# An Analysis of the Effect of Tilt Angle on MTF of KOMPSAT-3A

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**ABSTRACT:** After Korean Multi-Purpose Satellite-3A (KOMPSAT-3A) was launched, modulation transfer function (MTF) has been measured using edge target and star data to monitor the spatial quality of the satellite images. Recently, we found that the tilt angle of the satellite affects image quality, so we gathered the edge target data over the past four years and filtered the data on target location, season, focus mechanism controller (FMC) temperature. Using the filtered edge target data, we analyzed the change of MTF according to the tilt angle of the satellite. As a result, when the tilt angle increased, the MTF decreased. Theoretically, the MTF should not be changed according to the tilt angle when the optical system of the satellite is the same. However, the MTF of KOMPSAT-3A was decreased, so we analyzed various factors. Consequently, we could indirectly notice that several factors affect MTF degradation such as inaccuracy of line rate control/FMC temperature control of the payload system of the satellite and instability of attitude control of the bus system of the satellite and etc.

## 1. Introduction

Korean Multi-Purpose Satellite-3A (KOMPSAT-3A) has been performing normal operations since its launched in March 2015. The KOMPSAT-3A has advanced earth imaging sensor system-A (AEISS-A) and its spectral bands consist of panchromatic (PAN), near infrared (NIR), infrared (IR), red, green and blue band. A detailed description of each band is shown in Table 1.

Table 1. A detailed description of AEISS-A

| Band | GSD (@ Nadir) | Wave length |
|---|---|---|
| Panchromatic | 0.55 m | 450-900 nm |
| Near infrared | 2.2 m | 760-900 nm |
| Infrared | 5.5 m | - |
| Red | 2.2 m | 630-690 nm |
| Green | 2.2 m | 520-600 nm |
| Blue | 2.2 m | 450-520 nm |

KOMPSAT-3A utilized push broom mode when observing the earth's surface and it controls line rate. The line rate is the number of lines it can scan in one second. When KOMPSAT-3A scans certain areas with high line rate, blurry images were obtained. In the opposite case, squashed images are obtained and the squashed images lose information. Therefore, accurate line speed control is essential to obtain good quality image.

The quality estimation factors of KOMPSAT-3A are subjective assessment, signal to noise ratio (SNR), modulation transfer function (MTF), line spread function (LSF) and etc. Among them, in this paper, we only deal with subjective assessment and MTF. In order to estimate the MTF value of KOMPSAT-3A, we utilized the method (Lee et al., 2014) with edge target and star data.

During the monitoring of the image quality, we noticed that some images with a large tilt angle were slightly blurry. Therefore, we analyzed how the tilt angle affected the MTF. As a result, we found that the MTF decreased as the tilt angle increased. More details will be explained in the next section.

## 2. AN ANALYSIS OF THE EFFECT OF TILT ANGLE ON MTF OF KOMPSAT-3A

Recently, we found that the MTF decreased as the tilt angle of the satellite increased. Except for the payload aging effect, the MTF should not be changed according to the tilt angle because the optical system of the satellite is the same. However, during the monitoring of the image quality, we noticed that some images with a large tilt angle were slightly blurry. Therefore, in order to analyze the effect of MTF on tilt angle, we accurately controlled the environmental factors that can affect the MTF. The environmental factors that can affect the MTF are as follows:

Table 2. Relationship between tilt angle of KOMPSAT-3A and MTF

| Data # | Roll Angle | Pitch Angle | Yaw Angle | Tilt Angle | Across MTF | Along MTF |
|---|---|---|---|---|---|---|
| 1 | 0 | 0.2 | 2.8 | 2.8 | 11.4 | 10.7 |
| 2 | 7.5 | 0.5 | 2.8 | 8.0 | 13.6 | 11.2 |
| 3 | 15.3 | 0.9 | 2.6 | 15.5 | 12.6 | 9.2 |
| 4 | 18.7 | 2.9 | 1.8 | 19.0 | 13 | 10.7 |
| 5 | 22.9 | 1.2 | 2.4 | 23.1 | 12.3 | 11.2 |
| 6 | 24.5 | 1.2 | 2.3 | 24.6 | 10.6 | 10.3 |
| 7 | 53.9 | 1.2 | 0.7 | 53.9 | 8.8 | 7.8 |
| 8 | 35.8 | -3.5 | 51 | 62.4 | 5.6 | 8.8 |
| 9 | 31.9 | 24.3 | -18.3 | 44.1 | 10 | 6.3 |
| 10 | 41.6 | 0.4 | 47.7 | 63.3 | 7.8 | 8.3 |
| 11 | 47.1 | -19.5 | -63.3 | 81.3 | 8.5 | 4.2 |
| 12 | 61 | -1.4 | -37.4 | 71.6 | 8.5 | 4.4 |

