MTF analysis of KOMPSAT I from on-orbit image

Hong-Sul Jang, Dae-Jun Jung, Seung-Hoon Lee
Korea Aerospace Research Institute
45 Eoeun-Dong, Yuseong-Gu, Daejon 305-333, Korea
hsjang@kari.re.kr, djjung@kari.re.kr, shlee@kari.re.kr,

Abstract: The on-orbit MTF for the electro-optical camera (EOC) of the KOMPSAT I was calculated from sampled image of edge target. The image derived MTF values are smaller than ground measurement values but meet original requirements of EOC. The MTF from MTF compensated image was larger than and ground measurement result.

Keywords: On-orbit, MTF, KOMPSAT I, EOC, Edge image.

1. Introduction

The KOMPSAT I is the multi-purpose satellite launched December 21, 1999 to acquire ground image of the Korean peninsula and ocean. One of the three payloads, the Electro-Optical Camera (EOC) is main payload of the KOMPSAT 1, which has 6.6 m ground sampling distance in panchromatic wavelength range and 17 km swath width.

The MTF is spatial response function of electro-optical imaging system and one of prime parameters to be controlled and monitored from design stage to the on-orbit operation. Basically the MTF is measured in laboratory with thermal vacuum chamber before launch to check the final imaging quality of camera system in orbital condition. And on-orbit MTF is determined from on-orbit scenes of specific ground target with numerical method. Several methods was developed and applied to various imaging system. In this paper we show MTF values of EOC calculated from on-orbit images which have edge profile.

2. On-orbit MTF measurements

Generally the post-launch on-orbit MTF value is derived from sampled image of specific ground target. The natural or artificial objects on ground such as ice shelf [1], roof, tarp, parking lots [2] and bridge [3] are used. If the camera has high resolution, like IKONOS, it is easy to make artificial target and to find natural target for MTF calculation because the target size is small and easy to handing. But it is hard to use artificial target for the low resolution camera such LADNSAT which used bridge target for MTF calculation [3].

To use pulse target like bridge we need actual width of real target. And the calculated MTF have some unrealistic values because the Fourier transform of input pulse function image has some zero points [2]. With edge target we also can calculate MTF with Fourier transform of line spread function which is derivative of edge profile. The edge method does not need information of input image and there are no zero points in Fourier transform. If the scanning direction has some angle with edge line of target image we can use more sample data of edge line. The Fig.1 shows MTF calculation process from edge image.

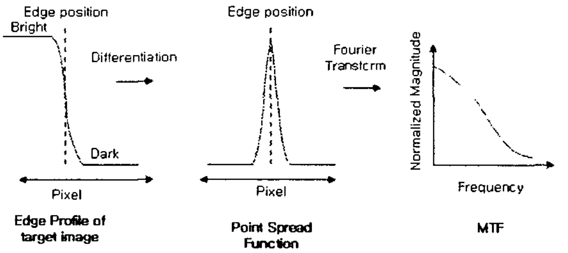

Fig. 1. MTF calculation process from sampled image[2].

3. MTF specification of EOC

The EOC is space-borne electro-optical camera for remote sensing of ground in 685 km altitude from surface. The ground sampling distance is 6.6 m and swath width is 17 km along flight direction. The EOC has one panchromatic channel and wavelength range is 510nm ~ 730nm.

1) MTF requirement and Design values

The MTF requirements of EOC [4] are depend on Jitter and Drift of spacecraft as shown in Table 1. The MTF values are defined at Nyquist frequency. The MTF without Jitter and Drift is static MTF and measured in laboratory with conventional method like Knife edge test while the MTF with Jitter and Drift need moving mechanism to simulate Jitter and Drift of satellite.

Table 1. EOC MTF Requirements

MTF type	Requirement
MTF without Jitter and Drift	0.1
MTF with Jitter and Drift	0.08

The designed MTF values of EOC are shown in Table 2. The MTF are allocated to several sources at cross-track and in-tract direction respectively. The reason why the in-track MTF is lower than cross-track MTF is that velocity smearing effect in cross-track direction degrades the MTF. The Drift is a kind of linear motion and MTF effects on MTF is minor while the Jitter is random motion of satellite which is the result of several source of vibration including attitude control system and moving mechanism.

Table 2. EOC MTF design allocations.

MTF sources	Cross-Track MTF	In-track MTF
MTF without Jitter and Drift	0.199	0.161
Drift MTF	0.998	0.998
Jitter MTF	0.856	0.856
MTF with Jitter and Drift	0.17	0.138

2) Pre-launch MTF measurements

The cross-track MTF was measured in thermal vacuum chamber facility to check expected performance of EOC in space environment [5]. The MTF values are shown in Table 3 and do not include Jitter and Drift effect of spacecraft, which was calculated by analytical method in Table 2. The in-track MTF was not measured because the EOC did not have time delay integration (TDI) function.

