Analysis and Test results for the EOS(Electro Optical Subsystem) geometric mapping of the KOMPSAT2 Telescope

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ABSTRACT:

As a former level of MSC(Multi Spectral Camera) telescope of the KOMPSAT2 satellite, the several performance tests of EOS(Electro Optical Subsystem) were performed in the EOS level. By these tests, not only the design requirement of payload can be verified but also the test result can be the important criterion to estimate the performance of payload in the launch and space orbit environment. The EOS Geometric Mapping test is to verify the accuracy of the alignment & assembly on the Subsystem of the MSC by measurement like these; LOS(Line of Sight), LOD(Line of Detector), Band to Band Registration, Optical Distortion and Reference Cube. This paper describes the test results and the analysis for the EOS Geometric Mapping.

KEY WORDS: KOMPSAT2(Korea Multi Purpose Satellite 2) , EOS(Electro Optical Subsystem), MSC(Multi Spectral Camera), LOS(Line of Sight),LOD(Line of Detector)

1. INTRODUCTION

The MSC(Multi Spectral Camera) telescope is a large-aperture, high-resolution that produces panchromatic and multispectral images of the earth. It has been successfully aligned & assembled and passed the final performance verification tests.

In brief, we have finished the following tests for the final performance verification

- Spectral response uniformity verification test
- Dark signal & dark noise verification test
- Static MTF verification test
- Dynamic MTF verification test
- Polarization verification test
- Response linearity verification test
- Saturation verification test
- SNR verification test
- Programmable gain and offset verification test
- Radiometric calibration verification test
- Spectral band verification test
- On board radiometric calibration verification test
- Geometric mapping verification test (LOS, LOD, Distortion, Band to band registration)

Among these the final performance verification tests, the geometric mapping verification test is to verify the quality of the alignment and assembly. The purpose of this paper is to review and analyze an acceptance test results, which was performed on the system Flight Model in order to verify that the system design and manufacture withstand the specification requirements.

2. TEST DESCRIPTION

The LOS alignment position was tested by measuring, using auto-collimator (using theodolites and alignment cubes) in reference to the reference surface. The accuracy of the measurement shall be analyzed from the accuracy of the measurement arrangement.

The Optical distortion was verified by measuring, using theodolite, the tilt of a bar target and set of grid target images. The band-to-band image registration, for each spectral band, was tested and analyzed at zero, half and full field using a moving bar sample image projected through a collimator.

The images was recorded and displayed by the EGSE and later shall be analyzed using image processing tools in order to verify the image registration of the MSC payload.

The method used is based on the same principles of the above methods but slightly modified for better accuracy. In the current method, a pinhole (or any other point light source, like the tip of a triangle for instance) is inserted in the center of the collimator focal plane (on the collimator axis). The LOS and distortion mapping were performed by rotating (yaw) and tilting (pitch) the EOS gimbals to a position where the pinhole is imaged on a pixel of the desired band. The rotation and tilt angles were accurately measured by means of theodolites and a reflective reference surface installed on the EOS adapter mounting ring, aligned and adjusted at the initial position of the EOS, for reference. From the knowledge of the angles and the exact imaged pixel the mapping of the optical position of the pixel can be carried out. Out of these data the PAN (P & R) and MS (1 to 4) LOS and LOD can be calculated. Also, the distortion throughout the FOV, along the LOD (cross-scan, Y-axis) the TDI direction (scan, X-axis) of each band can be calculated. In addition to the above, each band distortion and the shift between Bands were mapped and recorded for ground station use in the band-to-band image registration

3. CONDITIONS

The test equipments listed in the table 1 below, or equivalent substitute with present calibration within its required calibration period for such equipments.

Table 1. Test Equipment Table

Equipment name	Manufacturer	Remarks
EGSE-EOS	ELOP	
Gimbals (LGM)	Mechanico	For the EOS
Gimbals (LGM)	Mechanico	For the Collimator
Ø80 Coll. incl. FP	SAGEM	
Integrating sphere	Lab Sphere	
Pinhole target	ELOP	
Translators (X, Y, Z)	Newport	
Theodolite (front)	Leica	
Theodolite (back)	Leica	
Light source	ELOP	

The measurements and tests were conducted at the following standard ambient conditions (Table 2)

Table 2. Environmental condition

Description	Requirement	Remarks
Temperature	21±4°C	
Relative Humidity	35%-55%	
Pressure	28" Hg – 32" Hg	
Cleanliness	Class 10,000	

The entire test configuration can be seen in Figure 2. The figure 1 shows that the PAN LOD is adjusted to be parallel to the ground by the measurement of the front theodolite with the aid of the bright light source.

