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LANDSAT-4 THEMATIC MAPPER
MODULATION TRANSFER FUNCTION (MTF) EVALUATION

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MODULATION TRANSFER FUNCTION (MTF)
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Introduction

During this contract period we completed TM MTF analysis using the San Mateo Bridge as a target. Both the December 31, 1982, and August 12, 1983, TM scenes have been analyzed. A summary of the results are reported here. We also obtained MTF results from comparison of the TM bands 1 and 4 with the aerial MSS bands 3 and 7 acquired at seven meter resolution on August 12, 1983. These preliminary results are also reported here.

MTF Results - San Mateo Bridge Summary

Using identical procedures to those applied to the December 31, 1982, TM scene (January 16, 1984, and April 5, 1984, progress reports), the TM MTF was measured from the August 12, 1983 scene. The MTFs for bands 1, 2, 3, 4, 5 and 7 are shown in Figures 4-8. Band 6 was again deleted because of its much lower resolution and consequent poor image contrast. For comparison purposes the MTFs reported earlier for the December 31, 1982, scene are shown as Figures 1-3. It can be seen that the results from the two dates are comparable.

The effective-instantaneous-field-of-view (EIFOV) was calculated for each band on both dates and is shown in Table 1.

Table 1

TM EIFOV (m)
San Mateo Bridge Analysis

	Date	
band	12/31/82	8/12/83
1	-	49.8
2	-	50.9
3	33.6	48.1
4	40.8	45.4
5	41.9	46.9
6	-	-
7	40.0	44.5

The EIFOV increases about + 10% for bands 4, 5 and 7 between the two dates. This could possibly be explained by the change in resampling function in early 1983 in the ground segment processing. The much large difference exhibited by band 3 could be an indication of higher noise levels (lower signal-to-noise) in the earlier scene which tend to bias the MTF to higher values. Bands 1 and 2 from the earlier data had such low contrast that they were not useful for MTF analysis.

Some data on image contrast were collected for the two scenes and are given in Table 2.

Table 2

Image Contrast Comparison

Date	band	Average gray level water	bridge	contrast
12/31/82	1	62.1	64.1	1.03
	2	24.6	25.3	1.03
	3	22.6	24.6	1.14
	4	10.4	15.0	1.44
	5	5.8	12.7	2.19
	7	3.4	8.9	2.61
8/12/83	1	96.6	106.6	1.10
	2	35.1	40.4	1.15
	3	28.7	39.4	1.37
	4	12.8	24.9	1.95
	5	8.1	25.1	3.1
	7	4.9	18.5	3.78

The contrast is calculated as the ratio average bridge gray level to average water gray level. It can be seen from Table 2 that bands 1 and 2 are relatively low contrast on both dates, as is band 3 on the earlier date. It is probable that an image contrast of at least 1.3 is necessary for accurate MTF calculations.

MTF Results-Two Image Analysis

On August 12, 1983, aircraft multispectral imagery was obtained in the San Francisco area in conjunction with a Landsat-4 overpass (and data acquisition test with the TDRSS). One of these sets of data was obtained with 11 spectral bands and at a ground resolution of about seven meters. Because of their much higher spatial resolution, these data may be used to "calibrate" the spatial frequency content of the corresponding TM data and thereby yield the TM MTF.

For the initial tests, we selected an area around the Stockton Sewage Pond east of San Francisco because of its high contrast edges in a variety of directions. The first step in the procedure is registration of this data to the TM data, which therefore serves as the reference coordinate system. To avoid aliasing resulting from under-sampling of the aerial data, the TM data were magnified a factor of four times by bilinear resampling. The effective sample interval for the TM was then seven meters since we began with the P-data which has been resampled to 28.5 meters. Control points were then visually located in the TM and aerial images and a polynoimal warp was performed on the aerial image to register it to the TM image. Again, bilinear resampling was used. TM band 1 and MSS band 3 were paired as similar spectral bands. In addition, the MSS data were linearly scaled to match the contrast of the corresponding TM image.

After registration, the FFT of both sets of data was calculated. The ratio of the TM image FFT to the aerial image FFT then yields the raw transfer function for the TM. We found that the raw transfer functions were very noisy, a characteristic of this technique. The signal-to-noise ratio is much lower at each frequency in a 2-D FFT of a 2-D image than in the concentrated energy found in the 2-D FFT of a linear target, such as the San Mateo Bridge. Because

this noise was of a spikey type, we filtered the real and imaginary parts of the FFT separately with a 3 x 3 median filter. This resulted in considerable smoothing of the raw data but did not alter the shape of the underlying transfer function which is much broader than 3 x 3 pixels.

Profiles of the 2-D MTF were extracted along 0^{o}, 90^{o}, $+45^{o}$ and -45^{o} azimuth angles and approximated by a power series polynomial as in all of our earlier MTF analysis. The results are shown in Figures 7- 8. The profiles along 0^{o} and 90^{o} are clearly in error and cannot be explained at this time. The more reasonable results along $+45^{o}$ and -45^{o} were used to calculate the EIFOVs given in Table 3. We see that they are comparable to, but larger than those obtained from the San Mateo Bridge analysis.

Table 3

TM EIFOV (m)
Two-image analysis

band	Azimuth angle $+45^{o}$	-45^{o}
1	55.1	65.4

Summary

We completed the San Mateo Bridge MTF analysis and began the two-image analysis during this contract period. The bridge results are consistent on both TM image dates for bands 4, 5 and 7 but there are indications that bands 1, 2 and 3 suffer from low contrast and consequently low signal-to-noise in the derived MTFs. The two image analysis produced reasonable results along $+45^{o}$ and -45^{o} azimuths in the 2-D MTF but poor results along 0^{o} and 90^{o} azimuths. This work is continuing in the current contract period.

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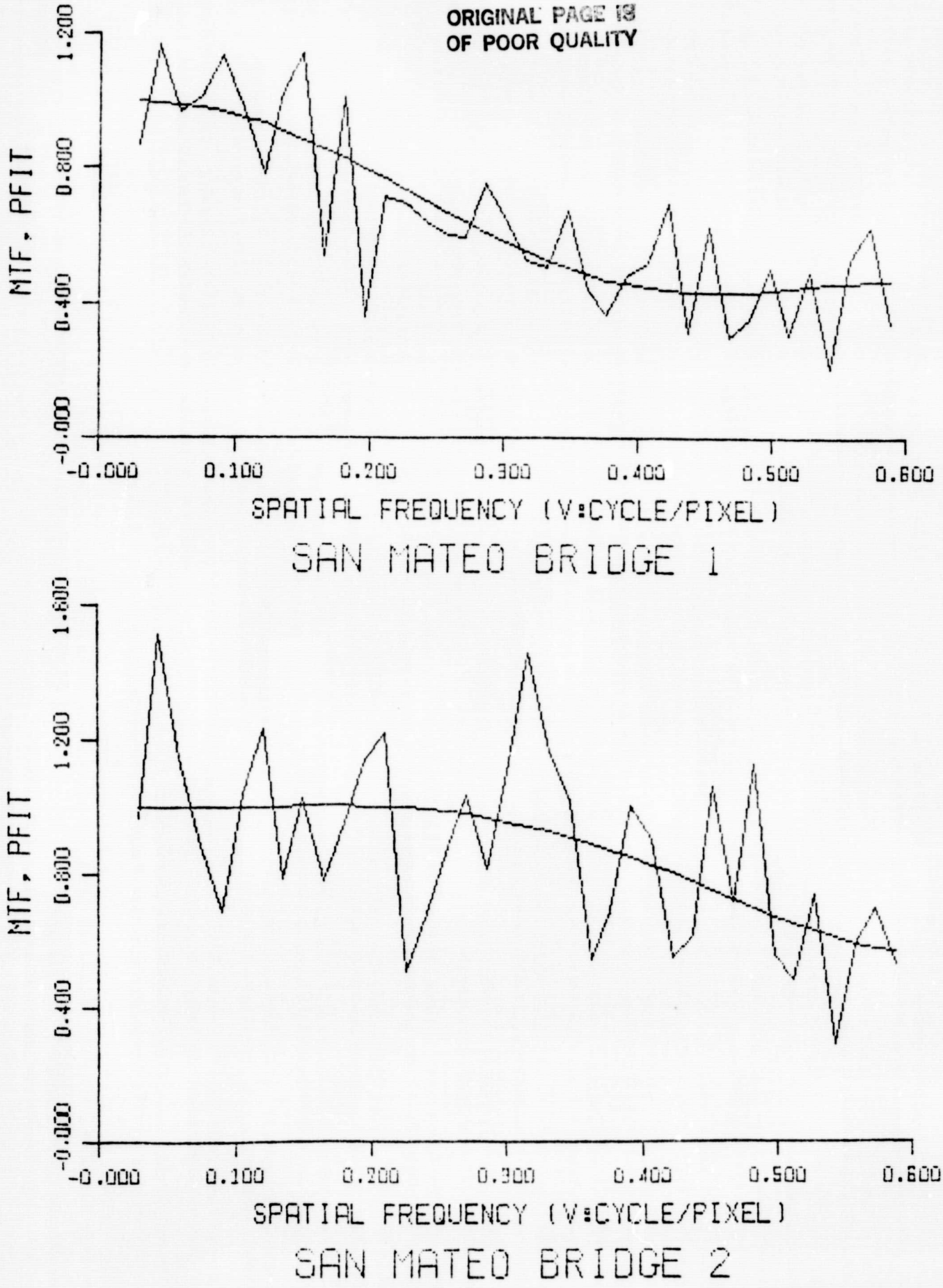

