Study on Solar Constraint in the Operation of COMS Meteorological Imager

Young-Min Cho
Korea Aerospace Research Institute
P.O. Box 113 Yuseong Daejeon 305-600,Korea
ymcho@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 according to the Korea national space program. A feasibility study on the solar constraint in the operation of the COMS meteorological imager (MI) is performed using the GOES imager hardware operation characteristics. The Earth observation areas of the MI are introduced and the observation time of the MI observation area is calculated. The sun light can enter into the MI optical system around the local midnight and impinge on the performance of the MI. The solar eclipse viewed from the satellite occurs near local midnight around the equinox. This study discusses the restriction of imaging operation time that should be considered in order to avoid the solar intrusion about local midnight and to keep acceptable image quality for the MI observation areas. This study could be useful to build the operation concept of the MI during the development of the MI.

Keywords: Communication Ocean Meteorological Satellite, COMS, meteorological imager, MI, solar intrusion, operation time restriction.

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 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 mission orbit for COMS will be selected in the range from 116° East to 138° East. The meteorological imager (MI) of COMS will be designed to have 5 spectral channels, 1 visible channel with the resolution of 1 km at nadir and 4 infrared (IR) channels with the resolution of 4 km at nadir.

In order to meet the three missions simultaneously the COMS requires 3-axis stabilized geostationary satellite. Commercially available imagers which can be accommodated to 3-axis stabilized geostationary satellite are limited to only a few including the GOES series imagers in the world. The GOES imagers have well known flight heritage history and easy access to information on its operation characteristics [2]. The GOES imager hardware operation characteristics is used for feasibility study on the solar constraint in the operation of the MI [3].

The MI observation areas which attract the users are introduced and the total frame time of the area observation is calculated using GOES imager scan mechanism characteristics. The sun light can enter into the MI optical system around the local midnight and impinge on the performance of the MI. The solar eclipse viewed from the satellite occurs near local midnight around the equinox. The solar constraint in the operation of the MI is analyzed for the MI observation area. Operation time restriction required for keeping normal image quality is calculated to investigate the dependence of the operation time restriction on each MI observation area.

Table 1. MI Observation Area

Observation Mode	Observation Area*	Observation Period (min.)	Field Of View† (FOV)
Global	FD	30	EW: ≥19° NS: ≥ 17.6°
	APNH	30	EW: -2.2° ~+4.3° NS: +8.1° ~+3.2°
Regional	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

2. MI Observation Area

The MI has 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 1 and the Fig. 1.

During imaging the frame of observation area the imager looks cold space and to update zero radiance reference value periodically. For this activity, the GOES imagers have two modes of scanning, scan clamp mode and space clamp mode. The scan clamp mode scans the full earth width (East-West (EW) direction) with overscan 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. This interruption requires additional invalid scans for every scan to space, which take additional time comparing with the overscan of the scan clamp. The space clamp periods are integer multiples of 4.58 sec. and 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 overscan from the end of the observation area to the space look point is indicated by shaded area in the Fig. 1.

The total frame time of the MI observation areas are calculated for the scan clamp mode and the space clamp mode based on the scan mechanism of the GOES imager (Fig. 2). The total frame time includes the time required for both the scan within the observation area and the overscan to the space look point of 10.4° away from the satellite sub point. As expected it is found that regardless of the size of observation area the slow space clamp takes the shortest time. Note that in large enough observation area like ENH and LSH the fast space clamp takes more time than the scan clamp. The reason for this paradoxical result can be explained by the interruption of the frame imaging scan in the space clamp. The scan clamp is recommended rather than the fast space clamp in large enough observation area like ENH and LSH. There is scarcely any difference between the frame time of the both side space clamps, the clamps at East and West space of the earth disk.

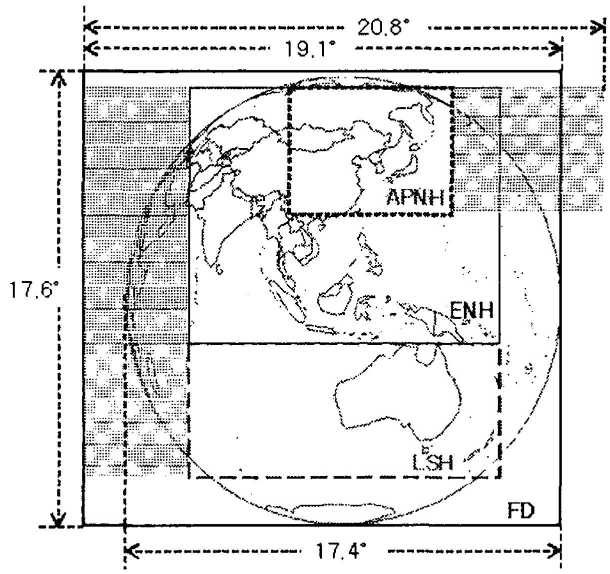

Fig. 1 Scan frames for scan clamp and space clamp (FD: scan clamp, APNH: space clamp East, ENH: space clamp West, LSH: space clamp West)