Table 3. EOC measured MTF (pre-launch)

Jitter & Drift	Field	MTF
Without	Left	0.24
Without	Center	0.20
Without	Right	0.16

4. MTF derived from edge image

Several kinds of target image were selected for MTF calculation. Because of large ground sampling distance of EOC we used natural target instead of artificial target image.

1) Target images

We select three kinds of target image for MTF calculation, roof of building, grass field and MTF compensated image. It was hard to find proper target which has good edge and wide background with uniform reflectance around edge. The Fig.2 shows target image samples used for MTF calculation. The roof target has sharp edge but the grass field target has small difference between bright ground and dark ground.

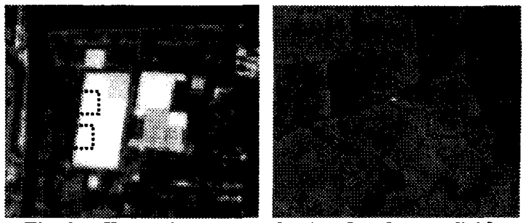

Fig. 2. Target image samples (roof and grass field)

2) MTF of roof target

The edge line and digital number (DN) profile of image are shown in Fig. 3 and Fig. 4 respectively. The signal to noise ratio (SNR) in Fig. 4 is the ratio of DN difference between bright side and dark side to mean values of standard deviation of two sides.

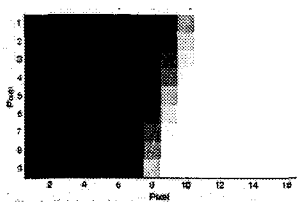

Fig. 3. Target image roof 1.

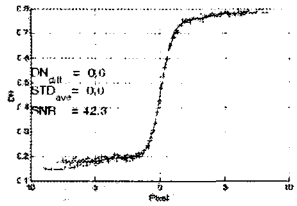

Fig. 4. DN profile of roof 1.

The Full With at Half-Maximum (FWHM) of the Line Spread Function (LSF) and MTF are show in Fig. 5 and Fig.6 respectively. Smaller FWHM means that the DN value changed quickly at edge point which tended to result in larger MTF at higher frequency.

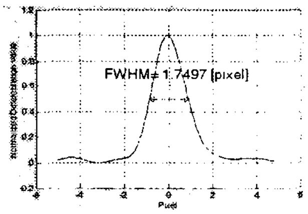

Fig. 5. LSF of roof 1.

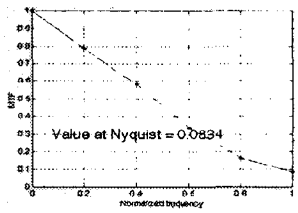

Fig. 6. MTF of roof 1.

3) MTF of grass field target

In case of grass field target, the MTF values are high than that of roof image. The Fig.3 and Fig.4 show edge image and DN profile of horizontal edge. The MTF curve and PSF are shown in Fig. 9 and Fig.10.

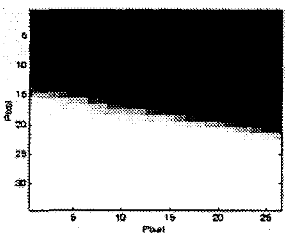

Fig. 7. Target image field 1.

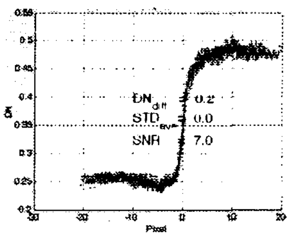

Fig. 8. DN profile of field 1.

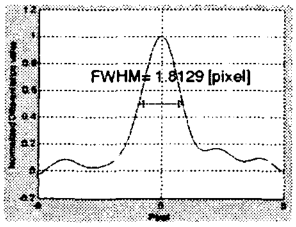

Fig. 9. LSF of field 1.

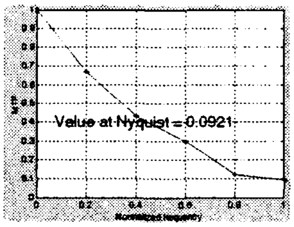

Fig. 10. MTF of field 1.

The target image and DN profile of vertical target are show in Fig. 11 and Fig. 12. The PSF curve and MTF curve are shown in Fig.13 and Fig. 14.

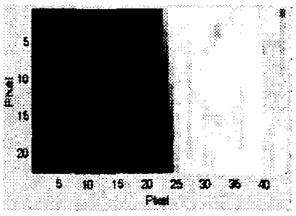

Fig. 11. Target image field 2.