Figure 1. Overall TM system MTFs for bands 1 and 2 - 12/31/82 scene

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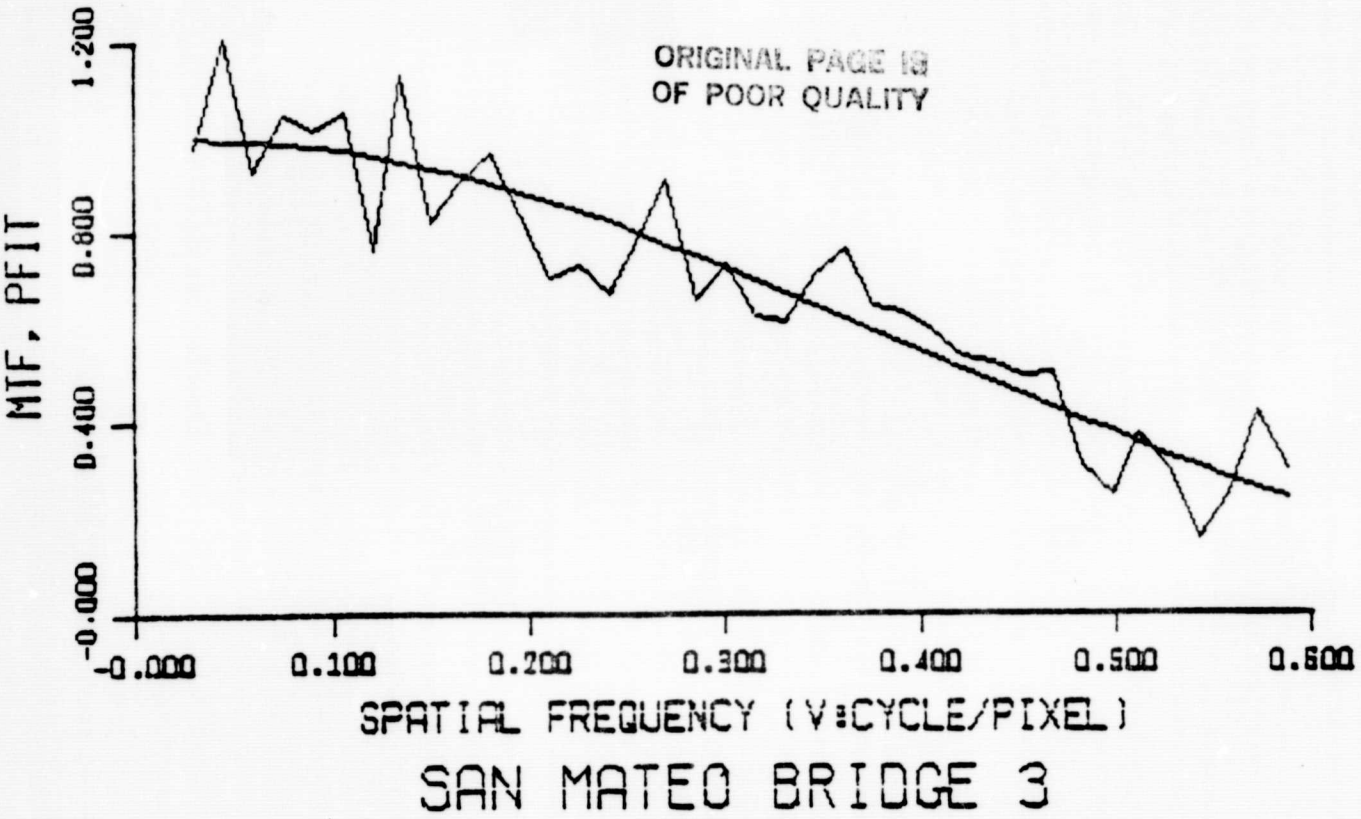

