SUMMARY OF CALIBRATION AND VALIDATION FOR KOMPSAT-2

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ABSTRACT:

KARI has been doing Calibration and Validation (Cal/Val) activities for the KOMPSAT-2 (KOrea Multi-Purpose SATellite-2) after launch at July 28th 2006. The Cal/Val for KOMPSAT-2 has already been done to guarantee the requirements of KOMPSAT-2 Users, and we are doing more Cal/Val activities to enhance the KOMPSAT-2 image quality for Users. The content of KOMPSAT-2 Cal/Val defined before launch has been a little changed after launch. After launch, we could find out the new and different phenomenon from analyzing the KOMPSAT-2 image data directly. Firstly, we tried to define the status of KOMPSAT-2 (e.g. the sequence of MS band, Line of Sight, Pointing accuracy, etc.). Secondly, every KOMPSAT-2 Cal/Val parameter was validated, and then KOMPSAT-2 was calibrated with the validated and uploaded initial value of them (e.g. Non-Uniformity Correction table, Misalignment between body and sensor etc.). Finally, we have done to implement the KOMPSAT-2 image data processing system with the results of K2 Cal/Val (e.g. De-noise, MTF compensation, Metadata, Users Manual, etc.)

1. INTRODUCTION

1.1 Overview

After KOMPSAT-2 launched at July 28th 2006, the Cal/Val for KOMPSAT-2 image quality has been doing and implementing the KOMPSAT-2 image data processing system with it in KARI. Generally, because the present remote sensing satellite technique cannot satisfy user's requirements for image quality, the Cal/Val for image quality must be carried out directly after launch before distributing the imagery to the users. In the broad concept of Cal/Val, the Cal/Val of the remote sensing satellite can be divided into two parts if we recognize the technical gap between the satellite technique and the users requirements; Cal/Val to validate and verify the requirements of satellite, and Cal/Val and image restoration to guarantee the image data quality for the users. The KOMPSAT-2 Cal/Val has been carried out with this concept. Before KOMPSAT-2 launched, KARI Cal/Val team had prepared and developed Cal/Val sites, equipments and Cal/Val code for KOMPSAT-2 in KARI's own way. After launch, we can immediately understand the gap between the real Cal/Val and our own way from the new and different phenomenon and our mistakes form analyzing the KOMPSAT-2 image data. The first gap between them was the understanding of image quality for the users. We re-defined the KOMPSAT-2 Cal/Val according to them, and have done it in the first step of the KOMPSAT-2 Cal/Val, and now work to get better image quality of KOMPSAT-2 in the second step in KOMPSAT-2 normal operation phase.

This paper explains the overview of KOMPSAT-2 Cal/Val and the basic Cal/Val results. Seo 2008 paper explains the Geometric Cal/Val of KOMPSAT-2, and Lee 2008 does Image Restoration for Cal/Val of KOMPSAT-2

1.2 KOMPSAT-2 basic specification

The next list explains mission orbit of the KOMPSAT-2;

Sun synchronous orbit
Altitude: 685.13km
Inclination: 98.127°
Local time of ascending node: 10:50 AM
180° phase difference with KOMPSAT-1
Roll tilt: ±30°

The next list explains the specification of the MSC (Multi-Spectral Camera) of the KOMPSAT-2 main payload;

Pushbroom imaging
20% duty cycle imaging per orbit
Swath width: 15km±2%
Effective Swath width: 13.6km
1m Panchromatic (1 ch.) & 4m Multi-spectral (4 ch.)
No. of Pixel
- PAN: 15000 pixel (3 CCD; 1 CCD = 5200 pixel x 32 TDI line)
- MS: 3792 pixel

