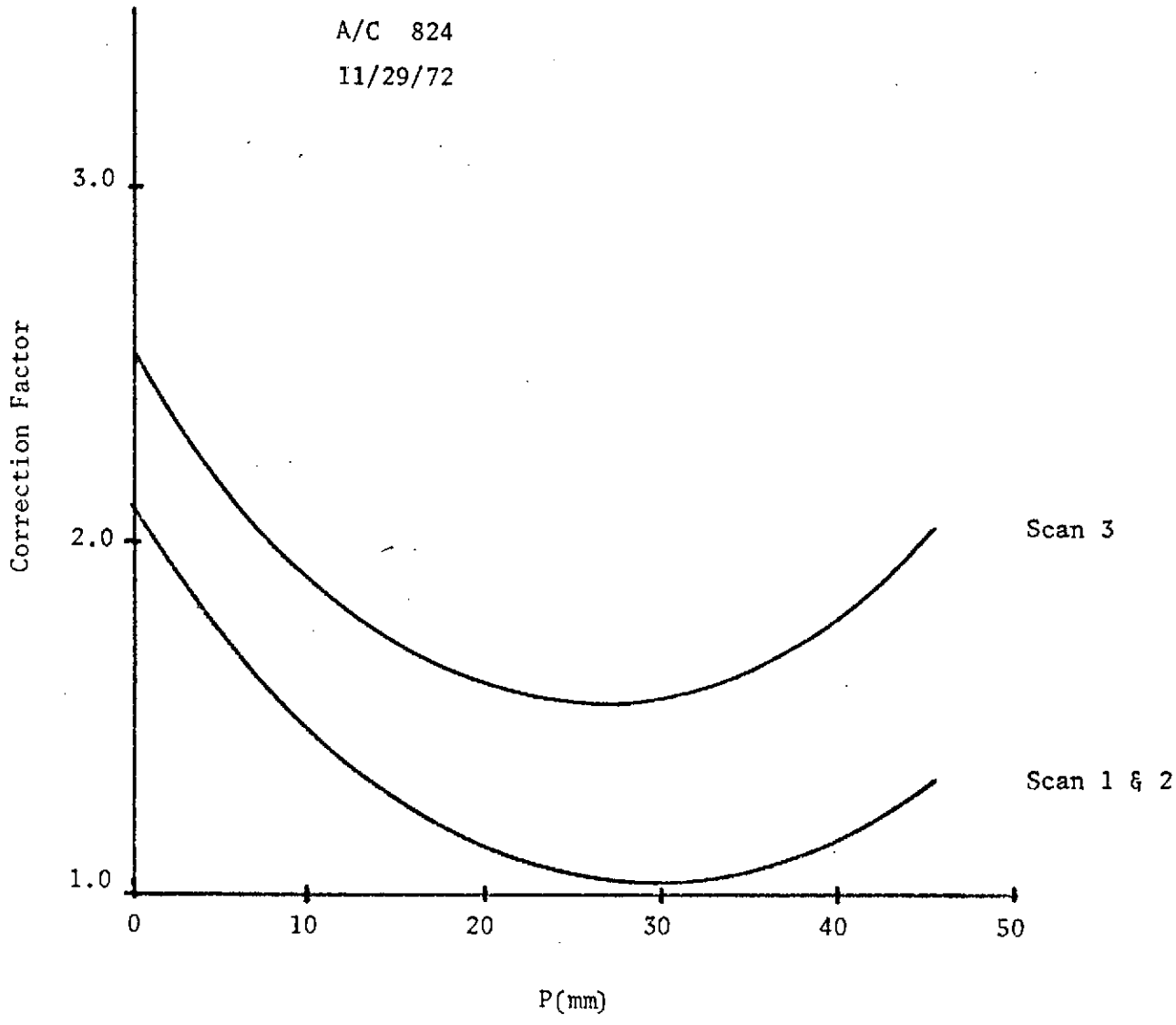


Figure 3: Correction Factor vs. Image Position



REPORT SUMMARY

Evaluation of ERTS-1 Image Sensor Spatial Resolution
in Photographic Form

Type I Report # 8

Category 9a - Sensor Technology

This report describes progress on contract number NAS 5-21849, during the period 11/1/73 - 1/1/74. A review of the analysis of ERTS-1 and U-2 imagery is given in terms of correction for irradiance falloff as a function of field angle in aircraft images and correction of digital data by the microdensitometer optical transfer functions. In addition, microdensitometer scans of imagery from 4/4/73 were completed and received. Optical Transfer function analysis is continuing for imagery from 11/29/72, 1/4/73, and 4/4/73.