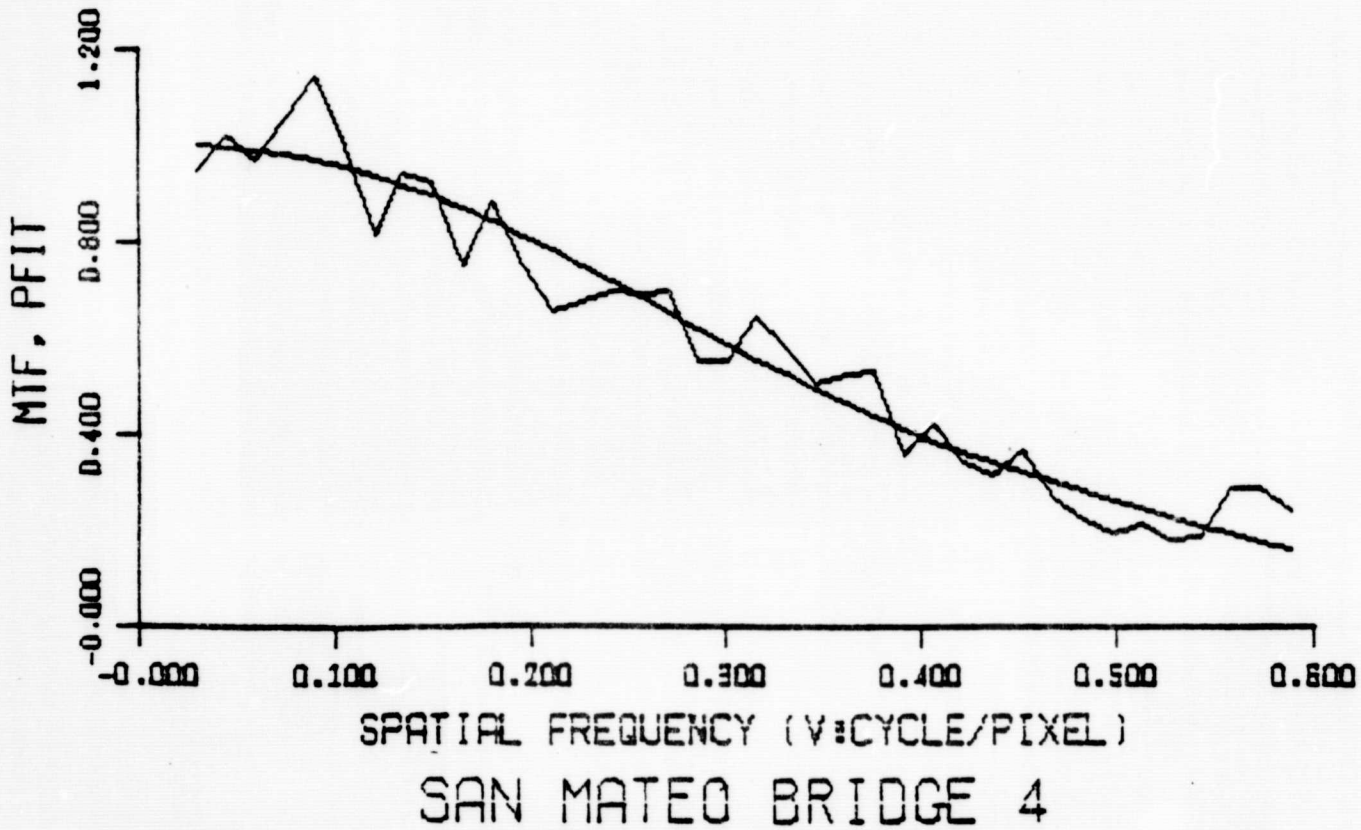

Figure 2. Overall TM system MTFs for bands 3 and 4 - 12/31/82 scene

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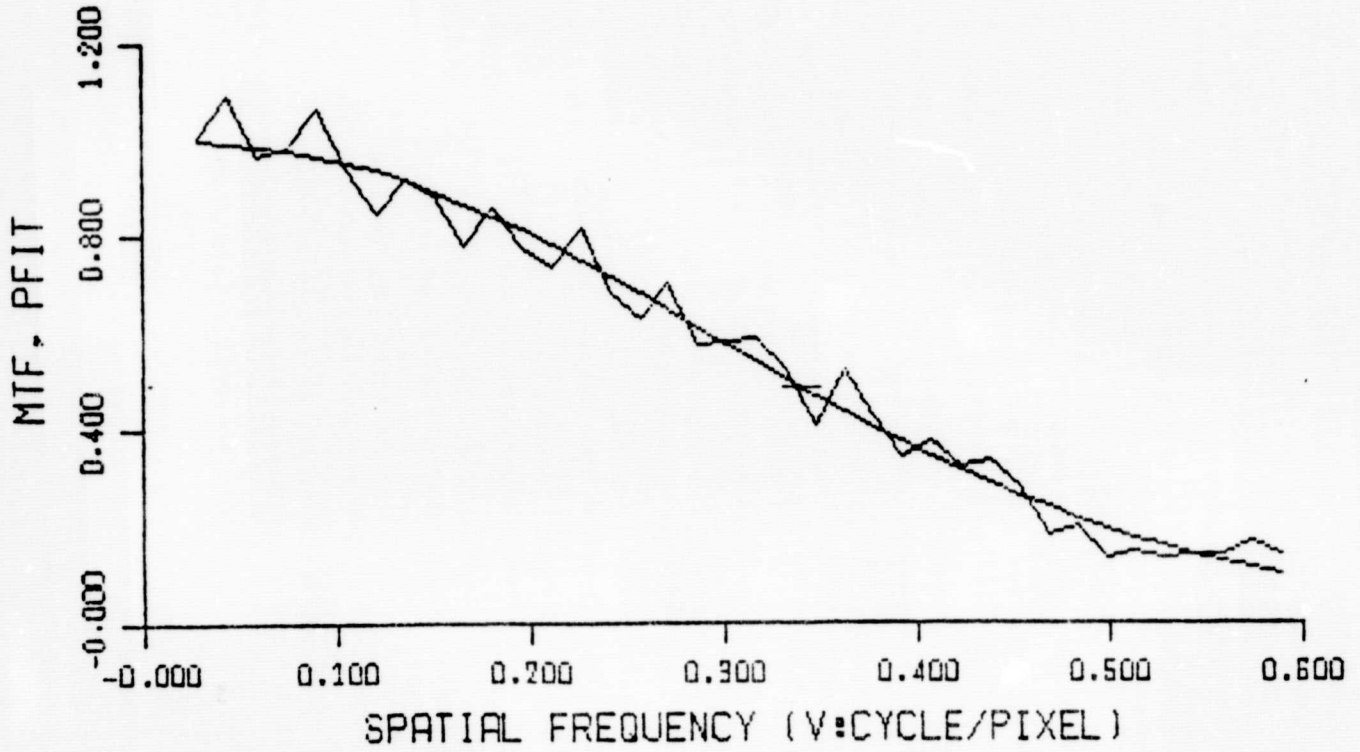