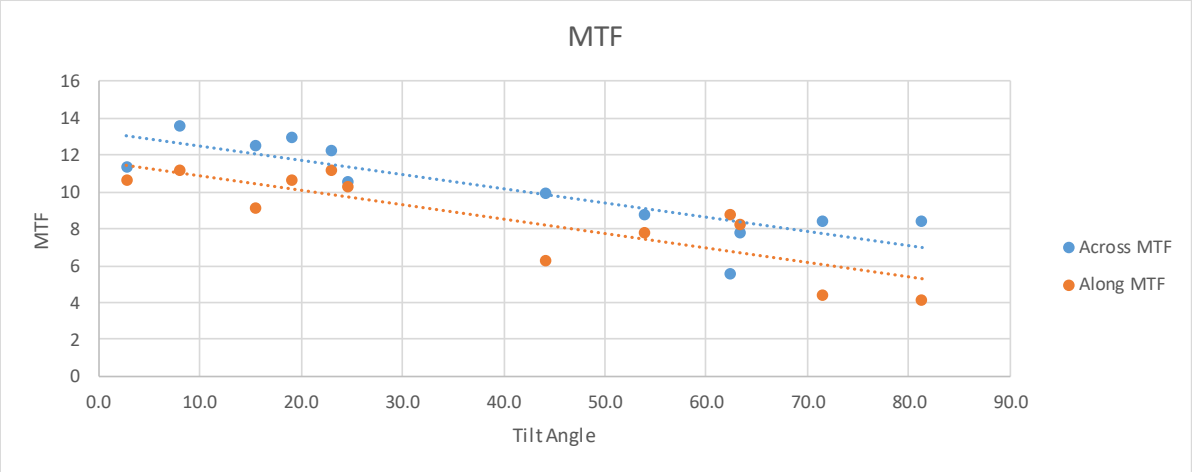
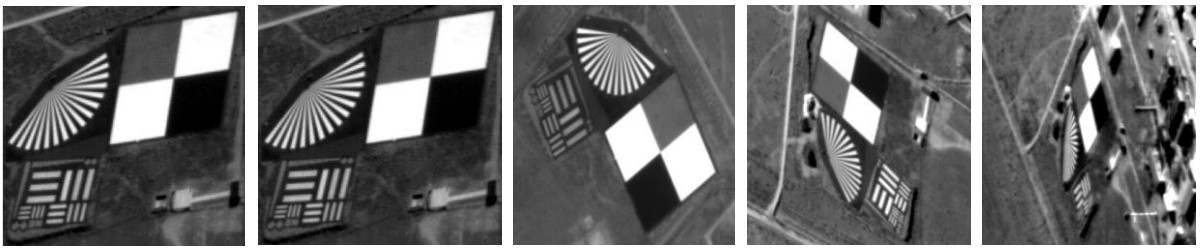



Fig.1 Relationship between tilt angle of KOMPSAT-3A and MTF



Data 8 Data 9 Data 10 Data 11 Data 12

Fig.2 Edge target data according to tilt angle of KOMPSAT-3A

1. Seasonal effect: In the case of images taken in winter, snow may accumulate on the edge target, and the snow may affect the MTF measurement. In addition, due to the seasonal variance of satellites [Park et al., 2018], edge target data with similar seasons should be used. Therefore, we only utilized edge target data from March to October.
2. Clouds: Clouds can obscure or blur the edge target, the cloudy data are excluded.

3. Edge target location: Edge targets are installed in various places around the world such as South Korea, France, Mongolia and etc. However, the management status of edge target and the materials of edge target are different. Therefore, we utilized edge targets in Baotou.
4. Edge target positon of image: We only used the data where the edge target was captured near the center of the image. This is because the MTF may be degraded due to the distortion of the camera lens when data is taken outside the center.
5. Focus Mechanism Control (FMC) temperature: KOMPSAT-3A adjust the payload focus using FMC temperature. Therefore, since the MTF can be changed according to the FMC temperature, we used only the edge target data taken with a certain range of FMC temperatures.
6. Line rate: The line rate is directly related to the quality of the image. The inaccuracy of the line rate control

causes motion blur and it incurs the MTF value. Therefore, we used data taken at a similar line rate.

Using the filtered edge target data, we analyzed the change of MTF according to the tilt angle of the satellite. As a result, when the tilt angle increased, the MTF decreased which shown in Fig.1, Fig. 2, and Table 2.

Theoretically, the MTF should not be changed according to the tilt angle. However, the MTF of KOMPSAT-3A was decreased, so we analyzed various factors.

Because we controlled a variety of variables that could affect the MTF value, we investigated variables that we did not control. As a result, we found some uncertainties that could affect the MTF and the uncertainties are as follows:

1. Attitude control of the bus system: The large tilt angle can increase the instability of the attitude control system, which may affect the image through jitter.
2. Line rate control of the payload system: As the tilt angle of satellite increases, the GSD increases, which can reduce the accuracy of the formula for calculating the line rate.
3. FMC temperature: As the tilt angle of satellite increases, the focus of the payload may be slightly distorted, which may cause inaccurate FMC temperature.

In the future, we will consider these factors and study how these factors affect MTF value.

## 3. CONCLUSION

We analyzed the change of MTF according to the tilt angle of the satellite. As a result, when the tilt angle increased, the MTF decreased. We could indirectly notice that several factors affect MTF degradation such as inaccuracy of line rate control/FMC temperature control of the payload system of the satellite and instability of attitude control of the bus system of the satellite and etc. In the future, we will consider these factors and study how these factors affect MTF.

## References

D. Lee, D. Helder, J. Christopherson, J. Storey, D. Seo and G. Stensaas, “RER, FWHM, MTF Processing Step for Edge target (Draft) & Standard Edge targets by KOMPSAT-3,” The Committee on Earth Observation Satellites Working Group on Calibration and Validation Workshop, May, 2014.

D. Park, H. Kim, Y. Seo, J. Jung, D. Seo and D. LEE, “Analysis of Aging Trends on KOMPSAT-3 using RER,” The Korean Society of Remote Sensing Fall Conference, 2018.