

Characteristics of Ocean Scanning Multi-spectral Imager(OSMI)*

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Ocean Scanning Multi-spectral Imager (OSMI)* 특성

조영민 · 용상순 · 우선희 · 이상규 · 오경환 · 백홍열

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Abstract

Ocean Scanning Multispectral Imager (OSMI) is a payload on the Korean Multi-Purpose Satellite (KOMPSAT) to perform worldwide ocean color monitoring for the study of biological oceanography.

The instrument images the ocean surface using a whisk-broom motion with a swath width of 800 km and a ground sample distance (GSD) of less than 1 km over the entire field-of-view (FOV). The instrument is designed to have an on-orbit operation duty cycle of 20% over the mission lifetime of 3 years with the functions of programmable gain/offset and on-orbit image data storage. The instrument also performs sun calibration and dark calibration for on-orbit instrument calibration.

The OSMI instrument is a multi-spectral imager covering the spectral range from 400 nm to 900 nm using a Charge Coupled Device (CCD) Focal Plane Array (FPA). The ocean colors are monitored using 6 spectral channels that can be selected via ground commands after launch. The instrument performances are fully measured for 8 basic spectral bands centered at 412, 443, 490, 510, 555, 670, 765 and 865 nm during ground characterization of instrument. In addition to the ground calibration, the on-orbit calibration will also be used for the on-orbit band selection. The on-orbit band selection capability can provide great flexibility in ocean color monitoring.

* The instrument name is changed from "Ocean Color Imager(OCI)" and the alternative name is "Low Resolution Camera(LRC)".

요 약

해양생물학 연구를 위해 전세계 바다색 관측을 수행하게 될 아리랑 1호 위성(KOrean Multi-Purpose SATellite: KOMPSAT)의 탑재체 Ocean Scanning Multispectral Imager(OSMI)를 개발하였다.

OSMI는 관측폭 800km 이내에서 1km 이하의 지상해상도를 갖고 whisk-broom 주사 기법으로 해양 표면의 영상을 얻는다. OSMI는 3년의 수명 동안 20%의 궤도 운영 duty cycle을 갖으며 궤도 운영 중 영상 자료의 gain/offset 조정이 가능하고 영상자료 저장 기능이 내장되도록 설계되었다. 궤도 운영 중 센서 보정을 위해 OSMI는 태양 보정과 암흑 보정을 수행한다.

OSMI는 2차원 Charge Coupled Device(CCD) Focal Plane Array(FPA)를 사용하는 다중 분광 촬영기로서 400nm에서 900nm까지의 파장 대역에 대한 결상이 가능하다. 이 파장대역 중에서 궤도 운영 중 지상명령을 통해 선택되는 6개 분광 채널을 사용하여 해양표면이 관측된다. 센서 성능은 지상 특성 시험 단계에서 412, 443, 490, 510, 555, 670, 765 그리고 865nm의 8개 분광 대역에 대해 측정되었다. 이 지상 특성 시험 결과와 더불어 태양/암흑 보정이 궤도 분광 채널 선택 및 보정에 사용될 것이다. 운영중 분광 채널 선택 기능은 바다색 관측 및 해양생물학 연구에 큰 유연성을 줄 것이다.

1. Introduction

The concentration of phytoplankton can be derived from satellite observation of ocean color. This is because ocean color in the visible light region (wavelengths from 400nm to 700nm) varies with the concentration of chlorophyll and other plant pigments in the water. For example, chlorophytes and diatoms absorb light at wavelength below 550nm, phycocerythin absorption peaks around 490nm, and gelbstoffe absorbs below 550nm.

The study of phytoplankton distribution on ocean can give the knowledge of ocean primary production and global biochemistry. The "primary producers", i.e. algae and some bacteria, use sunlight or chemical energy as sources of energy. It is thought that marine plants remove carbon from the atmosphere at a rate equal to terrestrial plants, but the details of this biochemistry is poor.

A satellite sensor can provide worldwide view of cloud-free ocean and satellite ocean color data are valuable for determining the abundance of ocean biota on a global scale. This information can then be used to assess the ocean's role in the global carbon cycle and the exchange of other critical elements and gases between the atmosphere and the ocean.

After the ocean data from Coastal Zone Color Scanner(CZCS) on Nimbus-7(Leonard and McCLAIN, 1996; McCLAIN, 1993) are known to be useful for global research of ocean, several advanced ocean monitoring sensors are currently operating (MOS, SeaWiFS) and will be launched in the near future(OCI, MODIS, MERIS, GLI, etc.).

The OSMI(Lee, *et al.*, 1997) is the first ocean monitoring space-borne sensor developed and

operated by Korea. The instrument is a payload on the KOMPSAT developed and built by the Korean Aerospace Research Institute (KARI) and TRW, Inc.