No. of PAN line: 2 (two; Primary & Redundant)
Pixel size: 13x13 μm
TDI line rate: up to 7100 lines/sec
Radiometric resolution: 10 bits per pixel
TDI (Time Delayed Integration): 32 lines
Data compression: JPEG-like, 1:3.6 for PAN & Multi
Non-uniformity correction before compressing
Electric Gain setting
Clear Aperture: 600mm
FOV: ±0.62°
PAN
- EFL: 9000mm
- Spectral region: 500nm - 900nm

MS Channel
- EFL: 2250mm
- Spectral region
  MS1 (Green): 450nm ~ 520nm
  MS2 (Blue): 520nm ~ 600nm
  MS3 (NIR): 630nm ~ 690nm
  MS4 (Red): 760nm - 900nm

MTF (@ Nyquist freq.): ~8%
Linearity: < 4% (5%-95% sat.)

The next list explains the specification of geometric part of KOMPSAT-2;

POD (Precision Orbit Determination) accuracy of 3m (3σ) with 1 day measurement data and IGS data

Geo-accuracy

- Post-processing without GCPs: 80m CE90; mono-scopic image of up to 26 degrees off-nadir case, after post-processing including POD, PAD and AOCS sensor calibration

2. OVERVIEW OF KOMPSAT-2 CAL/VAL

2.1 KOMPSAT-2 Cal/Val Parameters

The next table 1 is the list of KOMPSAT-2 Cal/Val parameters.

Group	Parameter		Method	Cal/Val target
Spatial	Focusing		Cal/Val	Edge, Siemens, Night Lamp
	GSD		Evaluate	GCP DB
	MTF		Evaluate, Restore	Edge, Siemens, Night Lamp
	TDI	Gain	Evaluate	Images
		Line rate	MTF	GCP DB
		Yaw Steering	AOCS	GCP DB
MTFC			Enhance	PSF matrix
DRA			Enhance	
Fusion			Enhance	
Absolute Radiometric			Enhance	Tarp, Images
Users Manual				

Group	Parameter	Method	Cal/Val target
Radio-metric	Noise	Restoration	Images
	Equalization (Vp + NUC)	Cal., Restoration	Images
	SNR	Evaluation	Tarp, Images
	Non-Linearity	Restoration	Images
	Dynamic Range		Images
	Electric Gain/Offset		Images
Geo-metric	Time Sync		
	POD		GCP DB
	AOCS On-Orbit Cal.		GCP DB
	KPADS initialization		GCP DB
	Interior Orientation		GCP DB
	Exterior Orientation		GCP DB
	Planimetric		GCP DB, DEM
	Registration		GCP DB, DEM
	Geo-Accuracy		GCP DB

1. Yellow: Evaluation & Validation
2. Blue: Calibration & Validation
3. Green: Cal/Val + Image Restoration
4. White: Image Enhancement & For user

✱ Interior Orientation = Optical Distortion + CCD Geometry

Table 1. KOMPSAT-2 Cal/Val Parameters

The KOMPSAT-2 Cal/Val parameters are divided for 4 groups; Spatial, Radiometric, Geometric and For User, and each group have several parameters according to its property (Ryan 2003). 'Interior Orientation' of Geometric includes 'Optical Distortion' & 'Registration' and 'CCD Geometry'. In Table 1, the blue items are the parameters to initialize the KOMPSAT-2 with Telemetry Command, the green items are the parameters to restore the KOMPSAT-2 performance, the yellow items are the parameters to validate, and the white items are product parameters for the end-users.

2.2 Cal/Val Site & Equipments

The next table 2 is the list of KOMPSAT-2 Cal/Val sites and equipments.

