Introduction of COMS Meteorological Imager

Young-Min Cho, Hwan-Chun Myung, Song-Doug Kang, Heong-Sik Youn
Korea Aerospace Research Institute
45 Eoeun Yuseong Daejeon 305-333, Korea
ymcho@kari.re.kr, mhc@kari.re.kr, kangs@kari.re.kr, youn@kari.re.kr

Abstract: Communication Ocean Meteorological Satellite (COMS) for the hybrid mission of meteorological observation, ocean monitoring, and telecommunication service is planned to be launched onto Geostationary Earth Orbit in 2008. The meteorological payload of COMS is an imager which will monitor meteorological phenomenon around the Korean peninsular intensively and of Asian-side full Earth disk periodically. The meteorological imager (MI) of COMS has 5 spectral channels, 1 visible channel with the resolution of 1 km at nadir and 4 infrared channels with the resolution of 4 km at nadir. The characteristics of the COMS MI are introduced in the view points of user requirements, hardware characteristics, and operation features.

Keywords: Communication Ocean Meteorological Satellite, COMS, geostationary satellite, meteorological imager, MI.

1. Introduction

Communication Ocean Meteorological Satellite (COMS) for the hybrid mission of meteorological observation, ocean monitoring, and telecommunication service is planned to be launched onto Geostationary Earth Orbit in 2008 according to the Korea national space program [1]. The mission orbit for COMS will be selected in the range from 116° East to 138° East. The meteorological payload of COMS is an imager which will monitor meteorological phenomenon around the Korean peninsular intensively and of Asian side full Earth disk periodically.

In order to meet the three missions simultaneously the COMS requires 3-axis stabilized geostationary satellite. Commercially available meteorological imagers which can be accommodated to 3-axis stabilized geostationary satellite are limited to only a few in the world. The imagers of GOES series have well known flight heritage history and are designed to be accommodated to 3-axis stabilized geostationary satellite [2]. ITT has produced eleven flight models of the imagers in the series. The Commercial Advance Geo-Imager (CAGI) of ITT is one of the recent imager models in the series, which is available commercially.

Korea Meteorological Administration (KMA) is the principal user of the image data of the meteorological imager (MI) of COMS and supports the development of the MI in the financial aspect. KMA defines the user requirements for the MI of the COMS [3]. Since the CAGI has high possibility to meet the user requirements with high quality for flight proof and can be accommodated to the COMS, it is selected for the MI. The MI will be provided by ITT for the COMS to be launched in 2008.

The user requirements, MI hardware characteristics and operation features are discussed as an introduction of the COMS MI.

Table 1. MI Spectral Channels and Applications

No.	Channel	Wavelength (㎛)	Meteorological Application
1	VIS	0.55 – 0.80	Daytime cloud imagery Detection of special event (yellow dust, fire, haze, etc.), Atmospheric motion vector
2	SWIR	3.5 – 4.0	Nighttime fog/stratus, Fire detection, Surface temperature
3	WV	6.5 – 7.0	Upper atmospheric water vapor, Upper atmospheric motion vector
4	WIN1	10.3 –11.3	Standard IR split window channel (cloud, Sea surface temperature, Yellow sand detection)
5	WIN2	11.5 -12.5	Standard IR split window channel (cloud, Sea surface temperature, Yellow sand detection)

2. User Requirements

It is required from the user that MI of COMS shall have 5 spectral channels in the visible and infrared (IR) region (1 visible channel and 4 IR channels) for the meteorological application as shown in the Table 1. The requirement for the spatial resolution of the MI is 1 km at nadir for the visible channel and 4 km at nadir for all the IR channels (Table 2). The MI is required to have the image data quantization of 10 bits for all the channels in the dynamic range of the Table 2. The user requirements specify the performance specification requirements such as Modulation Transfer Function (MTF), Signal to Noise Ratio (SNR), Noise Equivalent Differential Temperature (NEdT), calibration accuracy, and image navigation and registration for all the spectral channels. The user requirements also define the functional capabilities for the MI mission operation such as operation modes, imaging area control, in orbit calibration, image data formatting, thermal control, and etc..

Table 2. MI Resolution and Dynamic Range
(IFOV: Instantaneous Field Of View)

No.	Channel	IFOV (μrad)	GSD (km)	Dynamic Range
1	VIS	28	1	0 – 115 % albedo
2	SWIR	112	4	110 K – 350 K
3	WV	112	4	110 K – 330 K
4	WIN1	112	4	110 K – 330 K
5	WIN2	112	4	110 K – 330 K

The MI is required to operate its mission continuously through normal Earth imaging and in-orbit calibration with minimum performance degradation during the satellite eclipse periods.