The mission goal of OSMI is to perform worldwide ocean color monitoring for the study of biological oceanography. For the flexible mission in ocean color monitoring, the OSMI is designed to have on-orbit band selection capability. The OSMI image data are to be collected for various researches and applications in the fields of worldwide ocean resources management and ocean environment monitoring.

2. OSMI Operation Description

The KOMPSAT OSMI is designed to provide worldwide ocean color data from an altitude of 685km on the sun synchronous orbit. The orbit crossing time is 10:50 AM(ascending) and the inclination is 98.13 degrees. The orbit period is 98.5min., the orbit cycle frequency is 14+17/28 cycles per day, and the ground track repeating time is 28 days.

The OSMI instrument performs whisk-broom scan imaging operation with a ground sample distance(GSD) of 1km and a cross-track ground swath of 800 km. The scan width of 96 along-track pixels provides 0.5sec image overlap between two adjacent cross-track scans considering the satellite speed of 6.78km/sec.

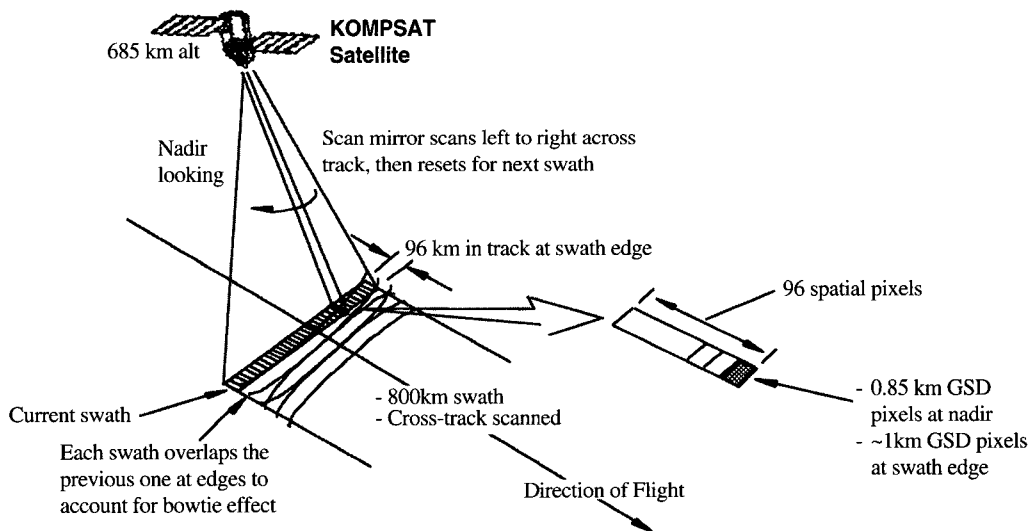


Fig. 1. OSMI Operation Design.

The OSMI instrument is designed to perform imaging operation for 20% per orbit and to generate 6 spectral image data of each cross-track scanning frame. The image data are digitized and lossless compressed before transfer to the payload data transmission subsystem(PDTS). PDTS will support worldwide imaging operation by providing data archive at on-board solid state recorder(data storage at the begin of life: 4Gbits) and X-band downlink of image data to the KARI ground station(KGS) at Taejon, Korea. Both the real time downlink and playback downlink of stored data are available with the data rate of 45Mbps. The KGS has the X-band acquisition radius of 1500km which allows two times data downlink per day, one is daylight(ascending orbit pass) and the other is nighttime(descending orbit pass).

3. OSMI Spectral Band Selection Capability

The OSMI is a multi-spectral instrument covering the visible spectrum from 400nm to 900nm. In the OSMI design there is built-in flexibility to provide band center and bandwidth selection capability via ground station command. Any 6 spectral band can be selected in the spectral range from 400nm to 900nm. There are always 6 bands without overlap among the bands. The band centers of the 6 spectral bands can be varied with the accuracy of 2.6 nm and the bandwidth for each of the 6 data channels can be changed from the minimum value of 5.2 nm to the maximum value of 166.4nm in steps of 2.6nm.

As the starting point in design step, the 6 primary spectral bands shown in the Table 1 are used to specify instrument performance. And its design is optimized to the 6 primary bands.

Table 1. OSMI 6 Primary Spectral Bands

Ocean Color Spectral Band	B1	B2	B3	B4	B5	B6
Band Center (nm)	443	490	510	555	670	865
Bandwidth (nm)	20	20	20	20	20	40

The OSMI ocean color spectral bands B1 through B4 provide ocean color data while band B5 and B6 provide information for atmospheric (aerosol) corrections.

