NASA EOS DB Receiving System Development by KARI

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Abstract: Recently, KARI implemented the receiving and processing system for MODIS sensor data from NASA EOS satellites (TERRA and AQUA). This paper shows the development strategy considered, system requirement derived, system design, characteristic and test results of processing system. System operation concept and sample image are also provided. Implemented system was proven to be fully operational through lots of pass operations activities from RF signal reception to level-1 processing.

Key words: NASA, EOS, MODIS, TERRA, AQUA, DB

1. Introduction

The NASA polar-orbiting EOS satellites, TERRA and AQUA, launched in 1999 and 2002 respectively provide greatly enhanced remote sensing capabilities for the observation of planet Earth. Both of these platforms have a direct broadcast X-band downlink that allows MODIS (TERRA) and MODIS, AIRS, CERES, HSB, AMSU, and AMSR (AQUA) sensor data to be received in real-time by sites having the proper reception hardware such as 3m dish tracking system and receiver system.

Historically, this direct broadcast follows the Automatic Picture Transmission (APT) service initially offered in December, 1963 (on TIROS-VIII) and presently used by thousands. APT operated in the UHF band (near 137MHz with a 2.4KHz AM data signal) and can be received by anyone with a PC and a modest receiver (e.g., a card in the PC). APT produces images with 2 channels and 4km resolution. APT was followed by High Resolution Picture Transmission (HRPT) data from National Oceanic and Atmospheric Administration's (NOAA) polar orbiting satellites in October, 1978. HRPT operated in L-band (around 1.7GHz) at a higher data rate of 665.4Kbps and produced images with 5 channels and 1.1km resolution.

The TERRA and AQUA instruments being supported by Direct Broadcast (DB) services are listed on Table 1 and equivalent and better instruments are expected to be available on subsequent satellites.

Table 1. EOS TERRA/AQUA DB instruments and rates

Spacecraft	Instruments	Data Rate (Mbps, avg)	Data Rate (Mbps, peak)
TERRA	MODIS	6.200	11.000 Total: 11.016
AQUA	MODIS	6.200	11.000
	AMSU	0.003	0.003
	CERES	0.020	0.020
	HSB	0.004	0.004
	AMSR	0.130	0.130
	AIRS	1.440	2.000
			Total: 13.157

EOS DB instruments in Table 1 provide various scientific data. Especially MODIS sensor plays a key role among DB instruments. MODIS stands for the MODerate-Resolution Imaging Spectroradiometer. It employs a conventional imaging radiometer concept, consisting of a cross-track scan mirror, collecting optics, and a set of linear detector arrays with spectral interference filters located in 4 focal planes.

MODIS is designed to measure biological and physical processes with 36 channels on a global basis every 1 to 2 days. Scientific data expected to be derived from MODIS include:

- Surface temperatures with 1km resolution
- Ocean color
- Chlorophyll fluorescence
- Concentration of chlorophyll alpha

- Vegetation/land surface cover, condition
- Cloud cover with 250m resolution
- Cloud/Aerosol properties
- Fire detection, size
- Global distribution of total precipitable water

A lots of data products available in MODIS sensor made KARI believe that it is imperative to develop the EOS TERRA/AQUA receiving and processing system.

In later section, detail descriptions for how DB receiving and processing system has been implemented at KARI is provided.

2. System design

KARI has been used 13m X-Band antenna system for KOMPSAT image data acquisition since 1999. Operational 13m system provides G/T value around 37dB/K, which is 14dB above than required G/T, 23dB/K.

Communication link margin analysis considering G/T value of 37dB/K showed that more than 16dB margin is always available for TERRA/AQUA DB service with operational 13M auto-track antenna system for BER of 1x10-5. Auto-track function for TERRA/AQUA was activated by adding spacecraft information like spacecraft name, NORAD ID, and downlink frequency into configuration file.

Existing Data Ingest Server (DIS) has a capability to record raw data itself into RAID system. Therefore, we focused on investigating what process have to be done to get flawless raw image data with DIS through reviewing RF/BB characteristics of TERRA and AQUA described in several documents in public domain.

Major RF/BB characteristic for both EOS satellites is shown in Table 2.

Table 2. RF/BB characteristics of TERRA/AQUA

Satellite	TERRA	AQUA
Frequency	8212.5MHz	8160MHz
Data rate	13.125Mbps	15.000Mbps
Polarization	RHCP	RHCP
Modulation	UQPSK(I:Q=1:4)	OQPSK
PCM code	NRZ-M	NRZ-M
Channel Code	PN for only VCDU -> RS encoding for only PN-ed code -> 1/2 convolutional encoding	RS encoding for VCDU -> PN code for CVCDU

KARI decided to procure a EOS DB-dedicated receiver instead of adding bit-sync cards into operational demodulator because dedicated receiver guarantee required performance with less budget and independent EOS DB system, leading no interaction with operational KOMPSAT-1 receiving hardware and software.