The user requirements define that the MI shall have three observation modes of global, regional, and local mode which are specialized for the meteorological mission of periodical global weather observation, intensive monitoring of meteorological phenomenon around interested area such as the Korean peninsular, and early detection of local severe weather activity in Korea, respectively. The global mode is evoked for taking images of the Full Disc (FD) of the Earth. The regional observation mode is evoked for taking images of the Asia and Pacific in North Hemisphere (APNH), the Extended North Hemisphere (ENH), and Limited Southern Hemisphere (LSH). The image of Limited Full Disk (LFD) area can be obtained by the combination of the images of ENH and LSH. The local observation mode is activated for Local Area (LA) coverage in the FD. The user interest of the MI observation area for FD, APNH, ENH, LSH, LFD, and LA is shown in the Table 3 and the Fig. 1.

Table 3. MI Observation Area

Observation Mode	Observation Area*	Observation Period (min.)	Field Of View† (FOV)
Global	FD	30	EW: ≥19° NS: ≥ 17.6°
Regional	APNH	30	EW: -2.2° ~+4.3° NS: +8.1° ~+3.2°
	ENH	30	EW: -6.2° ~+6.2° NS: +8.1° ~-1.8°
	LSH	30	EW: -6.2° ~+6.2° NS: -1.8° ~-6.9°
	LFD	Combination of ENH and LSH	
Local	LA	10	EW: 1000km NS: 1000km (Random selection in the FD area)

* FD: Full disk, APNH: Asia and Pacific in Northern Hemisphere, ENH: Extended Northern Hemisphere, LSH Limited Southern Hemisphere, LFD: Limited Full Disk, LA: Local Area

† FOV Center: the Satellite Sub Point of 116° East, EW : East-West, NS: North-South

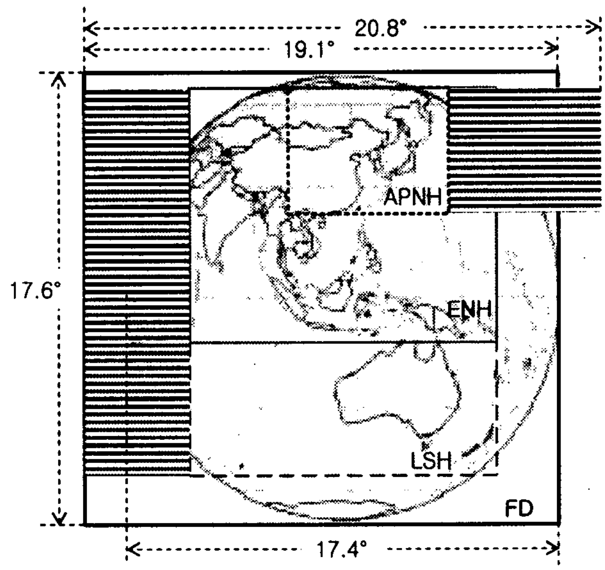

Fig. 1 Scan frames for scan clamp and space clamp (FD: scan clamp, APNH: space clamp East, ENH: space clamp West, LSH: space clamp West)

3. Hardware Characteristics

The MI is a five-spectral channel two-axis scanning imaging radiometer to sense radiant and solar reflected energy from the Earth simultaneously and to provide imagery and radiometric information of the Earth's surface and cloud cover.

The MI consists of three modules, that is sensor module, electronics module, and power supply module as shown in Fig. 2. The sensor module is mounted on an earth facing panel of the spacecraft. Electronics and power supply modules are mounted inside the body of the spacecraft.

