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Analysis of the MSC(Multi-Spectral Camera) Operational Parameters

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Abstract : The MSC is a payload on the KOMPSAT-2 satellite to perform the earth remote sensing. The instrument images the earth using a push-broom motion with a swath width of 15 km and a GSD(Ground Sample Distance) of 1 m over the entire FOV(Field Of View) at altitude 685 km. 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-board image data compression/storage.

The MSC instrument has one channel for panchromatic imaging and four channel for multi-spectral imaging covering the spectral range from 450nm to 900nm using TDI(Time Delayed Integration) CCD(Charge Coupled Device) FPA(Focal Plane Assembly). The MSC hardware consists of three subsystem, EOS(Electro Optic camera Subsystem), PMU(Payload Management Unit) and PDTS(Payload Data Transmission Subsystem) and each subsystems are currently under development and will be integrated and verified through functional and space environment tests. Final verified MSC will be delivered to spacecraft bus for AIT(Assembly, Integration and Test) and then KOMSAT-2 satellite will be launched after verification process through IST(Integrated Satellite Test).

In this paper, the introduction of MSC, the configuration of MSC electronics including electrical interface and design of CEU(Camera Electronic Unit) in EOS are described. MSC Operation parameters induced from the operation concept are discussed and analyzed to find the influence of system for on-orbit operation in future.

Key Words : MSC, CCD, GSD, TDI, MTF, Line Rate.

1. Introduction

A lot of remote sensing instruments loaded on earth observation satellite have been developed and many users throughout the world have found the data from instruments to be a very useful source of information for applications and studies of the earth(Chen, 1985 & Pease 1991). KOMPSAT-1 was developed in Korea and successfully launched in 1999 as one of earth remote sensing satellite and is performing the mission of Korea cartography by EOC(Electro-Optic Camera) and ocean monitoring by OSMI(Ocean Scanning Multi-spectral Imager). And the collected and processed image data are distributed for the applications in several fields(Yong *et*

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al., 2000).

KOMPSAT-2 is being developed to continue the earth observation after KOMPSAT-1. MSC on KOMPSAT-2 has improved capability compared to EOC on KOMPSAT-1 from the point of GSD. MSC has 1m GSD and EOC has 6.6m GSD. The main mission objectives of KOMPSAT-2 are to provide information for surveillance of large scale disasters and its countermeasure, acquisition of high resolution images for GIS(Geographic Information Systems), composition of printed maps and digitized maps for the territories, balanced development of Korean territories, and survey of natural resources. The MSC is a main payload on KOMPSAT-2 to comply with the mission requirements and images the earth using a push-broom motion with a swath width of 15 km and a GSD of 1 m over the entire FOV.

The MSC has one panchromatic band of 1m GSD and four multi-spectral bands of 4m GSD covering the spectral range from 450nm to 900nm using TDI CCD FPA. The MSC is designed to have an on-orbit operation duty cycle of 20% over the mission lifetime of 3 years. The MSC are being developed and will be delivered to spacecraft BUS for AIT(Assembly, Integration and Test) after space qualification process is passed and final KOMSAT-2 satellite will be launched after verification process through IST(Integrated Satellite Test) and ETE(End-to-End) test.

In this paper, the configuration of MSC electronics including electrical interface and design of CEU in EOS are described. MSC Operational parameters induced from the operation concept are discussed and analyzed to find the influence of system for future operation.

2. General Description and Requirements

The MSC provides a panchromatic band information and four multi-spectral bands information in the spectral range from 450nm to 900nm using TDI CCD FPA over the swath width of 15 km. The MSC is specified to meet the performance requirements as shown in Table 1 and also has the functions of programmable gain and offset, and on-board compression and storage and the white and dark calibration for on-board radiometric calibration. The acquired image data is formatted and transmitted to Ground station through X band as 320Mbps downlink rate.

The mass property is complied with 120 kg and the peak power is required to 335 watts including heater power.

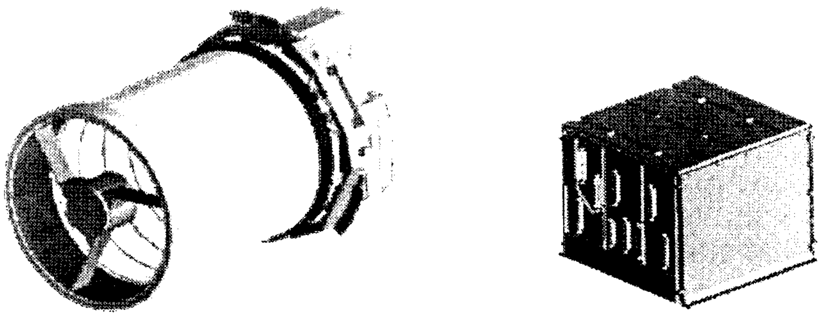
Other requirements reflected to MSC design from spacecraft system are automatic normal operation capability, stereo imaging capability by spacecraft tilting, and compatibility with spacecraft roll tilting of $\pm$ 56 degrees and pitch tilting of $\pm$30 degrees.