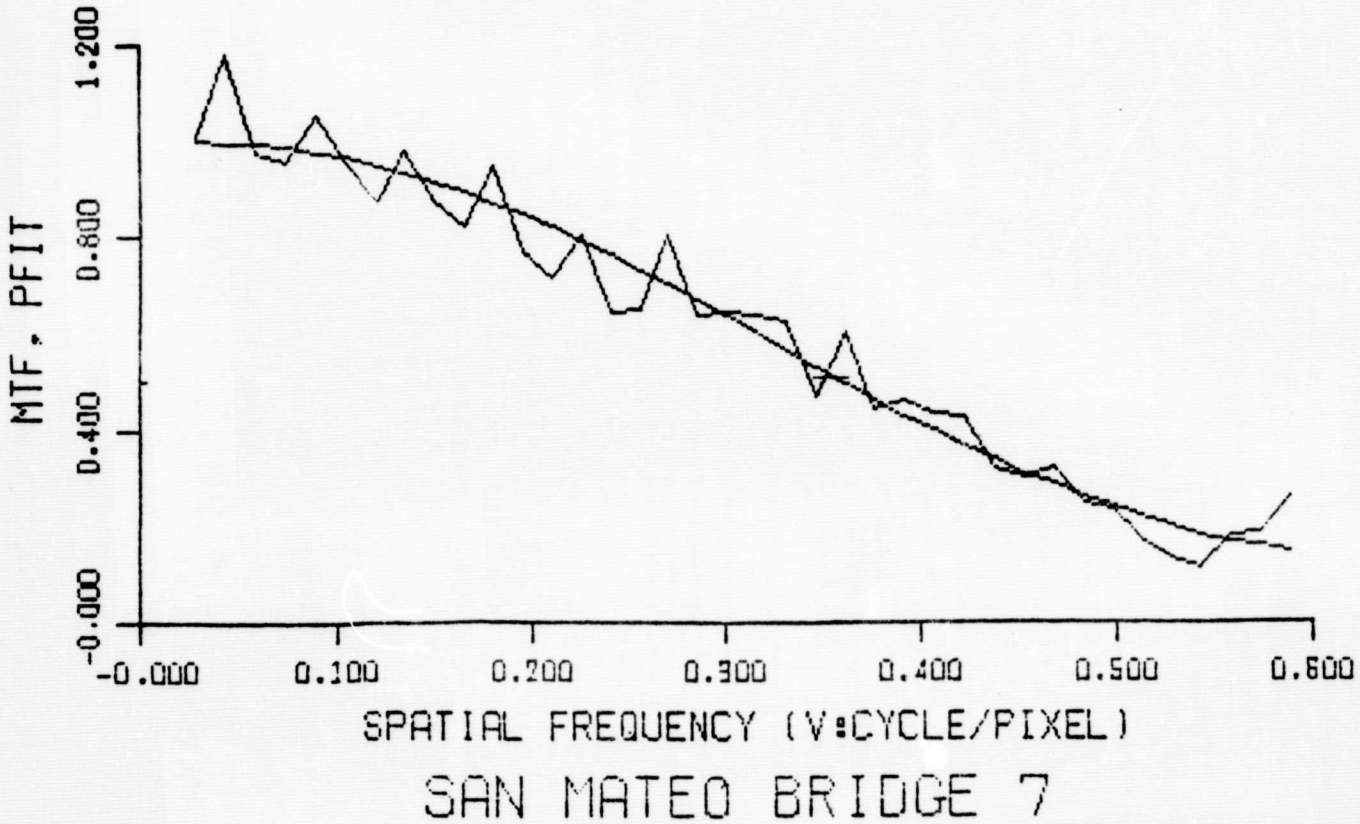
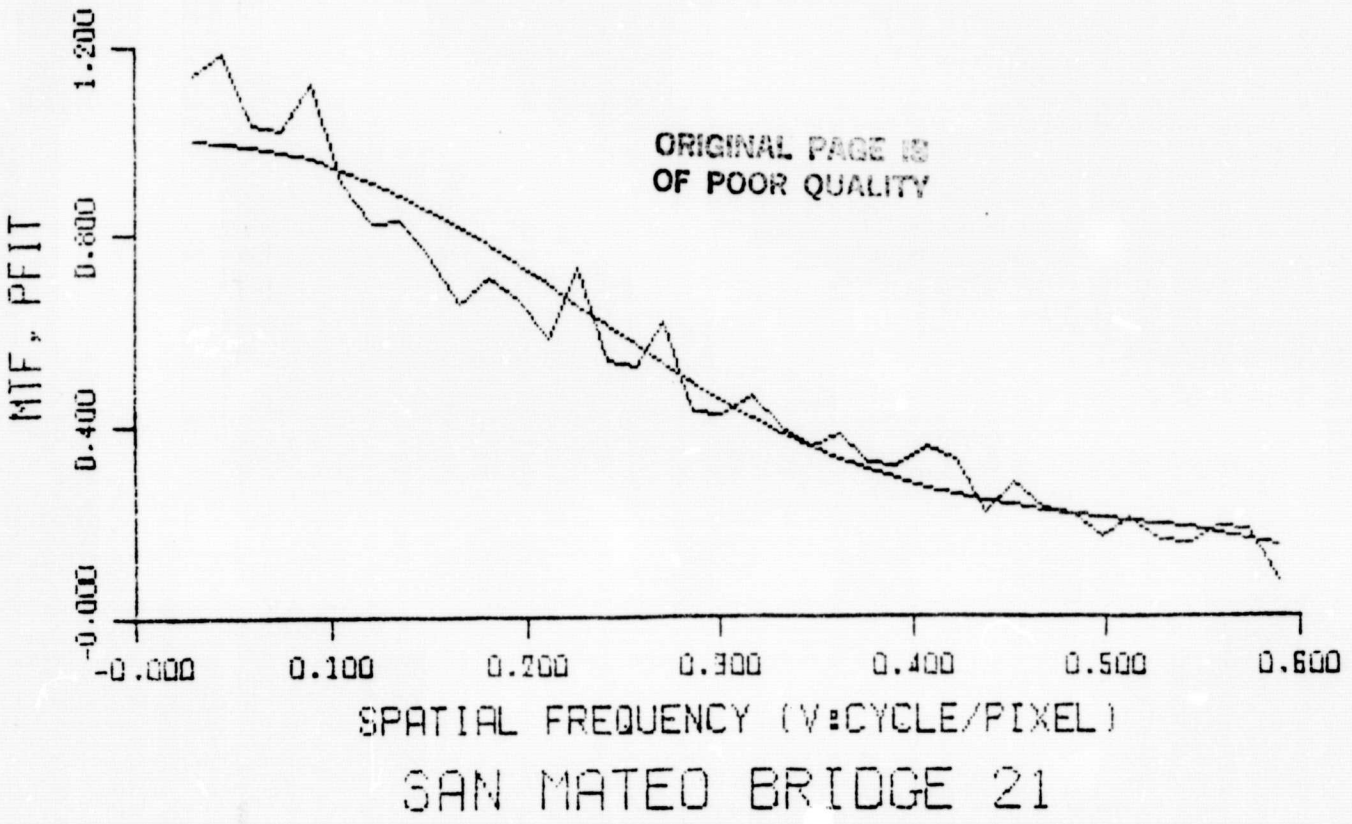