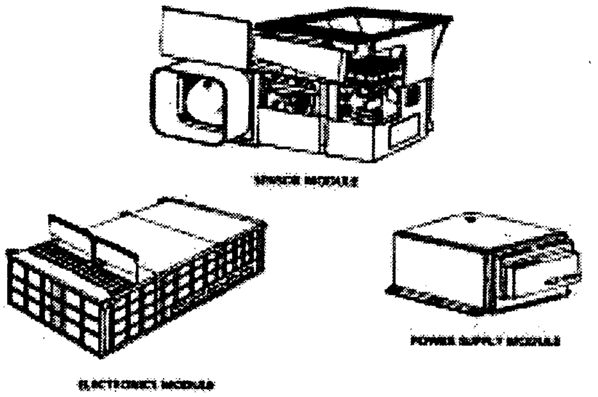

Fig. 2 MI Hardware Configuration

The sensor module contains a scan assembly, a telescope, aft optics, detectors, preamplifiers, a passive radiant cooler assembly, an on-board blackbody target, and an albedo monitor assembly. The electronics module performs command, control, signal processing, and telemetry conditioning. It has redundant circuits for command, signal processing, and some telemetry. The power supply module contains power converters, fuses, and power control for the interface with the spacecraft power system with redundancy.

The servo-driven, 2-axis gimballed scan mirror of the MI reflects scene energy reflected and emitted from the Earth into the telescope of the MI as shown in the Fig. 3. The mirror scans the Earth with a bi-directional raster scan, which sweeps a swath with 8 km width along East-West (EW) direction and steps every 8 km along North-South (NS) direction. The area of the observed scene depends on the 2-dimessional angular range of the scan mirror movement. The scene radiance, collected by the scan mirror and the telescope, is separated into each spectral channel by dichroic beam splitters, which allow the geometrically-corresponding detectors of each channel to look at the same position on the Earth. Each detector converts the scene radiance into an electrical signal.

The five channel detectors of the MI are divided into two sides, which are electrically redundant each other as shown in the Fig. 4. Only one side operates at one time by choosing side 1 or side 2 electronics. The visible silicon detector array contains eight detector elements which are active simultaneously in the either side mode. Each visible detector element produces the instantaneous field of view (IFOV) of 28 μrad on a side, which corresponds to 1km on the surface of the Earth at the spacecraft's suborbital point. Each IR channel has two detector elements which are active simultaneously in the either side mode. The SWIR channel employs InSb detectors and the other IR channels use HgCdTe detectors. Each IR detector element produces the IFOV of 112 μrad on a side, which corresponds to 4km on the surface of the Earth at the spacecraft's suborbital point. The 8 visible detector elements and 2 IR detector elements produce the swath width (8 km) of one EW scan line respectively.

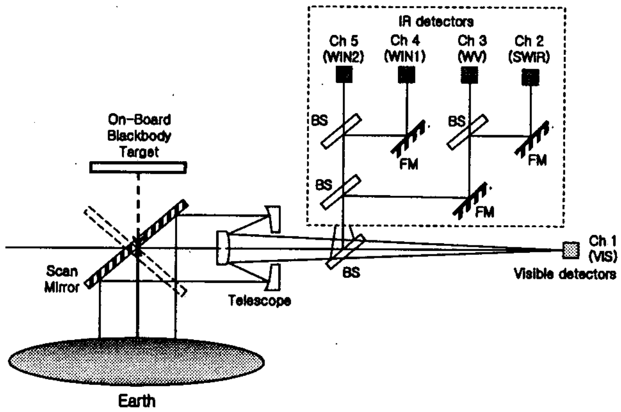

Fig. 3 Schematic Layout of MI Optics
(BS: Beam Splitter, FM: Folding Mirror)

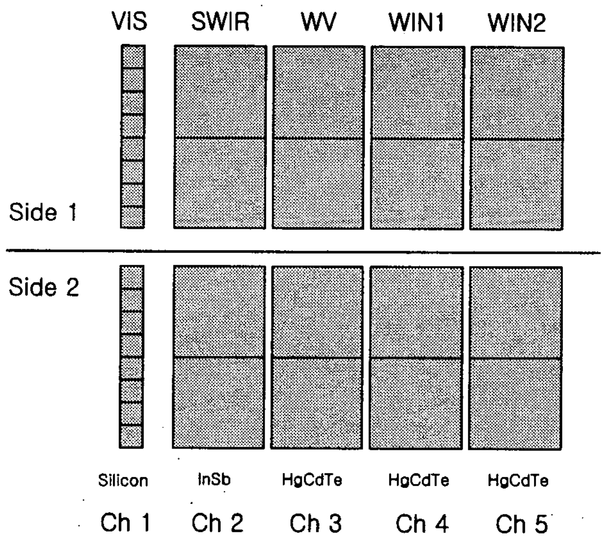

Fig. 4 MI Detector Layout

The passive radiant cooler with thermostatically controlled heater maintains the infrared detectors at one of three, command-selectable, cryogenic temperatures. Visible light detectors are at instrument ambient temperature. Preamplifiers convert low level outputs of all detectors into higher level, low impedance signals for input to the electronics module.