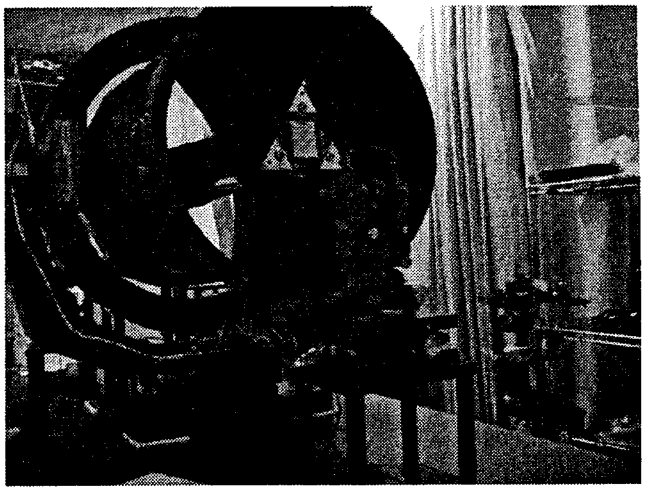

Figure 1. The Theodolite in front of the EOS for the detector leveling

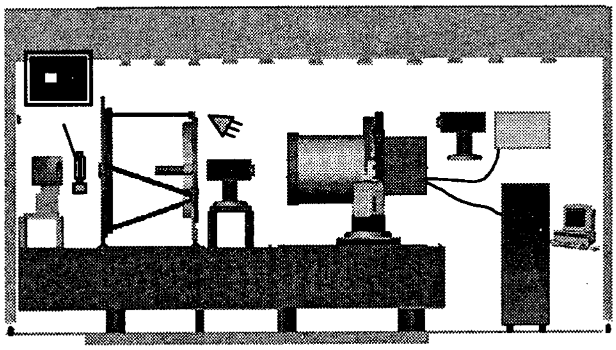

Figure 2. EOS (Electro-Optical Subsystem) Geometric Mapping Test Set-up

4. TEST RESULTS AND ANALYSIS

The LOS(line of sight) of the each channel was measured by the reference of the central pixel. The test results are in the table 3 and satisfied the specification requirements.

Table 3. Installation Accuracy(LOS) Test Results by Bands

Band	LOS		Notes
	Pass	Fail	
PAN-P	√		[-0.3181° on the central pixel] (Spec: 0.3°±0.2°, to the reference)

PAN-R	√		[-0.3442° on the central pixel] (Spec: ``)
MS1	√		[0.9856° on the central pixel] (Spec: 1.01°±0.3°, to the PAN-P LOS)
MS2	√		[0.8842° on the central pixel] (Spec: ``)
MS3	√		[0.8833° on the central pixel] (Spec: ``)
MS4	√		[0.9864° on the central pixel] (Spec: ``)

The LOD(line of detector) was measured by this mapping process in the reference of the central pixel of the PAN-primary channel with help of the side theodolite. In order to define the LOD of the EOS, the relative position of the detector to the EOS is significant, therefore the angle of reference cube-primary attached in the bezel was recorded in the table 4.

Table 4. Installation Accuracy(LOD) Test Results

BAND	MEASUREMENT RESULT (LOD)
PAN-P	Azimuth: 0.0003° Elevation: 269.7228° (Angle of Reference Cube1, Reference Pixel: PAN-P pixel# 7587)

For the installation accuracy of the detector of the each channel, the parallelism between the PAN-primary and the MS-bottom was measured by the front theodolite. The test results are in the table 5 and satisfied the specification requirements.

Table 5. Installation Accuracy(PAN to MS Paralleism) Test Results

BAND	PAN to MS Parallelism		NOTES
	PASS	FAIL	
PAN-P MS Bottom	√		0.0941mrad (Spec: ±1.5mrad)

MS to PAN Parallelism measurement

		Left	Right	Delta[mrad]
PAN	Elevation	90°03'00"	90°03'11"	-0.054
MS	Elevation bottom	89°09'22"	89°09'14"	0.0396
	total			0.0941

The optical distortion was measured by back theodolite according to the angle of the EOS with help of the triangle target image through the collimator. The test results are in the table 6 and satisfied the specification requirements.