Target	Cal/Val Parameter	Site
Siemens	MTF	Goheung
Convex mirror, Simulated target	MTF, GCP	Portable
Night Lamp	MTF, PSF	Portable
Tarp	Radiometric, MTF	Portable
GCP target	Interior Orientation, Geo-accuracy, KPADS S/W, AOCS On-orbit sensor calibration, Planimetric, Registration	Daejeon, Goheung, Worldwide
Radiometric Equipment	Spectrometer, Skyradiometer, etc.	
Geometric Equipment	Total station, (GPS Receiver)	

Table 2. Cal/Val Equipments

For the KOMPSAT-2 Cal/Val works, we need the Cal/Val targets that can be imaged by KOMPSAT-2 MSC, and has made Siemens, tarp, convex mirror, night lamp and GCP target. Siemens target located at Goheung has been designed to validate MTF and PSF etc.

a. Siemens target

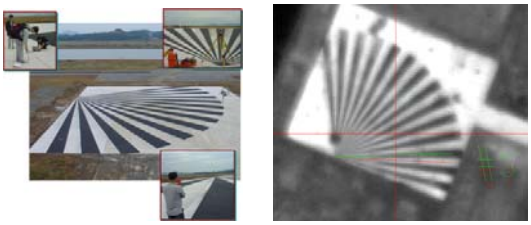

Figure 1. Siemens target at Goheung & KOMPSAT-2 image at Sep 1, 2006

Angle (Deg.)	Radius (m)	Number	Arc length (m)	Total angel (Deg.)
4.2	68.1	27	5	113.4

Table 3. Spec. of Siemens target

b. Tarp target
Tarp target, portable, has been designed to validate MTF, PSF, SNR, Absolute radiometric Cal., etc.

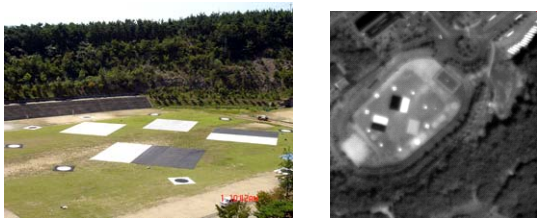

Figure 2. Deployed Tarp target, KOMPSAT-2 image at Oct 1, 2006

Reflectance	3.5%	23%	35%	53%
Number	8	8	8	8
Size	5m x 20m			

Table 4. Spec. of Tarp target

c. Night Lamp
Night lamp (1KW) has been used to validate the MTF and PSF, etc.

Figure 3. Night lamp and KOMPSAT-2 image at Feb 27, 2007

d. GCP DB

GCP DB for the KOMPSAT-2 Geometric Cal/Val has been establishing at Daejeon, Goheung, Seosan, Gwangyang and Kimje in Korea located along with KOMPSAT-2 orbit pass before KOMPSAT-2 launch to calibrate and validate the KPADS S/W initialization, AOCS on-orbit Cal., interior orientation, exterior orientation, band-to-band registration and geo-accuracy check. 5 GCP DB sites have 200 ~ 300 GCPs with less than 10 cm accuracy.

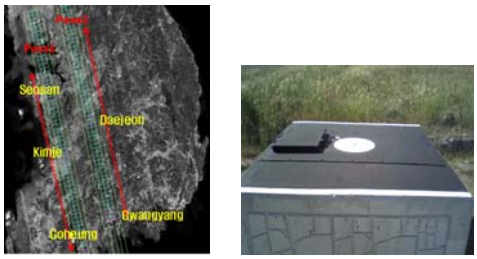

Figure 4. (Five) GCP DB sites in Korea located along with KOMPSAT-2 orbit pass

2.3 Cal/Val Work Step

The next Figure 5 explains the KOMPSAT-2 Cal/Val work step after launch. IRPE means KOMPSAT-2 data processing system.

