# Modulation Transfer Function (MTF) Measurement For 1 m High Resolution Satellite Images such as KOMPSAT-2 Using Edge Function

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**ABSTRACT:**

The Modulation Transfer Function (MTF) is commonly used to characterize the spatial quality of imaging systems. This work is the attempt to measure the MTF at Nyquist frequency of the satellite imaging system what has 1m spatial resolution for KOMPSAT-2 image using the edge function. Artificial tarp targets are used in this study. A type of this tarp edge consists of two adjacent uniform bright and dark sides commonly used to test the performance of an optical system in edge function.
The results from this work demonstrate the potential applicability of this method to estimate the response characteristics for KOMPSAT-2 that is scheduled to be launched.

**KEY WORDS:** KOMPSAT-2, High-Resolution Satellite, MTF, Edge Method

## 1. Introduction

The edge method is very useful for the measurement of the MTF of various imaging systems especially on-board satellite. The profile of an edge in an image is called the Edge Spread Function (ESF) and Differentiation of the ESF results in a one-dimensional Line Spread Function (LSF). In this theory the modulus of the Fourier Transform of the LSF of an imaging system is the MTF.

In order to avoid the effects of noise in some degree, most MTF estimation approaches have used smooth numerical models, which are called the parametric method. Generally Gaussian model and Fermi function are used to reduce the random noise in the output edge profiles.

## 2. Edge Method Algorithm

Firstly the edge method calculates edge locations in each row with sub-pixel accuracy. Each line in an image are interpolated using cubic splines and averaged by the sub-pixel edge locations to obtain an Edge Spread Function (ESF). The ESF is differentiated to obtain the Point Spread Function (PSF). Finally, the PSF are Fourier Transformed and normalized to obtain the corresponding MTF.

### 2.1 Edge Spread Function

The first step in the edge method is the detecting the target edge that is taken to be a blurred line edge between two relatively uniform regions of differing intensity. Then the target edge is trimmed.
Edge points at sub-pixel locations for each profile are estimated by a cubic polynomial fitting around the maximum slope location. The inflection point is declared to be a sub-pixel edge location.
Edge detection is applied on every row and the sub-pixel edge positions are adjusted by performing the least squares fit function.

The data are interpolated with splines and averaged to obtain an Edge Spread Function (ESF).

### 2.2 Line Spread Function

Numerical differentiation of the edge response yields the Line Spread Function (LSF).

$$LSF(n) = ESF(n) - ESF(n-1)$$

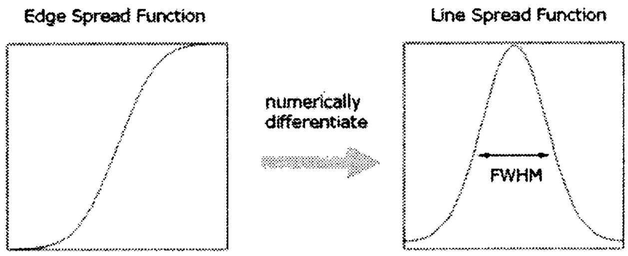



Figure 1. Description of ESF and LSF

The average profile is normalized by the differentiation between the mean of each side DN value. The differentiation of ESF is applied at every sub-pixel location to get the corresponding LSF.

### 2.3 Modulation Transfer Function

The LSF profile is trimmed to reduce the noise from uniform pixels on either side of the edge. Then a Discrete Fourier transform is applied to the trimmed LSF functions.

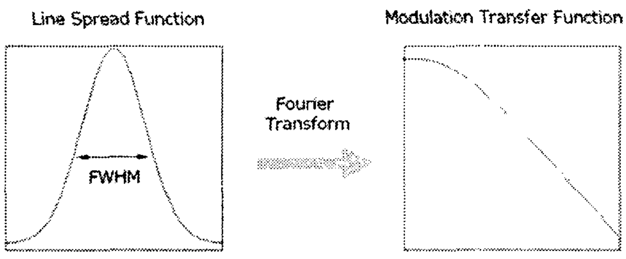



Figure 2. Description of MTF Plot from LSF

Most specifications are written in terms of MTF as a function of spatial frequency. Dominant parameter is typically MTF at Nyquist frequency, which depends on GSD.

$$\text{Nyquist Frequency} = \frac{1}{2 * \text{GSD}}$$

The Nyquist frequency is calculated from the product of the data set size and interpolation resolution or the number of pixels equivalently.

$$\text{Nyquist Frequency} = \frac{\text{whole data size} \times \text{resolution}}{2} + 1$$

#### 4) Signal-to-Noise Ratio (SNR)

Signal-to-Noise Ratio (SNR) is a critical parameter that drives image utility and assessment accuracies.

$$SNR = \frac{\mu}{\sigma}$$

where, $\mu$ = mean signal
$\sigma$ = standard deviation of signal

## 3. Result and Analysis

The edge method was applied to the high resolution satellite image that has 1m spatial resolution such as KOMPSAT-2 images obtained from May 27, 2005 using artificial tarp target in Jeonnam Goheung Cal/Val site.