The MI carries an on-board blackbody target inside of the sensor module for in-orbit radiometric calibration of the IR channels. The blackbody target is located at the opposite direction to the nadir, so that the scan mirror is rotated 180 degrees in the NW direction from imaging mode to the blackbody calibration. The full-aperture blackbody calibration can be performed by the scan mirror's looking at the on-board blackbody target via ground command or automatically (Fig. 3). The albedo monitor is mounted in the sensor module to measure the in-orbit response change of the visible channel over the mission life. It uses sunlight through a small aperture as a source. In addition to radiometric calibration, electrical calibration is provided to check stability and linearity of the output data of the MI signal processing electronics by using internal reference signal. The MI has a star sensing capability in the visible channel, which can be used for image navigation and registration purposes.

4. Operation Features

The MI sweeps a swath along EW direction and step along NS direction for one visible and four IR channels using its 2-axis rotation scan mirror. During imaging operations, a scan line is generated by rotating the scan mirror in the East-to-West direction. At the end of the line, the scan mirror elevation is changed by a stepped rotation in the North-to-South direction. The next scan line is then acquired by rotating the scan mirror in the West-to-East direction after turn around at the end of the scan line. This process continues to the end scan line of the imaging area. The MI has flexible scan control enabling coverage of small areas as well as full earth disk and continuous observation of severe storms and of dynamic weather phenomena. The MI is controlled via a defined set of command inputs. Position and size of an area scan are controlled by command to provide imagery of full Earth disk, regional and local area.

The MI has predefined modes of operation such as observation (global, regional, and local), space look, blackbody calibration, star sensing, priority frame, idle, storage/standby, and radiant color outgas modes, which are controlled by ground command and whose statuses are monitored via telemetry [4]. Because of high demand for continuous data acquisition from the user, interruption of normal operation is minimized.

The IR radiometric quality of the MI image data is maintained by frequent and timed interval views of space for reference and timely view of the full-aperture on-board blackbody mounted for calibration in orbit.

During imaging the frame of observation area the imager looks cold space and to update zero radiance reference value periodically. For this activity, the MI has two modes of scanning, scan clamp mode and space clamp mode. The scan clamp mode scans the full earth width (the EW direction) with over-scan on the side toward the designated space position (normally 10.4° away from the satellite sub point). Imaging scan is kept going to the space position in the every scan line of the scan clamp. The scan clamp mode is used when scanning the FD or a sector of the earth having full E-W width. The space clamp mode is the choice for scanning a small frame within Earth's disk. This mode interrupts the frame imaging scan process every designated time interval for a scan to space. Two space clamp intervals are used normally. The fast space clamp mode scans to space every 9.2 sec. and the slow space clamp mode scans to space every 36.6 sec.. The scan clamp and space clamp can use either side space, East or West space of the earth disk. The scan frames for the MI observation areas with scan clamp or space clamp are shown in the Fig. 1. The space clamp over-scan from the end of the observation area to the space look point is indicated by shaded area in the Fig. 1.

The IR blackbody calibration is performed automatically every 19.4 minutes or manually by ground command. The space look occurs before and after the blackbody calibration. In case of the full Earth disk imaging, normally the blackbody calibration follows the imaging. The temperature of the blackbody target is measured precisely by the imbedded thermistors and is sent through telemetry to ground station.

The MI operates throughout a 24-hour day, every day of the year. Direct sun light can enter the interior of the imager around midnight spacecraft local time. The direct solar intrusion can affect imager performance such as NEdT and on-orbit absolute radiometric IR calibration accuracy and consequently reduce image quality.

5. Conclusions

The characteristics of the COMS MI are introduced in the view points of user requirements, hardware characteristics, and operation features.

The MI is two-axis scanning imaging radiometer which has 5 spectral channels, 1 visible channel with the resolution of 1 km at nadir and 4 infrared channels with the resolution of 4 km at nadir. The MI produces imagery of full Earth disk and small area of the Earth with space look and blackbody calibration.

The MI will be mounted on the spacecraft bus of the COMS to be launched onto Geostationary Earth Orbit in 2008 and will monitor meteorological phenomenon around the Korean peninsular intensively and of Asian side full Earth disk periodically.

References

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