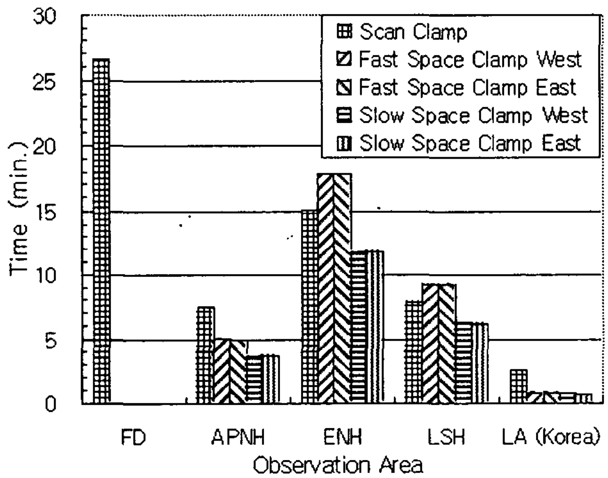

Fig. 2 Total frame time of the observation Area

3. Solar Constraint

The MI operates throughout a 24-hour day, every day of the year. Direct sun light can enter the interior of the imager before and after midnight spacecraft local time when the Sun gives bright background illumination to the Earth which is viewed by the imager. The solar eclipse viewed from the satellite can also occur about local midnight around the equinox. During the eclipse the direct solar intrusion does not occur.

The solar heating of the interior of the imager makes reliable zero reference by space look and on-orbit IR calibration difficult or impossible. So the direct solar intrusion can affect imager performance such as NEDT and on-orbit absolute radiometric IR calibration accuracy and consequently reduce image quality. In order to keep normal image quality it is required that the imager scan frames without solar intrusion i.e. the Line-Of-Sight (LOS) of the imager avoid to view the vicinity of the Sun.

The GOES imager has a solar Keep-Out Zone (KOZ) which is a circular angle zone of reduced image quality with a radius described by the angle between the imager's LOS and the line from the imager to the Sun. The boundary of the KOZ of the GOES imager is 6° (Fig. 3).

The KOZ can be violated during imaging operation before and after the local midnight. In other words there is a restriction in operation time that should be avoided for keeping normal image quality. The operation time restriction due to the solar intrusion can be express by the scan start time of a frame scan that violates the KOZ during its scan.

4. Operation Time Restriction

The operation time restriction for normal image quality is analyzed for the MI observation areas of the Table 1 in case of no interruption during the frame imaging of the observation area due to operation of higher priority activity such as blackbody calibration. Slow space clamp which shows the shortest total frame time in the Fig. 2 can be a good typical case for this analysis. Clamp West is used for the FD, the ENH, and the LSH in the analysis (Fig. 1). Clamp East is applied to the APNH which is located toward the East.

The operation time restriction zones for the FD, APNH, ENH, LSH, and LA around Korea are shown in the Fig. 4~8, where the equinox of the year 2004 is applied to the date of year at the perpendicular axis of the figures. The figures are obtained using the North-South scan from the North to the South and the KOZ boundary radius of 6° from the LOS to the center of the Sun. The figures show, for each day of the year, the time at which the KOZ violation occurs for each scan frame. A frame can be initiated and complete without reduced image quality if the start time of the frame is outside the operation time restriction zone which is indicated by shaded area in the figures. The hole of the Fig. 4 and the concave part of the Fig. 5~8 indicate that images can be obtained during the eclipse without solar intrusion, because the Sun is obstructed by the Earth during the eclipse.

The rectangular boundary which contains the operation time restriction zone is summarized in the Table 2. Considering all the observation areas together, the operation time restriction boundary become 22:29 ~ 1:05 a day during Feb-10 ~ Apr-28 and Aug-15 ~ Nov-01. The operation time restriction boundary of the FD is 149 minutes around local midnight a day for about 78 days in spring and autumn respectively. The restriction boundary of the APNH is 101 minutes a day for about 43 days. Therefore the observation for small area such as APNH and LA is more effective than that of large area like FD and ENH in order to avoid image quality reduction due to the solar intrusion around local midnight.