Band #	Sensing Objective
B1: (443nm)	Concentration of chlorophyll
B2: (490nm)	Concentration of pigment
B3: (510nm)	Turbidity of chlorophyll
B4: (555nm)	Turbidity
B5: (670nm)	Calibration of atmospheric effect
B6: (865nm)	Calibration of atmospheric effect

The OSMI's on-orbit spectral band center and bandwidth selectability provide great flexibility in ocean color monitoring. For example, the 412 nm band, which is of interest in the Yellow Sea area near the Korean peninsula, can be monitored just by selecting the band via ground command without adding instrument complexity during on-orbit operation. In addition, this flexibility in band selection can provide research opportunities to support the next generation of sensor design.

4. OSMI Instrument Design

OSMI is designed to provide 6 spectral image data with GSD less than 1km over 800km swath width by whisk-broom scanning method at the altitude of 685km.

The OSMI instrument optics consists of the image scanner, the objective lens group and the multi-channel spectrometer. The scanner consists of a scan mirror driven by a servo-motor. The scanner has a +/-30 degree scan angle with respect to nadir resulting in an 800km swath from 685km altitude. The objective lens group forms the primary image which is dispersed into its various colors by the spectrometer. The dispersed image is then focused onto and detected by the focal plane assembly (FPA).

The OSMI electronics consists of (1) the FPA electronics section providing timing and voltage bias for the CCD FPA, (2) the analog signal processing and analog-to-digital (A/D) conversion section providing analog gain and offset signal adjustment and a 10-bit A/D signal conversion, (3) digital data processing and compression section providing 6 channels of data with the desired band centers and bandwidths, and uses data compression to reduce data volume, (4) a control processor section to provide control, communication and house keeping, (5) a motor drive section providing servo control for the scan motor and read out of the optical encoder for the position of the scan mirror, and (6) the power converter section to regulate DC power.

For on-orbit calibration, the OSMI design employs a two-level, black and white, calibration scheme. The sensor black calibration level is provided by a dark cell while the white calibration level uses attenuated solar radiance. The solar calibration is performed over the northmost part of the satellite orbit and the dark calibration is done at the beginning and end of each continuous image scan.

Physically, the OSMI instrument consists of two components (Figure 2), the sensor assembly and the electronics assembly. The sensor assembly includes optics chain,

FPA, analog signal processing. The electronics assembly has digital data processing, control processor, motor driver and power converter. The OSMI instrument nominal weight is about

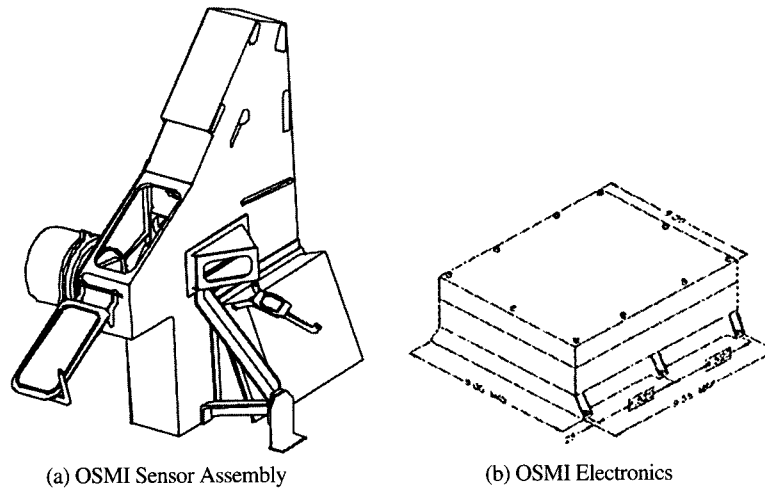


Fig. 2. OSMI Configuration

18kg and the peak power consumption is about 30 watts.

5. OSMI Mission Parameters

The OSMI has 4 operational modes; (1) the standby mode, (2) the imaging mode, (3) the dark calibration mode, and (4) the solar calibration mode. The mission parameters are summarized in the Table 2. The mission parameters are controlled by ground command and the

Table 2. OSMI Mission Parameters

Items	Mission parameters
- Band selection parameter	<ul style="list-style-type: none"> • Maximum selectable band numbers : 6 bands • Selectable spectral range : 400nm to 900nm • Band width step : 2.6nm • Selectable minimum band width : 5.2nm • Selectable maximum band width : 166.4nm
- Gain and Offset control parameter	<ul style="list-style-type: none"> • Gain control parameter : 8 step • Offset control parameter for 4 CCD channel : 256 step
- On-orbit calibration by Ground command	<ul style="list-style-type: none"> • Solar calibration on North pole per orbit • Normally dark calibration before and after image acquisition /solar calibration
- Image data storage capability	<ul style="list-style-type: none"> • on board memory: 4Gbits allocated at the begin of life • mission data can be stored for less than 6 days.