3dB power divider was used to provide IF frequency into receiver from operational down-converter. ECL router configuration was updated to secure ECL signal routing. RG58 cables were used to minimize the signal loss between receiver and DIS.

Figure 1 shows a KARI EOS DB system diagram.

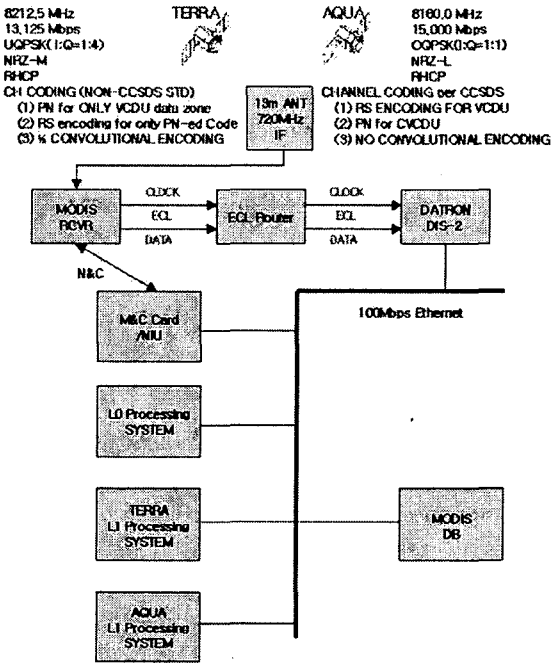

Figure 1. KARI EOS DB system

Saved raw DB data is moved to level-0 processing system via FTP, then processed into several EOS standard Product Data Set (PDS) files, and finally moved to level-1 processing system for further processing.

All equipment status are monitored and logged for operational purpose, which includes signal strength, frequency offset, demodulation lock status, bit-sync status, ingest status. For this purpose, KARI implemented in-house RS232 controller system for receiver. RS232 controller can be operated remotely over Ethernet via Network Interface Unit (NIU).

Pentium-4 PC with window2000 OS was decided for processing system due to its easiness to handle and cost-effectiveness.

100Mbps Ethernet interface was used for fast transfer of massive DB data between systems.

Overall system operation was planned to be automatic via scheduling, which eventually reduces operational work-load during real-time pass.

3. Level-1 processing system

The core level-1 processing software has been developed and released by both NASA and SSEC, university of Wisconsin. The International MODIS/AIRS Processing Package (IMAPP) allows any ground station capable of receiving DB from TERRA and AQUA to produce calibrated and geo-located MODIS radiances. IMAPP is derived from the operational MODIS processing software developed at NASA GSFC, and is modified to be compatible with DB data by SSEC.

SSEC ported IMAPP to a range of UNIX platforms while ScanEx done a windows port, namely IMAPPW.

KARI decided to use IMAPPW for DB level-1 processing software under window 2000 in Pentium-4 PC.

IMAPPW can be used for entry levels processing of MODIS data level-0 received with DB. The processing includes following operations:

- reformatting data from a sequence of CCSDS packets (level-0 data) into a level-1A HDF file
- calculation of geolocation parameters for each 1km pixel
- calibration of earth view raw MODIS digital counts into radiance values

To achieve above operations, 3 command prompt applications (Unpack, Geolocate, Calibrate) are provided in IMAPPW.

Program unpack.exe reformats science and telemetry information from MODIS level-0 files into the level-1a files in a HDF format. MODIS level-1A contains raw sensor data, on-board telemetry and created processing quality information formatted as HDF objects.

Geolocate.exe performs a geo-location processing of MODIS data and outputs an HDF files containing arrays of latitude, longitude and imaging angles for each 1km pixel. Output file has identifier MOD03.

Last program, calibrate.exe performs systematic calibration of MODIS earth view data from raw device counts to absolute radiances. As a result standard MOD02 product is generated. Output files consists of 4 separate files: MOD02QKM, MOD02HKM, MOD021KM, MOD02OBC. As an input the calibration process utilizes both level-1A and geo-location files generated at previous steps.

KARI designed to use 2 mission-dedicated level-1 processing systems because several ancillary files needed to process DB data have to be separated but processing software uses fixed name.

