Modulation Transfer Function (MTF) Measurement for KOMPSAT EOC image data Using Edge Method

J. H. Song
Korea Aerospace Research Institute (KARI)
45 Eoeun-dong Yuseong-gu, Daejeon, 305-333, Korea
newssong@kari.re.kr

D. H. Lee
Korea Aerospace Research Institute (KARI)
45 Eoeun-dong Yuseong-gu, Daejeon, 305-333, Korea
dhlee@kari.re.kr

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 for KOMPSAT EOC using the non-parametric method as ground inputs. The spatial performance of the KOMPSAT EOC was analyzed by edge method while in flight using multi-temporal image data collected over test site in Seoul.

The results from this work demonstrate the potential applicability of this method to estimate MTF for high spatial resolution satellite KOMPSAT-2 that is being developed to be launched in 2005.

Keywords: KOMPSAT EOC, MTF, Edge Method

1. Introduction

The Modulation Transfer Function (MTF) of an imaging system is widely used to estimate its spatial performance.

The edge method has been used successfully for the measurement of the MTF of various imaging systems for many years. 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). The theory states that the modulus of the Fourier Transform of the LSF of an imaging system is the MTF.

Every image includes noise in some degree. To avoid the effects of noise, most MTF estimation approaches have used smooth numerical models. It is called the parametric method. Gaussian model and Fermi function are generally applied to reduce the random noise in the output edge profiles. Consequently a non-parametric approach that does not presume an underlying model should be followed.

2. Edge Method Description

Sharp edges excite an imaging system at all spatial frequency. The edge method algorithm first calculates edge locations with sub-pixel accuracy using the output image. Each line in a 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.

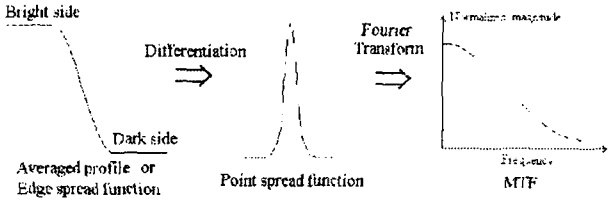

Figure 1. Edge Method [3]

1) Edge Detection

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.

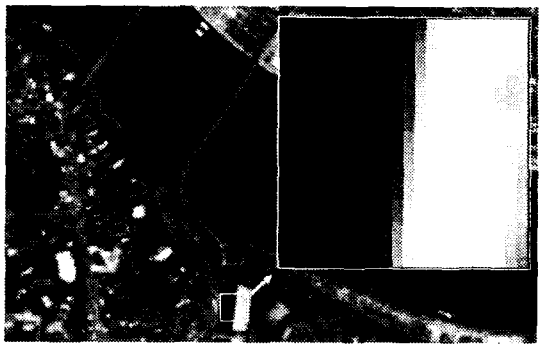

Figure 2. An Example of Target Edge Trimming

Edge points at sub-pixel locations for each profile are estimated by a cubic polynomial fitting to the edge data that used four values around the maximum slope location. The inflection point is declared to be a sub-pixel edge location.

It has been assumed that the sub-pixel edge locations of target lie along a straight line. Any deviations from a straight line edge represent errors in the geometry of the image and a potential contribution to the overall MTF of the system.

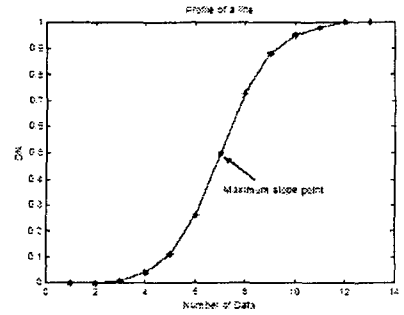

Figure 3. An Example of Edge and Differentiation [3]

Edge detection is applied on every row and the sub-pixel edge positions are adjusted by performing the least squares fit function.

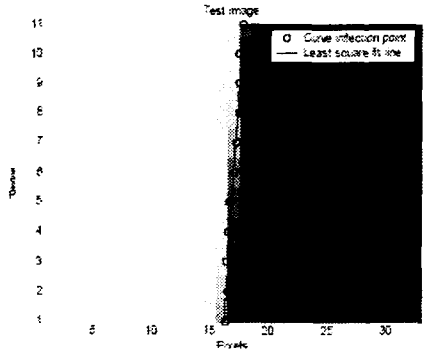

Figure 4. An Example of Least Square Fitting Line [3]

2) Obtaining the Line Spread Function (LSF)

The data are interpolated with splines and averaged to obtain an Edge Spread Function (ESF). Numerical differentiation of the edge response yields the Line Spread Function (LSF)..