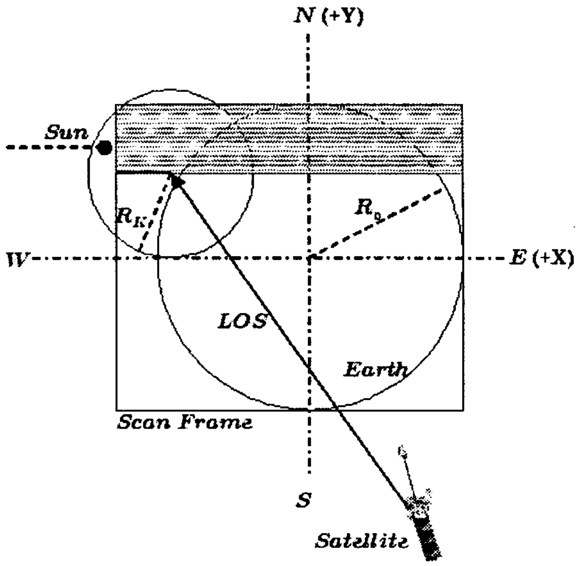

Fig. 3 Solar Keep-Out-Zone with the boundary radius of R_K

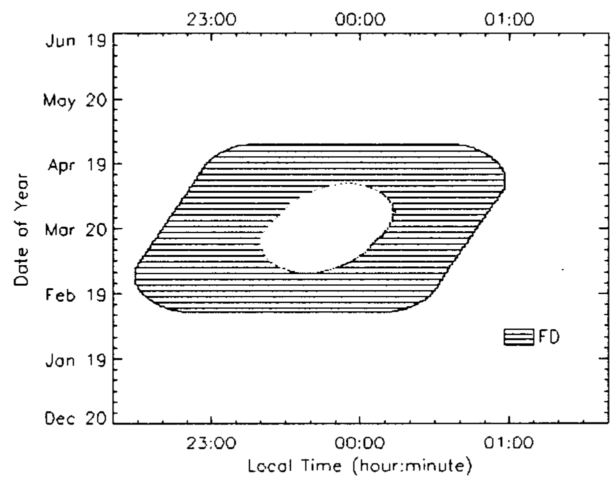

Fig. 4 Operation time restriction for the FD with scan clamp west

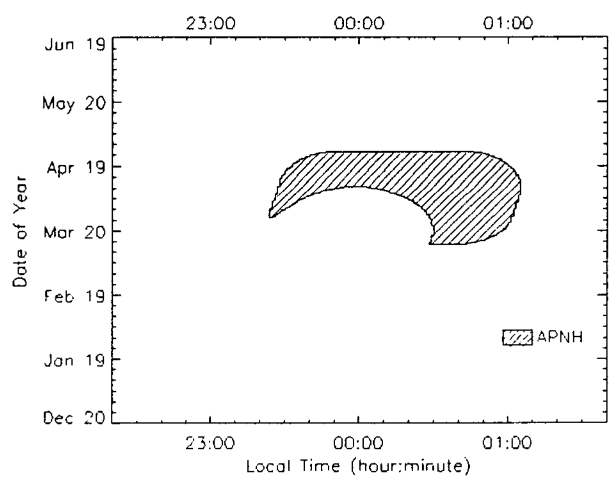

Fig. 5 Operation time restriction for the APNH with slow space clamp east

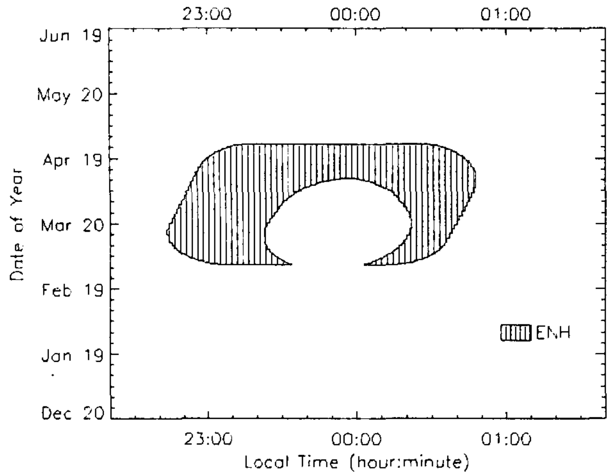

Fig. 6 Operation time restriction for the ENH with slow space clamp west

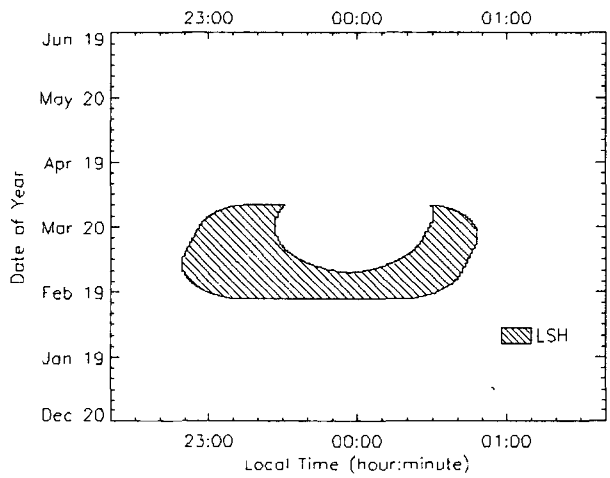

Fig. 7 Operation time restriction for the LSH with slow space clamp west

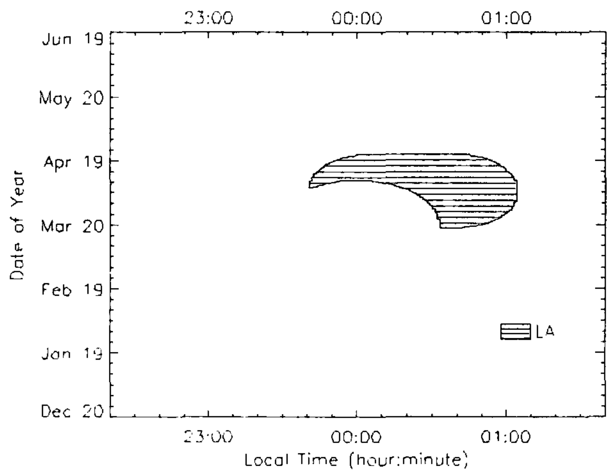

Fig. 8 Operation time restriction for the LA around Korea with slow space clamp east

Table 2. MI Operation time restriction boundary summary (for the equinox of the year 2004)

	Date	Local Time
FD	Feb-10 ~ Apr-28 Aug-15 ~ Nov-01	22:29 ~ 0:58
APNH	Mar-14 ~ Apr-26 Sep-17 ~ Oct-30	23:24 ~ 1:05
ENH	Mar-01 ~ Apr-26 Sep-04 ~ Oct-30	22:43 ~ 0:48
LSH	Feb-16 ~ Mar-30 Aug-21 ~ Oct-03	22:49 ~ 0:48
LA (Korea)	Mar-19 ~ Apr-22 Sep-22 ~ Oct-26	23:41 ~ 1:04

5. Conclusions

The feasibility study on the solar constraint in the operation of the COMS meteorological imager (MI) is performed using the GOES imager hardware operation characteristics.