Figure 3. Overall TM system MTFs for bands 5 and 7 - 12/31/82 scene



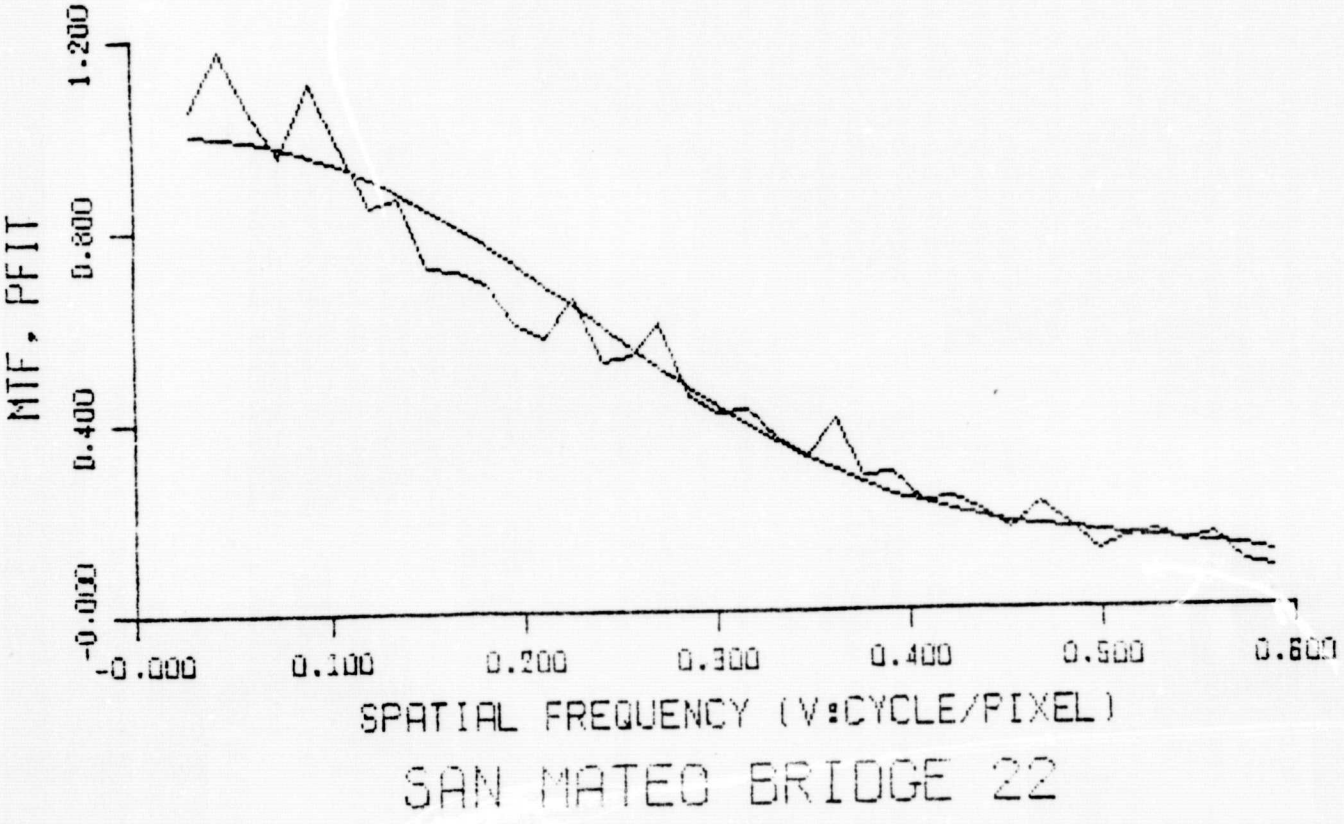


Figure 4.Overall TM system MTFs for bands 1 and 2 - 8/12/83 scene

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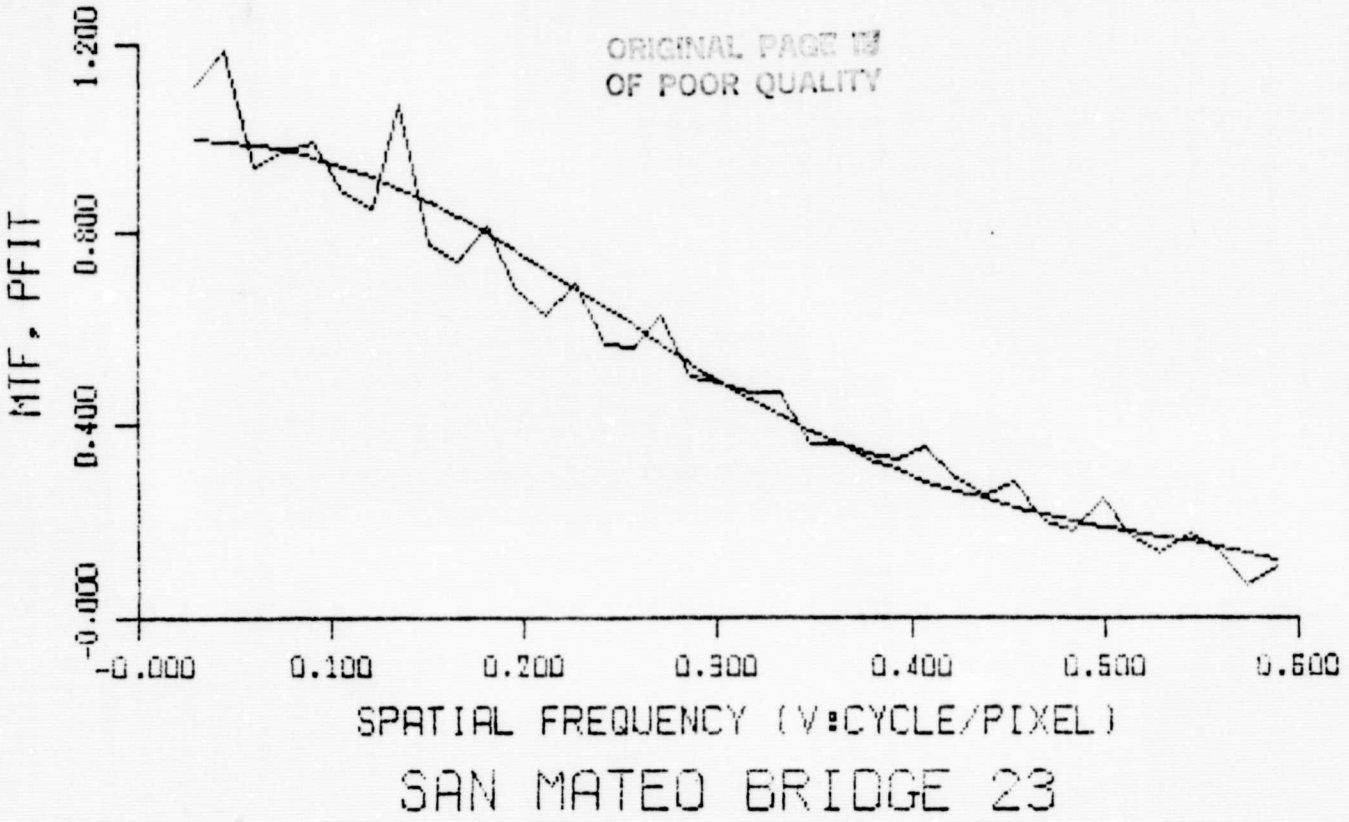