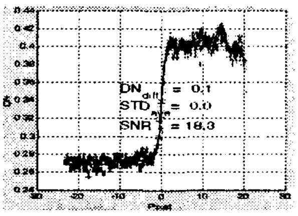

Fig. 12. DN profile of field 1.

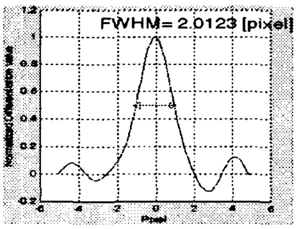

Fig. 13. LSF of field 2.

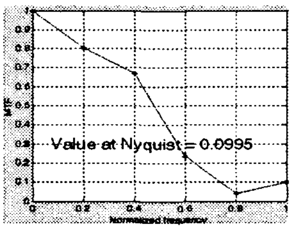

Fig. 14. MTF of field 2.

4) MTF of MTF compensated target

MTF Compensation(MTFC), image enhancement method, produces image with sharp edge. The images of Fig. 15 and Fig.19 have clear edge comparing with normal images. The FWHM are smaller than low image and the MTF values are higher.

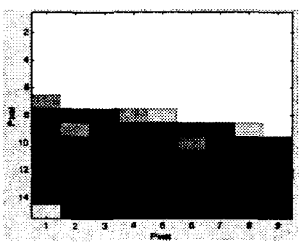

Fig. 15. MTFC image 1.

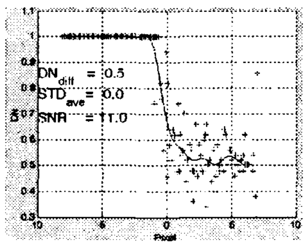

Fig. 16. DN profile of MTFC 1

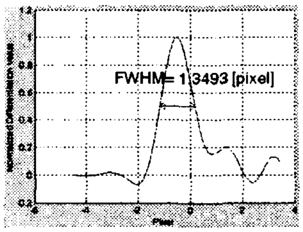

Fig. 17. PSF of MTFC imagel.

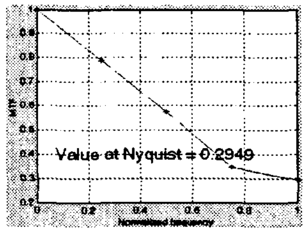

Fig. 18. MTF of MTFC image 1.

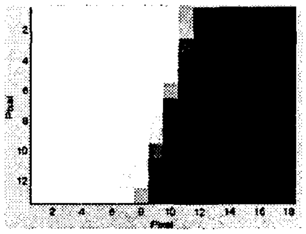

Fig. 19. MTFC image 2.

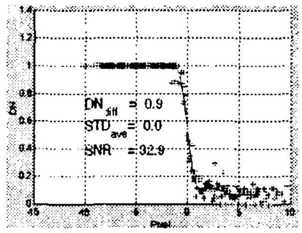

Fig. 20. DN profile of MTFC 2.

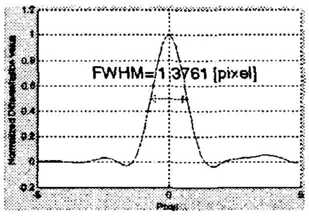

Fig. 21. PSF of MTFC 2 image.

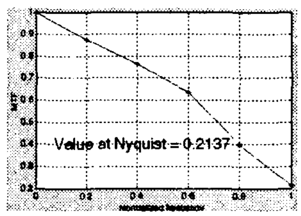

Fig. 22. MTF of MTFC image 2.

4. Conclusions

We calculated on-orbit MTF of EOC using several kind of edge target image. The MTF calculated from roof target and grass field target are lower than measured values of pre-launch test (0.16 without Jitter and Drift) even though considering the analysis result (0.138 with Jitter and Drift) while it meet MTF requirements (0.08 with Jitter and Drift) of EOC camera. The minimum MTF are 0.092 in in-track direction and 0.08 in cross-track direction. The MTF values calculated after MTF compensation are 0.21 and 0.29 in-track and cross-track direction respectively.

The following points are left as future work. The other targets such as bridge for pulse method and ice shelf for edge method are needed to check the difference between measured MTF in ground and MTF of edge target.

References

[1] N.R. Nelson, P.S. Barry, Measurement of Hyperion MTF from On-Orbit Scenes, IGARRS, 2001

[2] Taeyoung Choi, 2002, IKONOS Satellite on Orbit Modulation Transfer Function (MTF) Measurements using Edge and Pulse Target., MS thesis, 2002, SDSU

[3] James C. Storey, 2001. LANDSAT 7 on-orbit modulation transfer function estimation, SPIE, Vol. 4540.

[4] KOMPSAT I Critical Design Review, KARI, 1997.

[5] Final Acceptance Test Report KOMPSAT Electro-Optical Camera (EOC), TRW, 1998