The Earth observation areas of the MI, FD, APNH, ENH, LSH, and LA, are introduced and the observation time of the MI observation area is calculated using GOES imager scan mechanism characteristics. It is found that regardless of the size of observation area the slow space clamp takes the shortest time and that in large enough observation area like ENH and LSH the fast space clamp takes more time than the scan clamp.

The solar constraint in the operation of the MI is analyzed for the MI observation area to calculate the operation time restriction required for keeping normal image quality. When the KOZ boundary radius of 6° is used, the operation time restriction boundary of the FD is 149 minutes around local midnight a day for about 78 days in spring and autumn respectively. The restriction boundary of the APNH is 101 minutes a day for about 43 days. It is noted that the observation for small area such as APNH and LA is more effective than that of large area like FD and ENH in order to avoid image quality reduction due to the solar intrusion around local midnight.

This study could be useful to build the operation concept of the MI during the development of the MI.

References

[1] Zeen-Chul, Seong-Bong Choi, and Jung-Hoon Kim, 2003. Conceptual Design of Communication, Ocean and Meteorological Satellite System, *Proc. Joint Conference on Satellite Communication*, Tokyo, pp.31-37.

[2] Space systems Loral, 1996. GOES I-M Databook Revision 1, pp20-38.

[3] ITT Industries, 2003. ITT Imager Operational Reference Manual Revision B, pp. 2-1~2-44