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In-flight MTF stability assessment of ALSAT-2A satellite

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Abstract

Since the end of the commissioning phase, more than 130,000 imagery products of ALSAT-2A satellite are received to date. This positive assessment of the mission is due to the high performances of the imager system and the permanent in-flight follow-on of the image quality and its calibration. Due to launch vibrations, harsh space environment, change in material properties in time and the drift of the local solar time evolution, many radiometric and geometric calibration campaigns have been conducted. The modulation transfer function (MTF) is one of the most important characteristics carefully estimated in-orbit. It describes the ability of a sensor to resolve the spatial details of an image formed by the incoming optical information. This paper discusses an accurate in-flight measurement of the MTF of the ALSAT-2A images. Also, the evolution of the MTF and its stability since the launch is discussed. The assessment is performed on many panchromatic images of a painted black and white checkboard. The obtained results show that the MTF is still stable and higher than specification.

Keywords: Modulation transfer function; Spatial resolution; Image quality; Edge method; ALSAT-2A

1. Introduction

On 12 July 2010, the Algerian earth observation satellite ALSAT-2A satellite was successfully launched from Sriharikota site in Chennai. Since the end of the commissioning phase, more than 130,000 imagery products are received to date. This positive assessment of the mission is due to the high performances of the imager system and the permanent in-flight follow-on of the image quality and its calibration. Due to harsh space environment, change in material properties in time and launch vibrations, many radiometric and geometric calibration campaigns have been conducted. In addition, the drift of the local solar time is an important factor which several image quality parameters are related in particular the noise level and the DN gradient magnitude which represents respectively the radiometric resolution and the sharpness. Its control should be considered to keep the image quality at acceptable level. In practice, several pre-flight tests are applied in laboratories to measure the imaging system performances. However, the conditions between ground test and in-flight periods are different. Thus the image quality needs to be assessed in permanence after launch (Helder et al., 2004).

The image quality of high resolution remote sensing satellites can be expressed by the ground sample distance (GSD), the MTF and the signal to noise ratio (SNR) (Robert and Theodore, 1998) and (Javan et al., 2013). To measure the imaging system performances, several attributes must be taken into account in particular its ability to resolve spatial objects or its spatial resolution. In the literature, various metrics have been described to quantify the resolution of an imaging system, such as spatial frequency response (SFR), point spread function (PSF), MTF and aliasing ratio (Wei-Feng et al., 2000). The

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Acronyms and symbols

AIT assembly, integration and testing
AOCS attitude and orbit control system
DN digital number
ESF edge spread function
FWHM full-with at half-maximum
GSD ground sample distance
LSF line spread function
LST local solar time
MTF modulation transfer function
NAOMI new astrosat optical modular instrument
NIR near infra-red
PAN panchromatic
PSF point spread function
PSLV polar satellite launch vehicle
SNR signal to noise ratio
SFR spatial frequency response
TDI time delay integration
D number of days since the March equinox
K absolute calibration coefficient
Lat latitude
L_{ref} reference radiance
N number of days during one year
S_{LSB} signal in LSB
α incidence angle
β sun declination
φ inclination of the ecliptic versus the earth equator
α_{new} new incidence angle
α_{ref} initial or reference incidence angle
σ_{noise} total noise
σ_{dark} dark noise
σ_{photon} photonic noise
$\sigma_{quantif}$ quantification noise

modulation transfer function is one of the most important characteristics of optical payloads. It describes the ability of a sensor to resolve the spatial details of an image formed by the incoming optical information (Liao et al., 2011).

The state of the art study of the existing targets (artificial or natural) and associated methods used for on-orbit MTF and image quality assessments of high resolution remote sensing satellites reveals different techniques. These techniques are based on the characteristics of the selected targets and the performances of the imagery system. Many of these targets are deployable and are set out to support an aerial on satellite overpass (Pagnutti et al., 2010). These specific sites have at least one artificial or natural target dedicated to MTF assessment (Helder et al., 2004).

The absolute MTF of the SPOT 5 spacecraft is assessed using the painted black and white checkboard located at 'Salon de Provence' in France (Léger et al., 2002, 2004). Also, it is assessed using the artificial painted Siemens-star pattern of Stennis Space Center located in Mississippi, U.S. for HRG–THR camera (2.5 m) (Léger et al., 2004), or by using the artificial impulse targets of the ONERA's experimental site of Faugac-Mauzac (Léger et al., 2002, 1994).

The MTF of quick bird and IKONOS is measured rather than a painted checkboard (Choi, 2002) and (Reulke et al., 2006) by an array of point source targets created by a convex mirror (Rangaswamy, 2003). Regarding ORBVIEW, the MTF is estimated using the edge targets located at Stennis Space Center in Mississippi, U.S. (Kohn, 2004). The MTF of THEOS spacecraft is measured using both painted checkboard of 'Salon de Provence' and the painted surface checkboard located at Penghu, Taiwan (Pagnutti et al., 2010).

The MTF measurement techniques use different targets to determine the sensor response such as infinitesimal pulse, a set of sinusoidal targets, or a set of bar targets. However, the main limitation of those techniques is that the targets are almost never achieved in practice for multiple reasons (Tiecheng et al., 2009). To solve this issue, Choi (2002) used the knife edge method by involving useful targets images for estimating spatial response since they stimulate the imaging system at all spatial frequencies. These targets have a straight edge as suggested by Tzannes and Mooney (1995). Such images are relatively easy to produce comparing to the other techniques. In remote sensing field, the MTF must be estimated using only one edge and without using specially fabricated targets. Because sharp edges occur naturally in many scenes, the knife edge technique can be used even if an image of a specific target is not available (Stephen et al., 1991).

In the literature, there has been no report published on the image quality assessment of ALSAT-2A. This lack of an important common quality indicator results in a gap of understanding the quality and stability of ALSAT-2A images data. The only work published which considers some images of ALSAT-2A is done by Benbouzid and Taleb (2015). However, the obtained results of MTF are less accurate compared to the real image quality observed by the Algerian Space Agency experts.

The payload used for ALSAT-2A is a new developed Silicon Carbide Korsch-type telescope with a focal plane including five lines CCD. Today, more than ten cameras have already been manufactured for five different programs: ALSAT-2 (Algeria), SSOT (Chile), SPOT6 & SPOT7 (France), KRS (Kazakhstan) and VNREDSat (Vietnam). ALSAT-2A is the first satellite and the elder