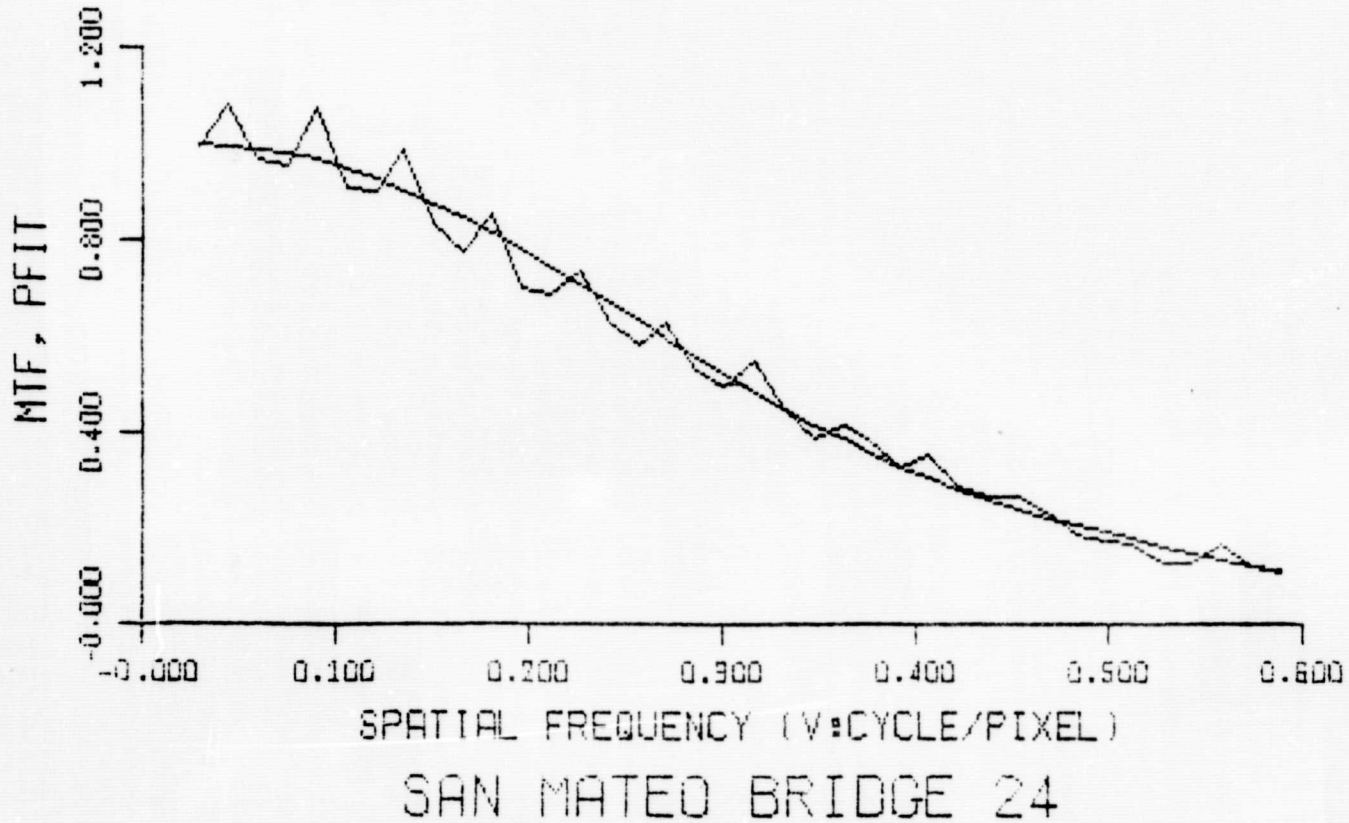

Figure 5. Overall TM system MTFs for bands 3 and 4 - 8/12/83 scene

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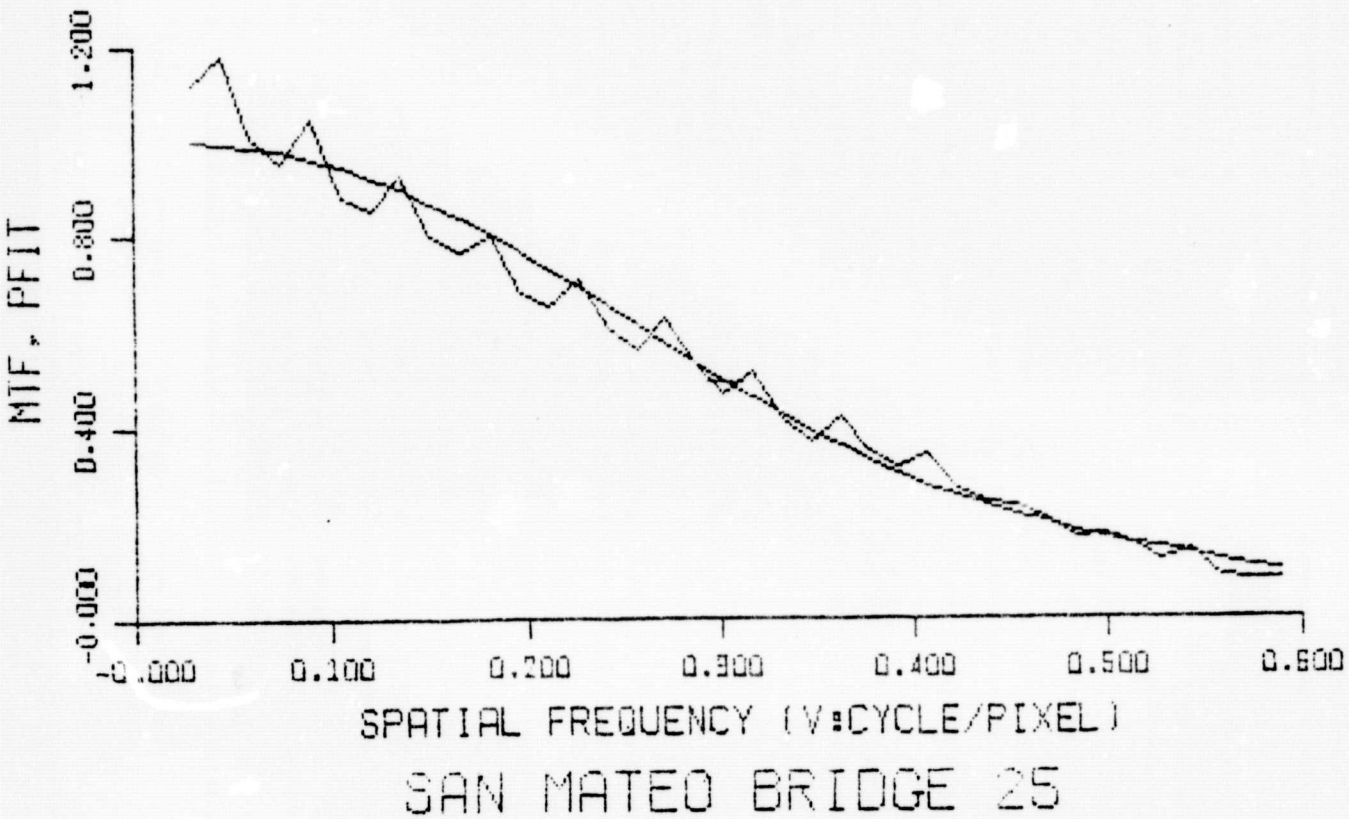