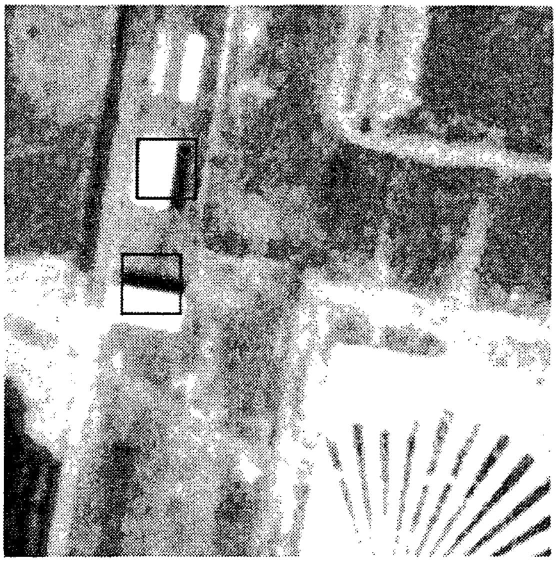


Figure 3. Tarp Targets at Goheung Site on May 27, 2005 in Jeonnam Goheung

The Results such as ESF, LSF, MTF plots and SNR values in each edge for along and cross scan directions are as follows:

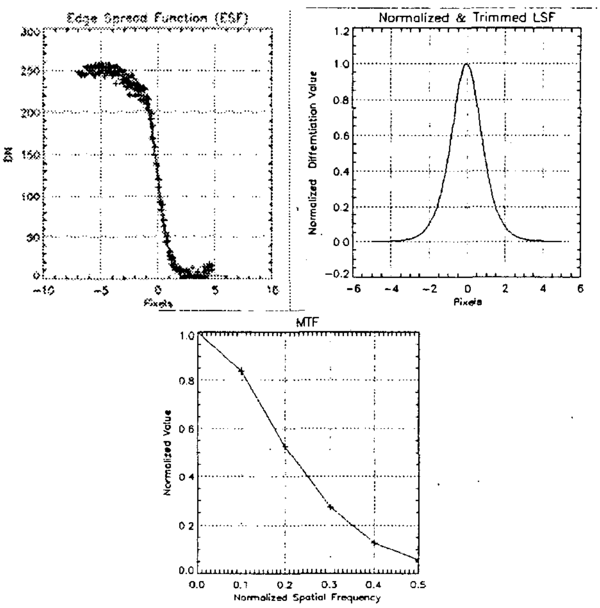
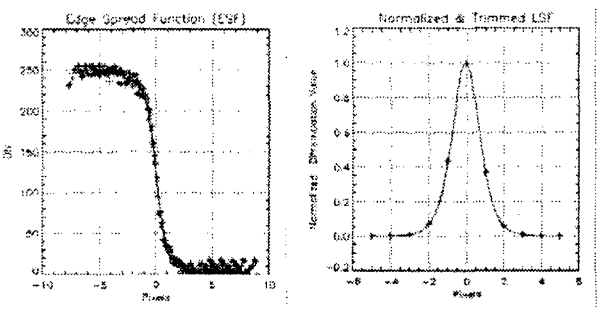



Figure 4. Results of Along Scan Direction (ESF, LSF, MTF Plot)



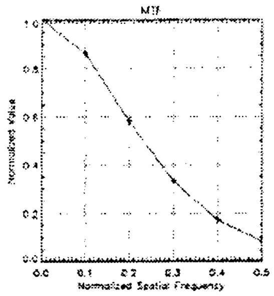



Figure 5. Results of Cross Scan Direction (ESF, LSF, MTF Plot)

Table 1. Results of Edge Method

| | Along Scan | Cross Scan |
|---|---|---|
| SNR | 27.3073 | 36.4927 |
| Edge Response | 0.4472 | 0.4752 |
| FWHM | 1.9472 | 1.8133 |
| MTF at Nyquist | 0.06 | 0.08 |

In this study we had the results less than expected value. So it must be developed that some approaching algorithm to accept the MTF at Nyquist frequency from LSF.

## 4. Conclusion

In this work, we has attempted to measure the MTF at Nyquist frequency of some satellite image system that has 1m spatial resolution for KOMPSAT-2 image using the edge function, and used tarp targets has uniform bright and dark sides for knife-edge response.

The primary purpose of this work was an attempt to measure the performance of the KOMPSAT-2 imaging system.

Furthermore, the results from this work demonstrate the potential applicability of this method to estimate MTF for high spatial resolution satellite KOMPSAT-2. And the edge method as well as the pulse method will be used to determine the spatial quality of the KOMPSAT-2 on orbit.

## Reference

[1] Robert Ryan, Braxton Baldridge, Robert A. Schowengerdt, Taeyoung Choi, Dennis L. Helder, and Slawomir Blonski, 2003, IKONOS Spatial Resolution and Image Interpretability Characterization, *Remote Sensing and Environment*, 88 (2003) 37-52

[2] Dennis L. Helder, and Taeyoung Choi, 2002, IKONOS Satellite on Orbit Modulation Transfer Function (MTF) Measurement using Edge and Pulse Method, *South Dakota State University*

[3] Manjunath Kempaiah Rangaswamy, 2003, Quickbird II Two-dimensional On-orbit Modulation Transfer Function Analysis Using Convex Mirror Array, *South Dakota State University*

[4] Gerald C. Holst, 2003, Electro-Optical Imaging System Performance 3rd Edition, *JDC Publishing*

[5] Rafael C. Gonzalez, and Richard E. Woods, 2002, Digital Image Processing 2nd Edition, Ch. 10 Image Segmentation, *Prentice Hall*