The MSC physically consists of EOS, PDTS, PMU and interconnection harness. The EOS comprises optical module including optical components and optical structure, panchromatic FPA, multi-spectral FPA and two CEUs. And the PDTS consists of DCSU(Data Compression Storage Unit), DLS(Data

Table 1. Performance of MSC PAN and MS bands.

MSC Channel	PAN	MS1	MS2	MS3	MS4
GSD (m)	1	4	4	4	4
Spectral Range(nm)	500 ~ 900	450 ~ 520	520 ~ 600	630 ~ 690	760 ~ 900
MTF*(%)	≥ 15	≥ 20	≥ 20	≥ 20	≥ 20
SNR	≥ 100	≥ 100	≥ 100	≥ 100	≥ 100

* MTF: Modulation Transfer Function



(a) EOS (b) PMU

Fig. 1. MSC configuration.

Link System) including CCU(Channel Coding Unit) and QTX(QPSK Transmitter), and APS(Antenna Pointing System).

3. MSC Electronics Design

The electronic parts of MSC consist of two CEU in EOS, CEU-PAN and CEU-MS, PMU which manages all MSC including PSM(Power Supply Module) for the distribution of power, and PDTS for compression, encryption, formatting and transmission of image data.

No single point failure, cold or hot redundancy, cross strap design(power control line, image data line and general communication line) and using of space qualified components are considered as reliability requirement for MSC electronics design.

EMI(Electromagnetic Interference)/RFI(Radio Frequency Interference) design in accordance with EV(Environment) requirements, minimum weight and optimum power consumption and function of BIT(Built-In Test) are also considered as other design requirements.

1) Configuration of MSC Electronics

The configuration of MSC Electronics is shown in Fig. 2. The MSC front end is the CEU that is built of two independent units. The CEU-PAN is based on a high-resolution panchromatic detector array that converts the same input light spectrum into a digital image data. The CEU-MS is based on a high-resolution multi-spectral detector array that converts the different input light spectrum into a digital image data. The image

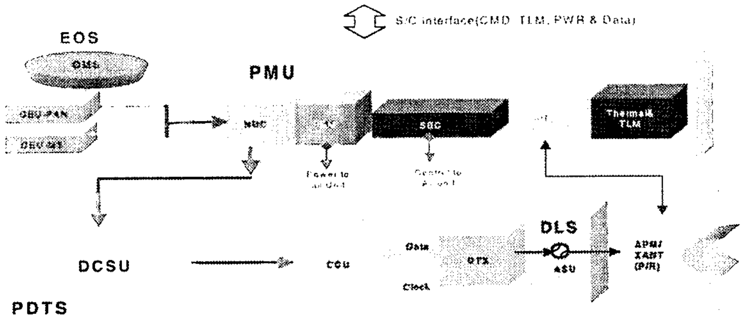


Fig. 2. MSC block diagram.

data are sent to DCSU for compression and storage using still image compression algorithms and sufficient storage control mechanism. Compressed/uncompressed data is encrypted in CCU before CCSDS encoding. The encoded data is translated into the RF signals that are sent through the antenna to Ground station. The PMU controls the overall MSC system, using communication channels and also communicates with the spacecraft, using RS422 and 1553B.

The MSC is powered by unregulated power of the spacecraft and the power of EOS thermal control is also supplied for normal or survival mode.

2) MSC Electrical Interface

MSC electrical interface consists of external interface with spacecraft and internal interface with MSC subsystems and units.

The MSC external electrical interfaces are power interface, analog and digital command/telemetry, such as 1553 interface for general control and discrete commands for such as reset, safe-hold and PMU active and so on. Spacecraft supply unregulated 28V power to PMU with latching relay on/off commands under the protection of fuse, and PMU report the status of each relay as well as power returns. MSC is communicated with spacecraft for general control through 1553B bus and discrete commands, such as reset, safe-hold and PMU active and accurate 1Hz time mark signal are sent to MSC. The antenna pyro mechanism status, PMU status, and temperature are transmitted through discrete and analog telemetry interface and other interface is OBC data interface for X band transmission of playback data.