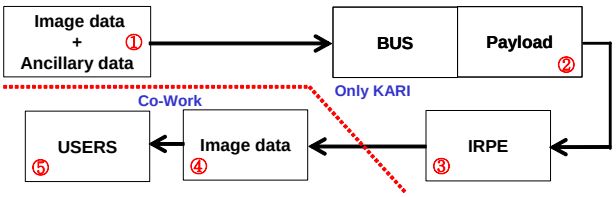

Figure 5. KOMPSAT-2 Cal/Val work step after launch

① Evaluate the basic KOMPSAT-2 Cal/Val parameters
- MTF, SNR, GSD, FOV, Linearity, Dynamic range

② Cal/Val the Payload and KOMPSAT-2 parameters
- Time sync, POD, AOCS, PAD, Interior orientation
- NUC, TDI gain, Electric gain/offset

③ Image restoration in IRPE
- Reduce Noise, LF NUC, Exterior orientation
- MTFC, Registration

④ Image enhancement
- DRA (Dynamic Range Assessment), Fusion

⑤ Information for Users
- Absolute radiometric Cal. & Image quality

3. THE RESULT OF CAL/VAL

3.1 Beginning results

After KOMPSAT-2 launch, the next Cal/Val parameters had been decided firstly;

- Primary TDI level: 43413 (PAN, Green, Blue, NIR, Red)
- Secondary TDI level: 32301
- Default PAN: PAN Redundant because of checking the image quality (Random & Pattern Noise)
- MS Color disposition
  MS1: Green, MS2: Blue, MS3: NIR, MS4: Red
- Spilling

Figure 6. Spilling in K2 MSC image

- Line of Sight
  MS2 (Blue) & MS4 (Red) → MS1 (Green) & MS3 (NIR) → PAN-R

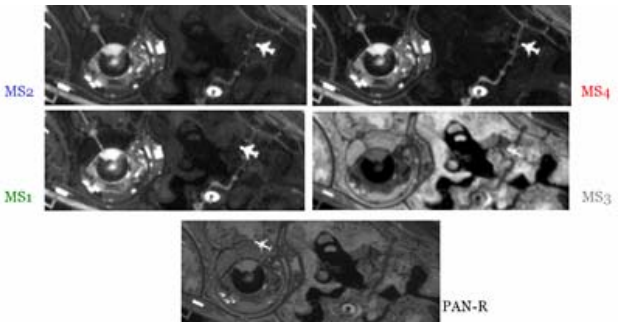

Figure 7. Line of Sight in K2 MSC

- MSC Pixel definition as reflected on Ground

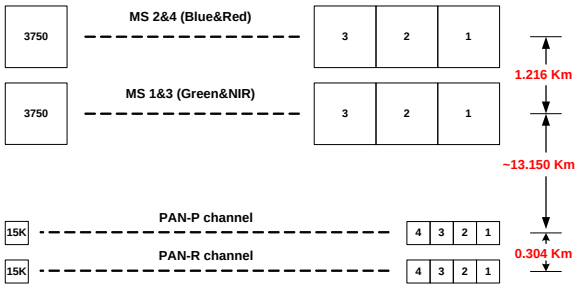

Figure 8. Line of Sight on Ground

- Check GSD (Ground Sample Distance)

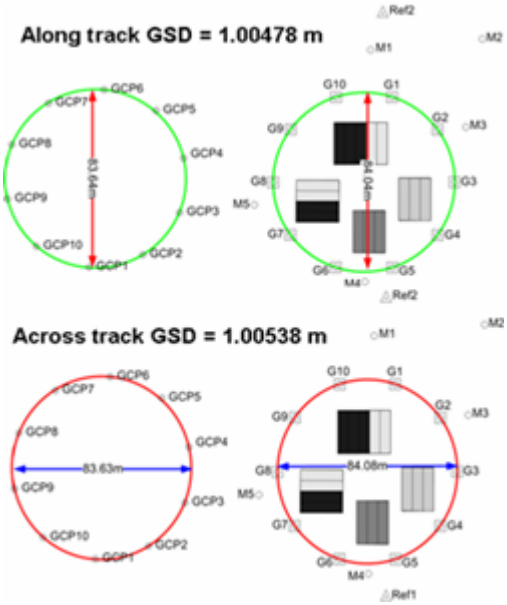

Figure 9. The result of GSD Check (3 deg Tilt)

• Fluctuation in MS2 & MS4

There is sometime a fluctuation of even and odd pixel in MS2 and MS4 band. This has been removed by FFT method.