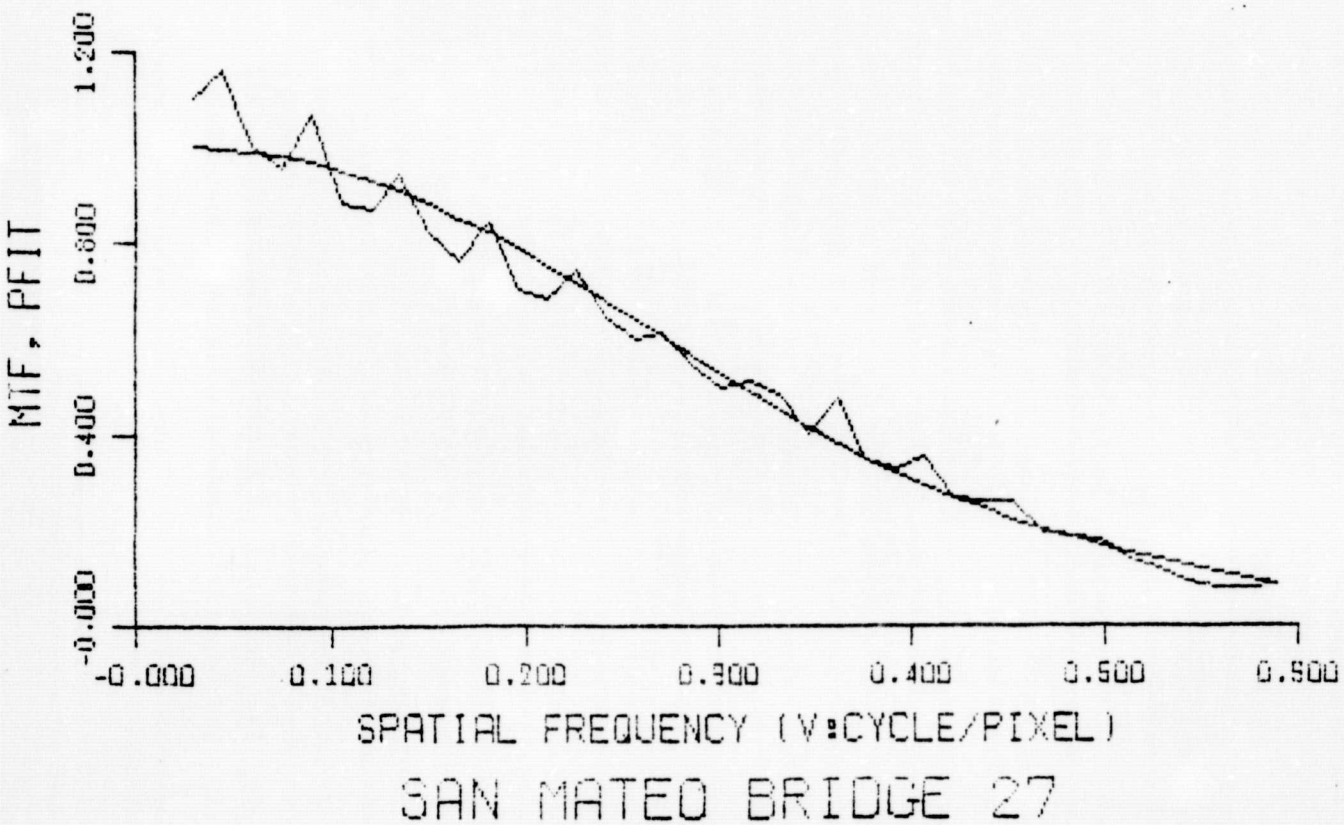

Figure 6. Overall TM system MTFs for bands 5 and 7 - 8/12/83 scene

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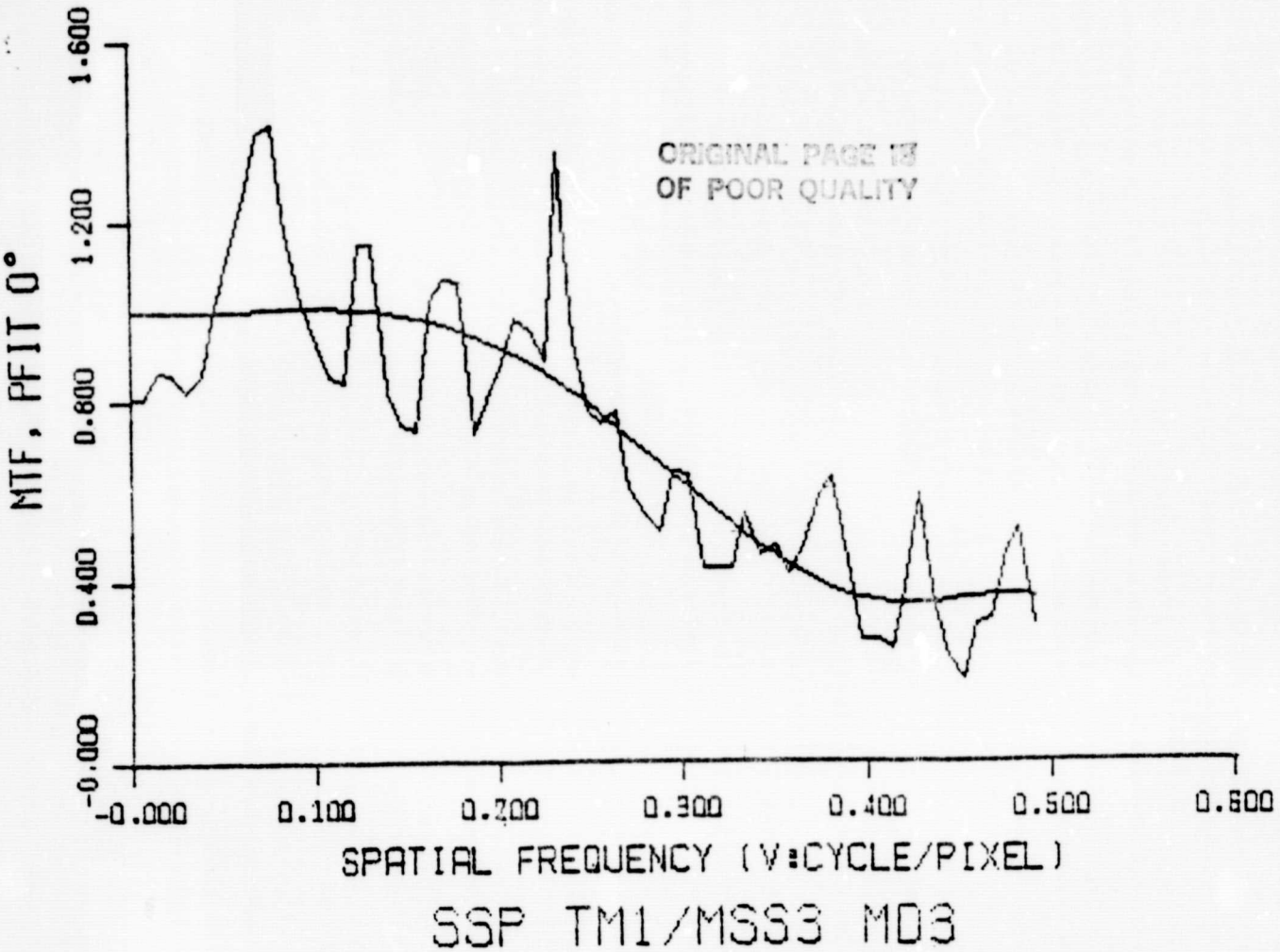