Table 6. Optical Distortion

BAND	OPTICAL DISTORTION		NOTES
	PASS	FAIL	
PAN-P	√		(Spec: Less than 2% over the entire FOV)
PAN-R	√		(Spec: ``)
MS1	√		(Spec: ``)
MS2	√		(Spec: ``)
MS3	√		(Spec: ``)
MS4	√		(Spec: ``)

Table 7. Optical Distortion Table

PAN-P			PAN-R		
DFPA(Pixel #)	Azim.	Elev.	DFPA(Pixel #)	Azim.	Elev.
84	-0.5828	-0.3181			
1959	-0.4292	-0.3181	1958	-0.4250	-0.3419
3837	-0.2747	-0.3178			
5126	-0.1658	-0.3172			
7512	0.0331	-0.3181	7512	0.0342	-0.3442
9395	0.1906	-0.3181			
11192	0.3333	-0.3178			
13068	0.4914	-0.3172	13067	0.4942	-0.3439
14940	0.6481	-0.3172			

MS1			MS2		
Pixel#	Azim.	Elev.	Pixel#	Azim.	Elev.
30	-0.5878	0.6661	31	-0.5869	0.5642
1056	-0.2506	0.6669	1057	-0.2503	0.5661
1893	0.0256	0.6675	1894	0.0264	0.5661
2948	0.3733	0.6675	2947	0.3742	0.5661
3757	0.6394	0.6678	3762	0.6419	0.5661
MS3			MS4		
Pixel#	Azim.	Elev.	Pixel#	Azim.	Elev.
18	0.6458	0.5650	30	0.6417	0.6689
1053	0.3050	0.5647	1054	0.3050	0.6689
1893	0.0286	0.5653	1893	0.0281	0.6683
2947	-0.3189	0.5647	2946	-0.3606	0.6681
3764	-0.5869	0.5642	3763	-0.5872	0.6667

Table 7 shows the optical distortion table which was measured by each angle of the EOS in the even spaced pixels. This table will be used in the ground station in order to compensate the quality of the image after satellite lunching.

Table 8. Stability Test Results

Item		Stability		Notes
		Pass	Fail	
LOS (PAN-P)		√		Deviation: 0.0081° 0.1413mRad on the central pixel (Spec: Better than 2.0mRad before & after environmental test)
LOS (PAN-R)		√		Deviation: 0.0089° 0.1553mRad on the central pixel (Spec: ")
LOS (MS1)		√		Deviation: 0.0105° 0.1831mRad on the central pixel (Spec: ")
LOS (MS2)		√		Deviation: 0.008° 0.1395mRad on the central pixel (Spec: ")
LOS (MS3)		√		Deviation: 0.0091° 0.1587mRad on the central pixel (Spec: ")
LOS (MS4)		√		Deviation: 0.0075° 0.1308mRad on the central pixel (Spec: ")
LOD (PAN-P)		√		Deviation: Azimuth 0.0003°=0.005mRad Elevation 0.039°=0.68mRad (Spec: ")
RCCS	Reference Cube1	√		Deviation: Azimuth 0.0003°=0.005mRad Elevation 0.039°=0.68mRad (Spec: ")
RCCS	Reference Cube2	√		Deviation: Azimuth 0.0087°=0.15mRad Elevation 0.04°=0.69mRad (Spec: ")
RCCS	Collimator Axis	√		Deviation: Azimuth 0.0018°=0.03mRad Elevation 0.0025°=0.04mRad (Spec: ")

In order to confirm the quality of the alignment and assembly of the EOS during the environment tests like vibration and thermal vacuum test, the EOS geometric mapping process was conducted three times in the pre-vibration, post-vibration and final-ATP. Table 8 shows the stability of the geometric mapping test results and the results are satisfied the specification requirements.

5. SUMMARY

In summary, this paper has presented the test results and the analysis for the EOS Geometric Mapping. The EOS Geometric Mapping test is to verify the accuracy of the alignment & assembly on the Subsystem of the MSC by measurement a variety of tests including: LOS(Line of Sight), LOD(Line of Detector), Band to Band Registration, Optical Distortion and Reference Cube. One of the final performance verification tests, the geometric mapping verification test was successfully finished and all the test results are satisfied the specification requirements.

6. REFERENCES

References from Journals:
John W. Figoski, "Alignment and test results of the Quickbird Telescope using the Ball Optical System Test Facility," *SPIE Vol.3785, july 1999*

References from Books:
Warren J. Smith, *Modern Optical Engineering*, McGraw-Hill, Inc.

Gerald C. Holst, *Testing and Evaluation of Infrared Imaging System*, JCD Publishing Co.

Daniel Malacara, *Optical Shop Testing*, John Wiley & Sons, Inc.

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