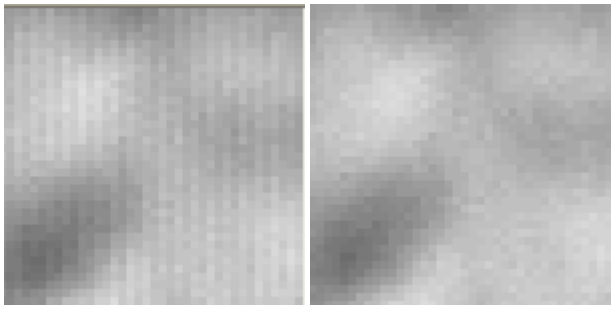

Figure 10. MS4 band fluctuation in K2 MSC image (Left: Raw image, Right: Restored image by FFT method)

3.2 Non-Uniformity Correction (NUC)

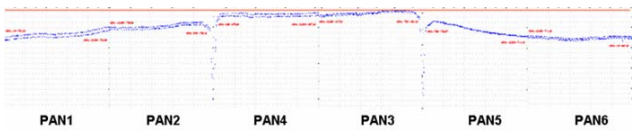

Figure 11. Blue line is full raw PAN image at same radiance, and Red line is full PAN image restored by NUC.

3.3 Butting zone

KOMPSAT-2 MSC PAN has three CCDs of 5200 pixels. There are two butting zone between CCDs that decrease the brightness gradually. We found out some non-linearity in the butting zone, and developed three algorithms to reduce it; Scatter plot, BSM (Butting zone Smoothing Method) and Dispersion method. (for more detailed; Lee 2007)

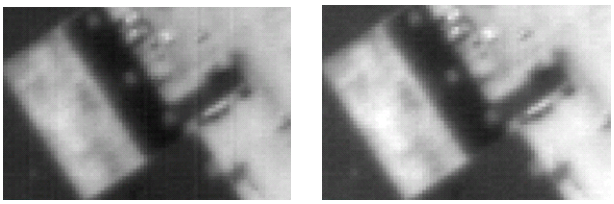

Figure 12. Up: Raw K2 MSC image data, Bottom: Applied by NUC

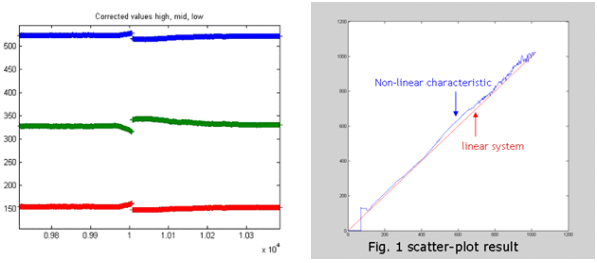

Figure 13. Non-linearity in Butting zone

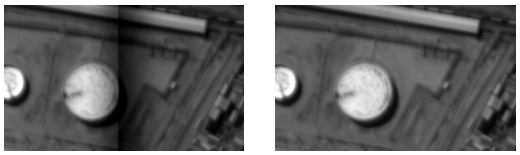

Figure 14. Up: The butting zone between PAN2 & PAN4, Bottom: Corrected

3.4 MTF & MTFC

See the paper; Lee 2007

3.5 Geometric Cal/Val

See the paper; Seo 2007

4. CONCLUSION

For one-half year after KOMPSAT-2 launch, KARI Cal/Val team has carried out the Calibration and Validation to guarantee the image quality of KOMPSAT-2 MSC image data, so that the Users can take the KOMPSAT-2 image data with good image quality now. Nevertheless, there is much room for more enhancements of the image quality of the KOMPSAT-2 image data; MTFC, Reduce noise, Geo-accuracy, Band-to-Band registration, Absolute radiometric calibration, Users Manual, etc .

REFERENCE

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