The MSC internal interfaces are digital command/ telemetry interface, high-level pulse command interface, analog telemetry interface and image data interface. RS-422 interface is selected for internal digital communication. Received commands from spacecraft will be transmitted to subsystem and each unit after interpreted by PMU. That is, RS-422 serial communication will be used for unit operation control, download or upload data parameter, and request/collect digital telemetry. Analog telemetry, such as temperature, voltage and status will be collected through dedicated interface, converted and encoded to report to spacecraft.

The design of interfaces configuration and the selection of interfaces type and related components are selected based on KOMPSAT-1 heritage and analysis results of required speed and concept of cross-strap so on(Yong and Heo, 2000).

4. MSC Operation Concept and Parameter

The MSC images the earth using a push-broom motion with a swath width of 15 km and a ground sample distance of 1 m over the entire field of view at Nadir.

The MSC has one panchromatic band of 1m GSD and four multi-spectral bands of 4m GSD covering the spectral range from 450nm to 900nm using TDI CCD FPA that has 32 TDI level. The MSC is designed to have an on-orbit operation duty cycle of 20%.

In a standpoint of operation, MSC has a capability of automatic normal operation and stereo imaging

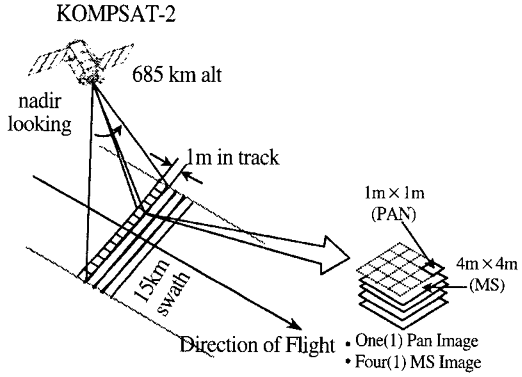


Fig. 3. MSC operation concept.

capability by spacecraft tilting, and a compatibility of spacecraft roll tilting of ±56 degrees and pitch tilting of ±30 degrees. In order to meet these requirements, MSC mission commands will be stored with execution time in PMU prior to actual operation. And MSC can also change line rate from 7100 to 2200 lines per second to reduce the degradation of image quality due to mismatching incurred by change of satellite ground velocity, and satellite roll and pitch tilting.

As above example, MSC have several parameters for mission control, such as line rate, gain & offset, number of sector for recording, compression ratio, Huffman & quantization table, encryption key and so on. These parameters setting is very important to achieve good quality image data from MSC and they should be selected and commanded taking into account operation environment, situation and hardware status.

The operation parameters are analyzed and described in next section for future operation, especially, line rate related which is known in current design and other parameters will also be analyzed as their configuration are finally frozen(Yong *et al.*, 2001).

1) MTF change by mismatched line rate

MSC image quality is changed by mismatched line rate with actual satellite ground velocity that is incurred by altitude change, satellite roll tilting, and pitch tilting.

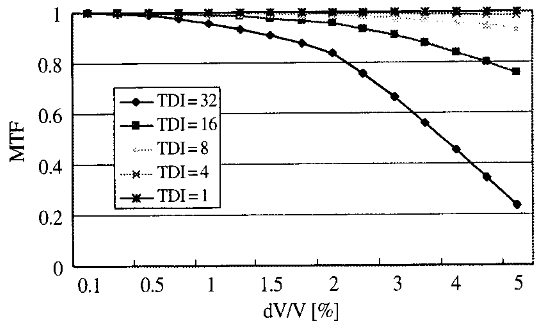


Fig. 4. MTF degradation Vs. mismatched line rate.

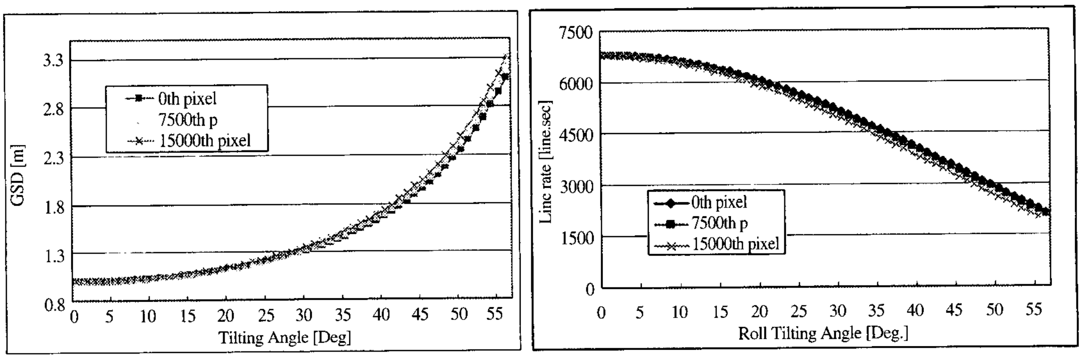
MSC can control line rate to minimize image quality within possible range. MTF is one of the major specification to evaluate image quality in electro-optic camera system and MTF degradation due to mismatching line rate is shown in Fig. 4.