telemetry from the satellite contains LRC state-of-health (SOH) data such as operation mode status, temperatures and powers status, gain and offset status, selected bands status, and scan mirror position status

6. OSMI Performance

The instrument performance is measured on the ground for 8 basic spectral bands within the 400 nm to 900 nm spectral range including the 6 primary bands. These bands will be used as the main spectral bands for the OSMI basic mission, among which 6 spectral bands will be selected at a time to collect image data after launch. Some major OSMI performance test results are summarized as follows:

1) Spectral Band Characteristics

Table 3. OSMI Spectral Band Characteristics (TBR: To Be Resolved)

Spectral Bands			Measured Value				
No	Center Wavelength [nm]	Bandwidth [nm]	Low Ban edge[nm]	High Band edge[nm]	Intra-band response Variation*	Band Edge Error[nm]	Spatial Co-registratio Error**
B0	412	20	401.64	422.47	<10%	+/-4.9(TBR)	+/-1/3pixel
B1	443	20	432.88	453.72	<10%	+/-1.0(TBR)	+/-1/3pixel
B2	490	20	479.76	500.59	<10%	+/-1.0(TBR)	+/-1/3pixel
B3	510	20	500.59	521.42	<10%	+/-2.0(TBR)	+/-1/3pixel
B4	555	20	544.86	565.69	<10%	+/-1.6(TBR)	+/-1/3pixel
B5	670	20	659.43	680.26	<10%	+/-0.8(TBR)	+/-1/3pixel
BX	765	40	745.36	787.03	<10%	+/-1.6(TBR)	+/-1/3pixel
B6	865	40	846.92	888.58	<10%	+/-2.5(TBR)	+/-1/3pixel

* Intra-band response variation: variation of spectrum profile within each band
 ** The size of 1 pixel at CCD corresponds to GSD on the ground.

2) MTF

The satellite-level MTF is predicted as shown in the Table 4 based on the instrument level MTF measurement, space environment (temperature change and vacuum) effect analysis and

Table 4. MTF

Wavelength[nm]	412	443	490	510	555	670	765	865
Measured MTF(%)	> 20	> 20	> 20	> 20	>18	>18	>15	>15

satellite motion (Jitter & Smear) effect analysis.

3) Radiometric Characteristics

The Table 5 lists the input radiance, SNR and Radiometric Linearity of the OSMI.

Table 5. OSMI Radiometric Characteristics

(TBR: To Be Resolved)

Spectral Bands		Measured Value			
No	Center Wavelength [nm]	Saturation Input Radiance ¹⁾	Nominal Input Radiance ¹⁾	SNR	Radiometric inearity
B0	412	TBR	91.0	TBR	<10%
B1	443	329	84.1	> 450	<10%
B2	490	206	65.6	> 450	<10%
B3	510	123	54.4	> 450	<10%
B4	555	80	44.5	> 350	<10%
B5	670	62	26.0	> 350	<10%
BX	765	TBR	16.1	> 350	<10%
B6	865	68	10.9	> 350	<10%

1) Radiance unit in W/m²/um/sr

4) Polarization

The polarization of OSMI spectral channels is less than +/-5%.

5) Digitization and Compression

The OSMI image data are digitized to 10-bit and compressed using USES chip(CCSDS 121.0 B-1, Bluebook, 1997) before CCSDS grade 2 formatting and encoding.

7. Summary

The KOMPSAT OSMI instrument is designed to perform worldwide ocean color monitoring using 8 calibrated basic spectral channels in the 400 nm to 900 nm spectral range. The instrument has a 800 km ground swath from the satellite's 685 km sun synchronous orbit. The satellite ground track repeating time is 28 days and the orbit period is 98.5min. The instrument is designed to operate with a 20% duty cycle limited only by power consumption and in some cases also by on-satellite data storage capacity.

The OSMI has the capability to perform on-orbit selection of the imaging spectral band centers and bandwidths. This capability is designed to provide the greatest flexibility to support

the study of ocean color science from space.

The manufacturing and testing of the OSMI flight model (FM) was completed at the end of 1997. The instrument will be integrated and tested with the spacecraft at KARI until the end of 1998. Upon completion of the spacecraft integration, a test on the interfaces between the satellite, the KGS ground station, and the Taurus launch vehicle will be performed. The satellite is scheduled to be launched in August of 1999. On-orbit characterization of the OSMI instrument will be performed during LEOP, about 3 month after launch. The OSMI image data will be available for distribution at the end of 1999. The OSMI instrument is designed to operate for at least 3 years on-orbit.

Acknowledgment

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