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

The average profile is normalized by the differentiation between the mean of bright side DN value and the mean of dark side DN value.

The differentiation is applied at every sub-pixel location to get the corresponding LSF.

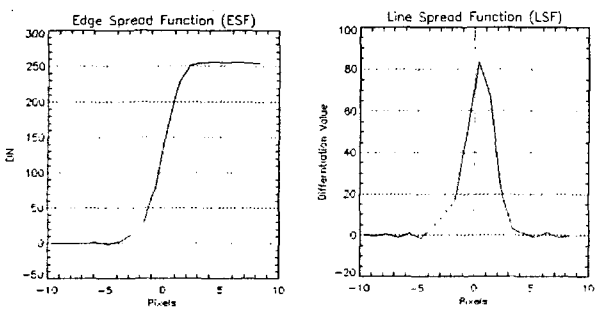

Figure 5. An Example of ESF and LSF

3) MTF at Nyquist Frequency

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.

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

$$Nyquist\ frequency = (whole\ data\ size \times resolution)\ /2+1$$

$$= (Number\ of\ trimmed\ pixel)\ /2+1$$

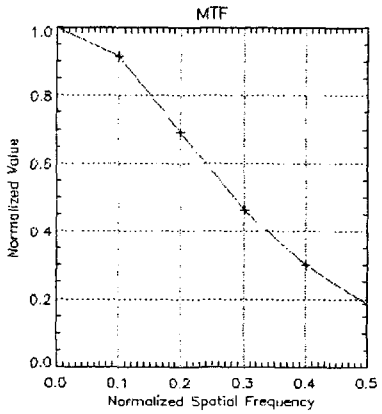

Figure 6. An Example of MTF Plot

4) Signal-to-Noise Ratio (SNR)

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

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

where, μ = mean signal
σ = standard deviation of signal

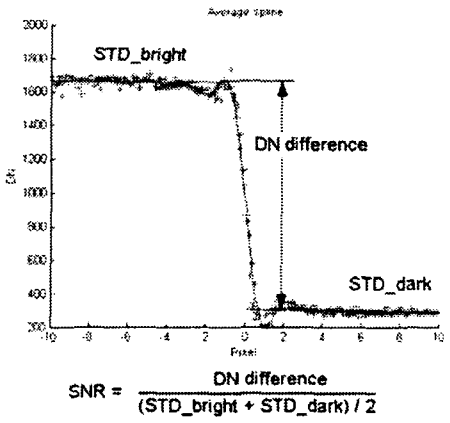

Figure 7. An Example of SNR for Edge Method [3]

3. Result and Analysis

The edge response method was applied to eight different images obtained from KOMPSAT-1 EOC between February 15, 2000 and February 03, 2004. The KOMPSAT-1 EOC ground sample distance (GSD) is 6.6 meter.

Figure 8. Target Edge Trimming (This image was captured by the KOMPSAT-1 EOC on October 07, 2003.)

The MTF value at the Nyquist frequency of the KOMPSAT-1 EOC and it was used that eight scenes collected over the Jamsil, Seoul test site [figure 8].

Table 1. Result of MTF and SNR (The MTF value at the Nyquist frequency varied from 0.1149 to 0.2608 in the cross track direction.)

No	Date	MTF	SNR
1	2000/02/15	0.1739	18.3803
2	2000/03/01	0.1149	19.7451
3	2000/03/09	0.2608	22.6073
4	2001/04/08	0.1863	18.0329
5	2003/10/07	0.1739	13.9373
6	2003/10/16	0.1211	17.4485
7	2003/11/06	0.2050	16.3032
8	2004/02/03	0.2018	13.7418

The Results present each target image's ESF, LSF, MTF plot and SNR value in the graphs as follows:

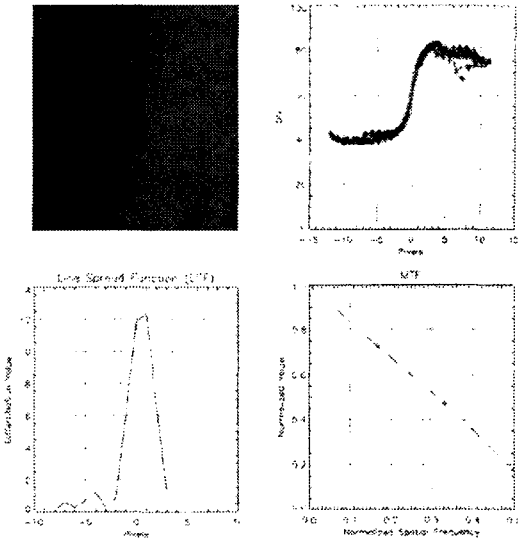

Figure 9. Target No.1 on Feb. 15, 2000

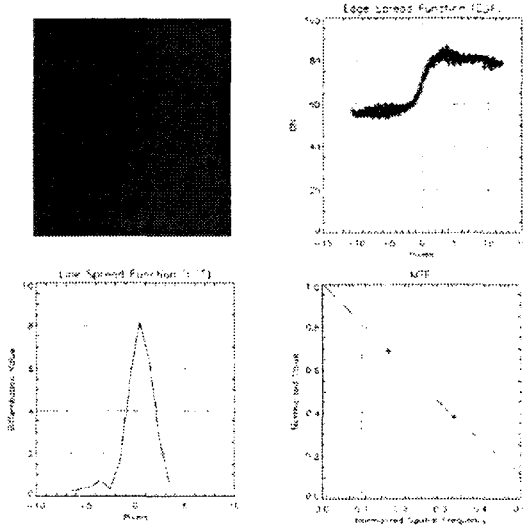

Figure 10. Target No.2 on Mar. 01, 2000

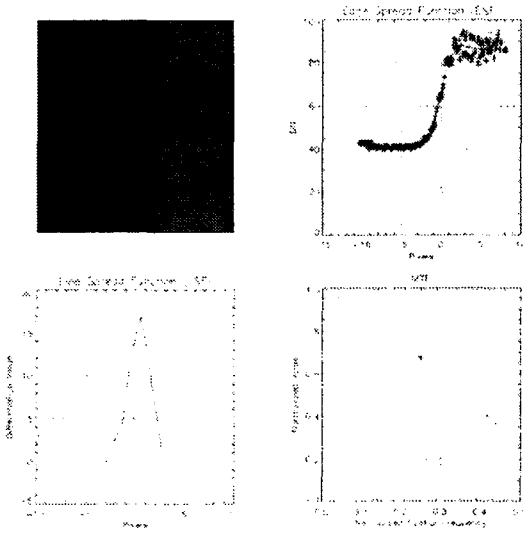

Figure 11. Target No.3 on Mar. 09, 2000

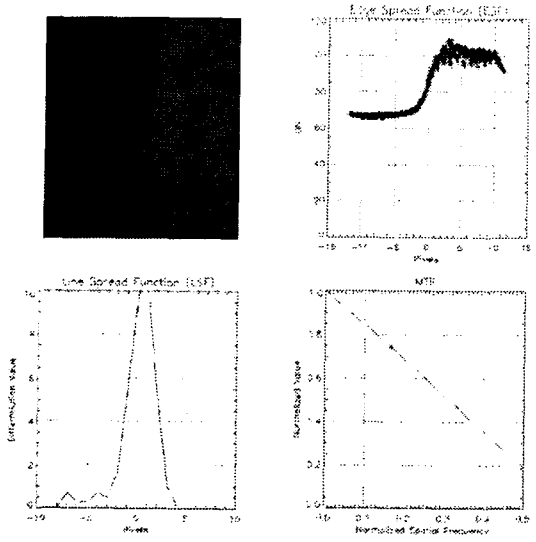

Figure 12. Target No.4 on Apr. 08, 2001

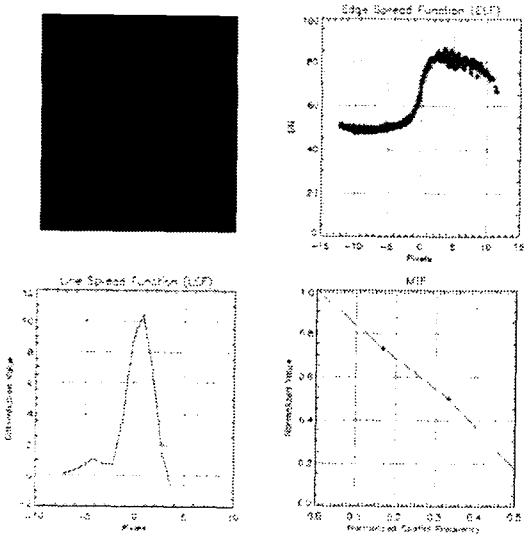

Figure 13. Target No.5 on Oct. 07, 2003

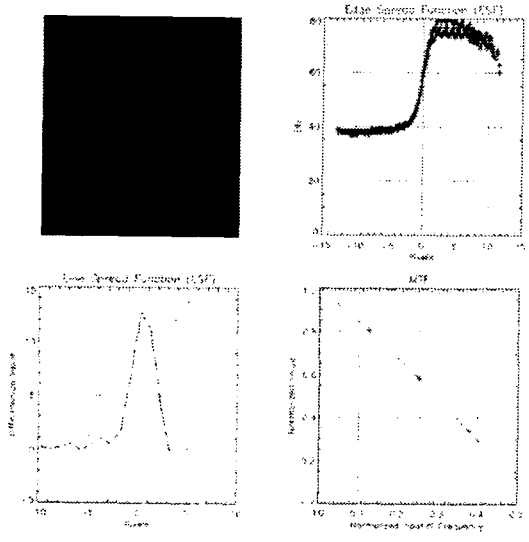

Figure 14. Target No.6 on Oct. 16, 2003

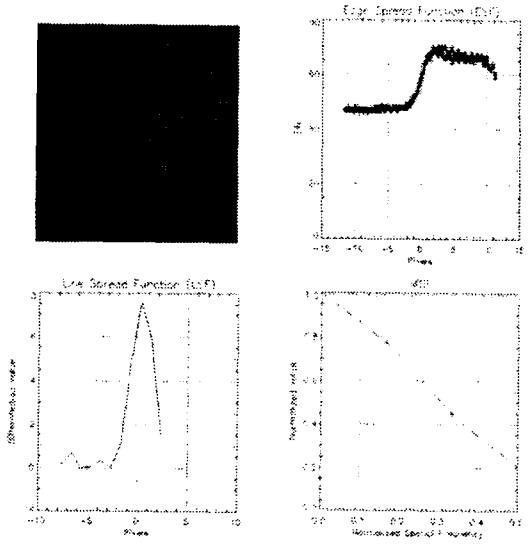

Figure 15. Target No.7 on Nov. 06, 2003

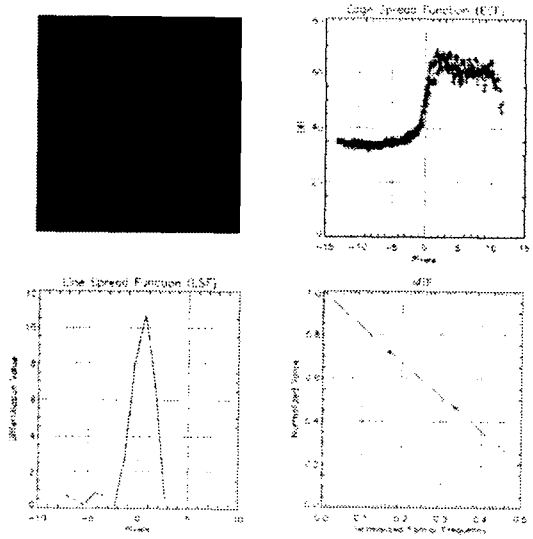

Figure 16. Target No.8 on Feb. 09, 2004

4. Conclusion

The primary purpose of this work was an attempt to measure the performance of the KOMPSAT-1 EOC imaging system while in flight.

The pulse method and impulse method with convex mirror will be used to determine the spatial quality of the KOMPSAT-1 EOC image. Furthermore, the results from this work demonstrate the potential applicability of this method to estimate MTF for high spatial resolution satellite KOMPSAT-2 that is being developed to be launched in 2005.

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 Sens-*

ing and Environment, 88 (2003) 37-52

[2] Mathieu Chambon, Jerome Primot, and Michel Girard, 1996, Modulation Transfer Function Assessment for Sampled Imaging System: Application of the Generalized Line Spread Function to a Standard Infrared Camera, *Infrared Physics and Technology*, 37 (1996) 619-626

[3] 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*

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

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

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