The small difference(5 %) of ground velocity which is same meaning with mismatched line rate is resulted as large degradation of MTF as shown in Fig. 4 and appropriate line rate setting as a operation parameter is very important to make a match even though controllable range in hardware is limited.

2) Line rate change by satellite tilting

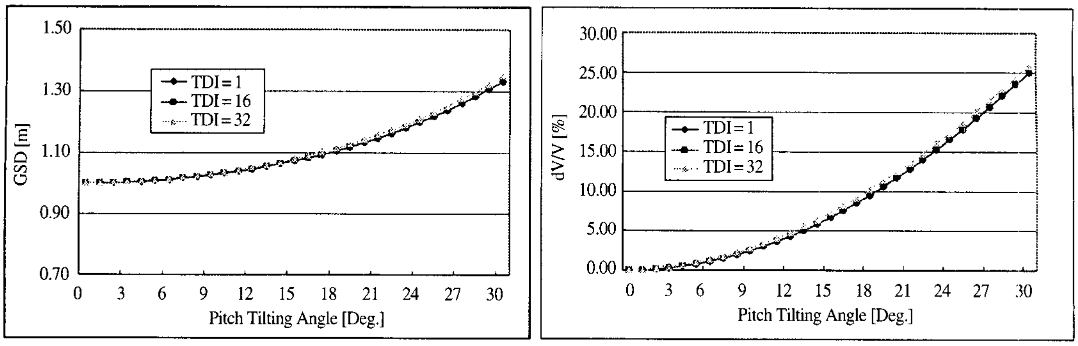
MSC is designed to be compatible with satellite tilting on pitch axis and tilting requirements are +/-56 degrees on roll axis and +/-30 degrees on pitch axis.

When satellite is tilted, MSC footprint will be



(a) GSD (b) Line rate

Fig. 5. GSD & line rate change by roll tilting angles.



(a) GSD (b) Mismatched line rate

Fig. 6. MSC characteristics change by satellite pitch tilting.

changed by tilting axis and angle.

In case of roll tilting, MSC has different results by tilting angles, like GSD at the pixels of different location in swath width and line rate change is also needed if square footprint is required as shown in Fig. 5.

In order to find best line rate for all swath, the center of swath which is 7,500th pixels is best location as a reference of line rate. When satellite is tilted on pitch axis, MSC has a different GSD and line rate at different TDI level and MSC image quality is improved by change of line rate based on analysis results as shown in Fig. 6.

GSD is changed according to tilting angle and adjustment of line rate is necessary in accordance with TDI level and tilting angle to achieve best image as satellite is tilting on pitch axis. If line rate is not adjusted, this mismatching is resulted to quality degradation as shown in Fig. 4.

5. Conclusions

KOMPSAT-2 is being developed to continue the earth observation after KOMPSAT-1 and has improved capability by MSC which has higher GSD of 1m resolution than EOC on KOMPSAT-1. The MSC images the earth using a push-broom motion with a swath width of 15 km and a ground sample distance of 1 m over the entire field of view.

The MSC has one panchromatic band of 1m GSD and four multi-spectral bands of 4m GSD covering the spectral range from 450nm to 900nm using TDI CCD FPA. The MSC is designed to have an in-orbit operation duty cycle of 20% over the mission lifetime of 3 years.

In this paper, indroduction of MSC with top level requirements, the configuration of MSC electronics including electrical interface and design of CEU in EOS are described. The operation parameter induced from the operation concept are analyzed to find the influence of system for future operation, especially, line rate related which is known in current design and other parameters will also be analyzed as their configuration are finally frozen.

As a results of analysis, this paper shows that appropriate line rate setting is very important to minimize degradation of image quality, like a MTF and change of line rate is necessary for best MSC image data as MSC mission is perform under satellite roll tilting and/or pitch tilting.

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