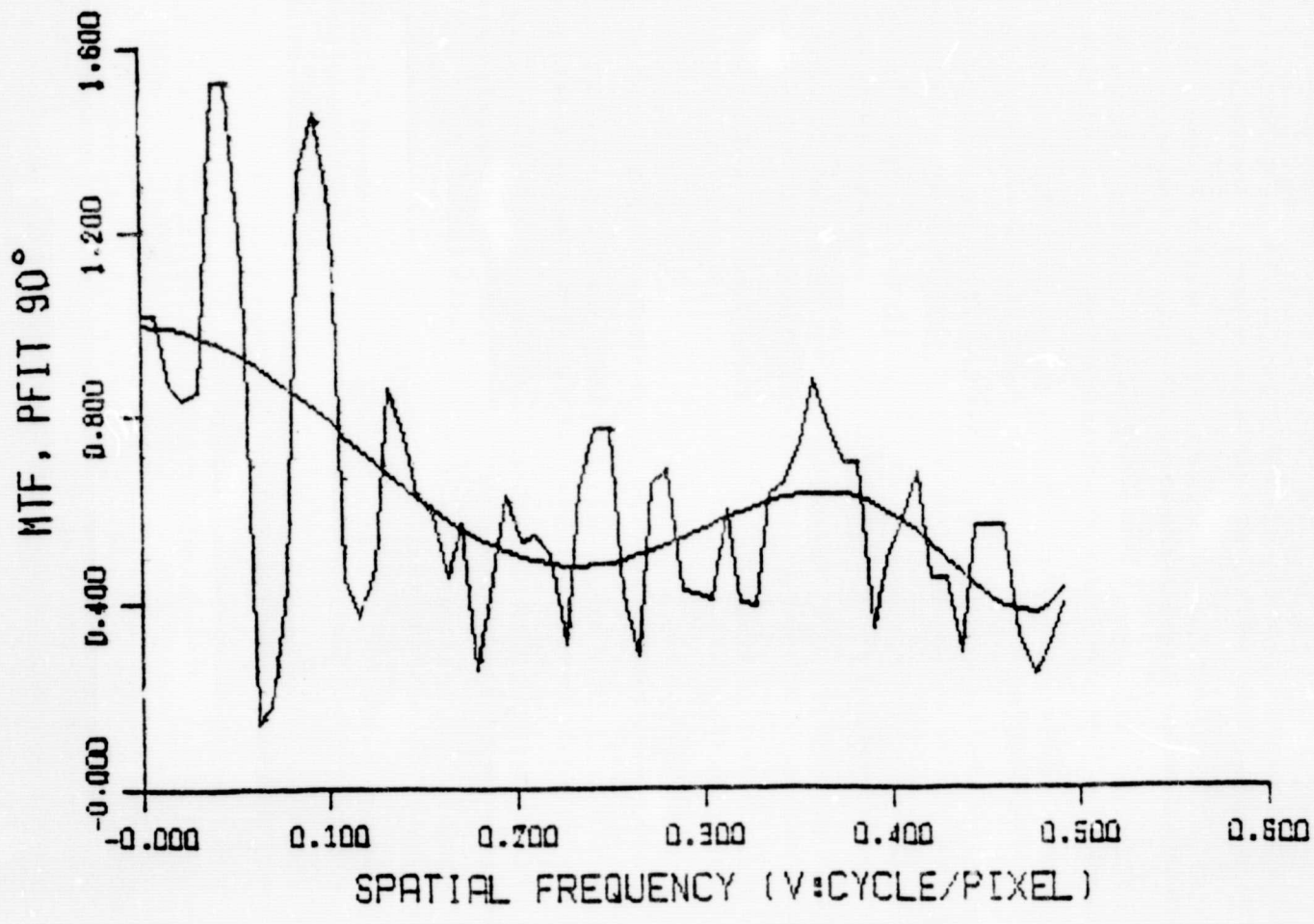

Figure 7. Overall TM system MTFs for band 1 - two-image analysis

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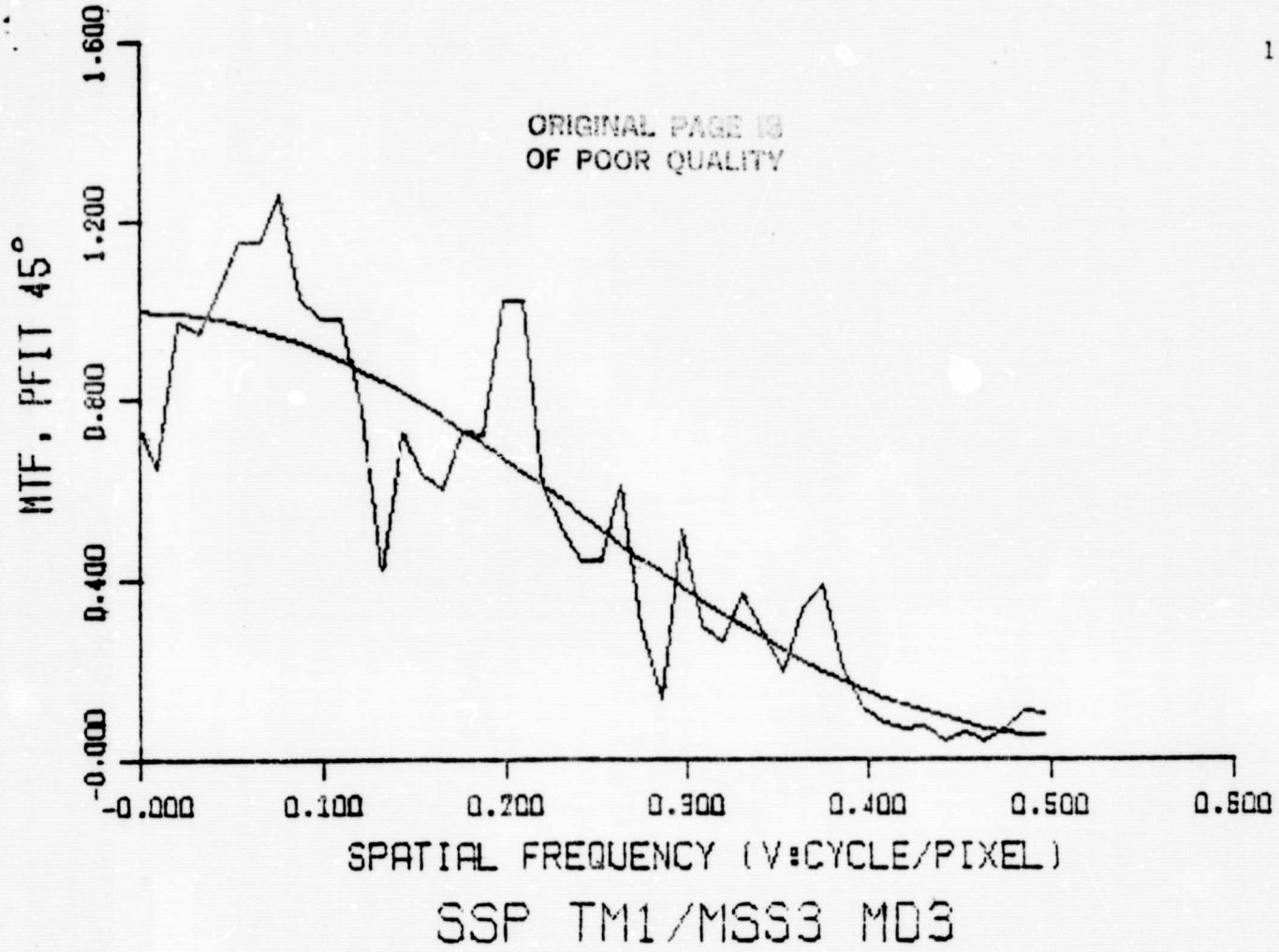

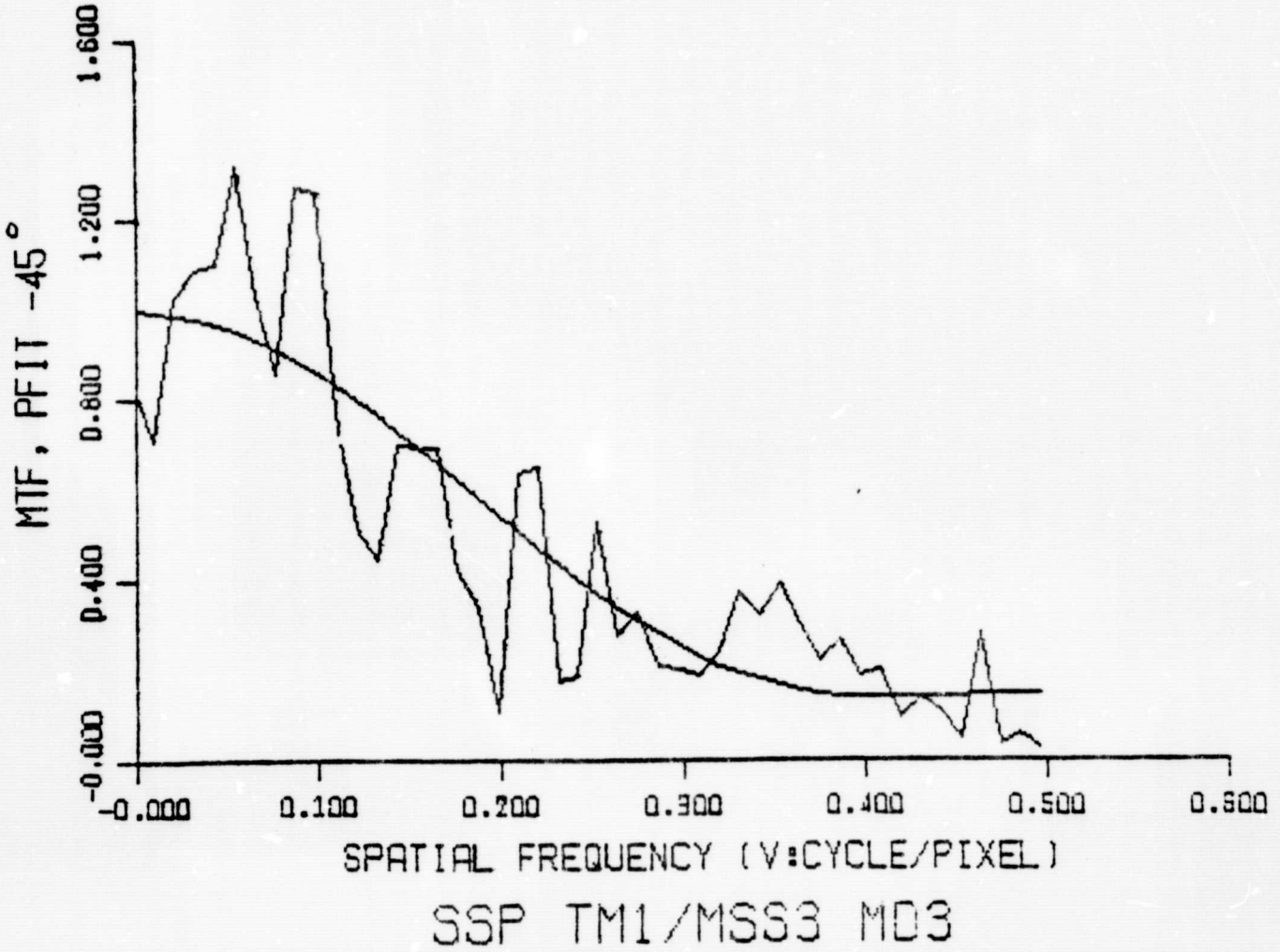

Figure 8. Overall TM system MTFs for band 1 - two-image analysis