4. Level-0 processing system

The input expected by IMAPPW, level-1 processing software, is level-0 MODIS data, defined as reconstructed time-ordered CCSDS packets with all communication artifacts including duplicate packets removed. This includes PN and RS decoding as well as reassembly of the raw telemetry packets. Processing of the data stream to this stage is the responsibility of the DB service user. Data in this format is known as a Production Data Set (PDS).

KARI developed in-house software named terra_wizard, and aqua_wizard, respectively. Each wizard program produces final level-0 PDS files from TERRA/AQUA raw data saved in DIS RAID.

Processing procedure in both programs is different due to different on-board coding schemes in two satellites. RS decoding step was skipped in both wizard software for rapid processing because link margin above 12.5dB is guaranteed without RS decoding in 13m receiving system for BER of 1x10-5.

Main processing steps in level-0 are as follows:

- Saved raw data get via FTP from DIS

- Removal DIS header
- Frame synchronizing, CCSDS
- PN decoding
- CCSDS CADU de-multiplexing per VCID
- CCSDS Packet assembly
- PDS file generation
- PDS file transfer to level-1 processing system

Figure 2 shows initial version of in-house wizard software.

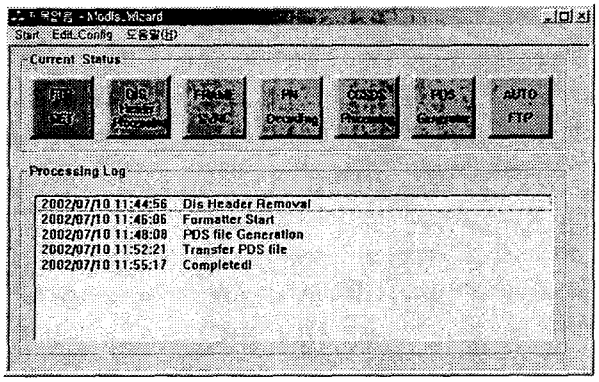

Figure 2. Wizard Diagram

Detail processing status log function was added for debugging purpose and following shows sample log for AQUA DB.

05:23:45 CAMNT requests for execution
05:23:45 Aqua_Wizard start!
05:23:45 Receiving file "MODIS_aqua.dat"
05:28:35 MODIS_aqua.dat created 2002/08/04 28:39:00
05:28:35 Dis Header Removal
05:41:24 Formatter Start
05:41:24 Sync pattern[3] D67FE0EC detected!
05:50:04 Last frame Sync pattern[3] D67FE0EC detected!
05:50:04 MODIS : 864331 frame
05:50:04 Fill : 73121 frame
05:50:04 AIRS : 103353 frame
05:50:04 AMSR-E : 7168 frame
05:50:04 SUM : 10837 frame
05:50:04 CERES+Y : 702 frame
05:50:04 CERES-Y : 703 frame
05:50:04 GBAD : 797 frame
05:50:04 HSB : 435 frame
05:50:04 AMSU-A1 : 145 frame
05:50:04 AMSU-A2 : 72 frame
05:50:04 Total : 1061664 frame
05:50:04 MODIS PDS file Generation
05:50:04 CERES+Y PDS Generation
05:50:04 CERES-Y PDS Generation
05:50:04 HSB PDS Generation
05:50:04 GBAD PDS Generation
05:50:04 AIRS PDS Generation
05:50:04 AMSR PDS Generation
05:50:04 AMSU-A2 PDS Generation
05:50:05 AMSU-A1 PDS Generation
05:50:05 CERES-Y PDS file Generated!
05:50:06 GBAD PDS file Generated!
05:50:06 AMSU-A2 PDS file Generated!
05:50:06 AMSU-A1 PDS file Generated!
05:50:06 HSB PDS file Generated!
05:50:06 CERES+Y PDS file Generated!
05:50:18 AMSR PDS file Generated!
05:53:11 AIRS PDS file Generated!
05:56:53 Transfer MODIS PDS file
05:59:00 Completed!

KARI has operated EOS DB receiving system since 20 July, 2002. All operation step from antenna operation to level-0 PDS data transfer is unmanned automatic.

5. Level-0 MODIS image

ScanView, generated by ScanEx., is windows 98/2000 application designed to view images written in MODIS level-0 PDS files.

The input file is assumed to be plain CCSDS packets. Values of the first two bytes is the packet primary header should be strictly 0840h, the packets length-642 or 276. Following 2 images are level-0 MODIS image obtained on 23 July, 2002 from TERRA and AQUA, respectively.

Figure 2 TERRA level-0 MODIS Image

23 July, 2002

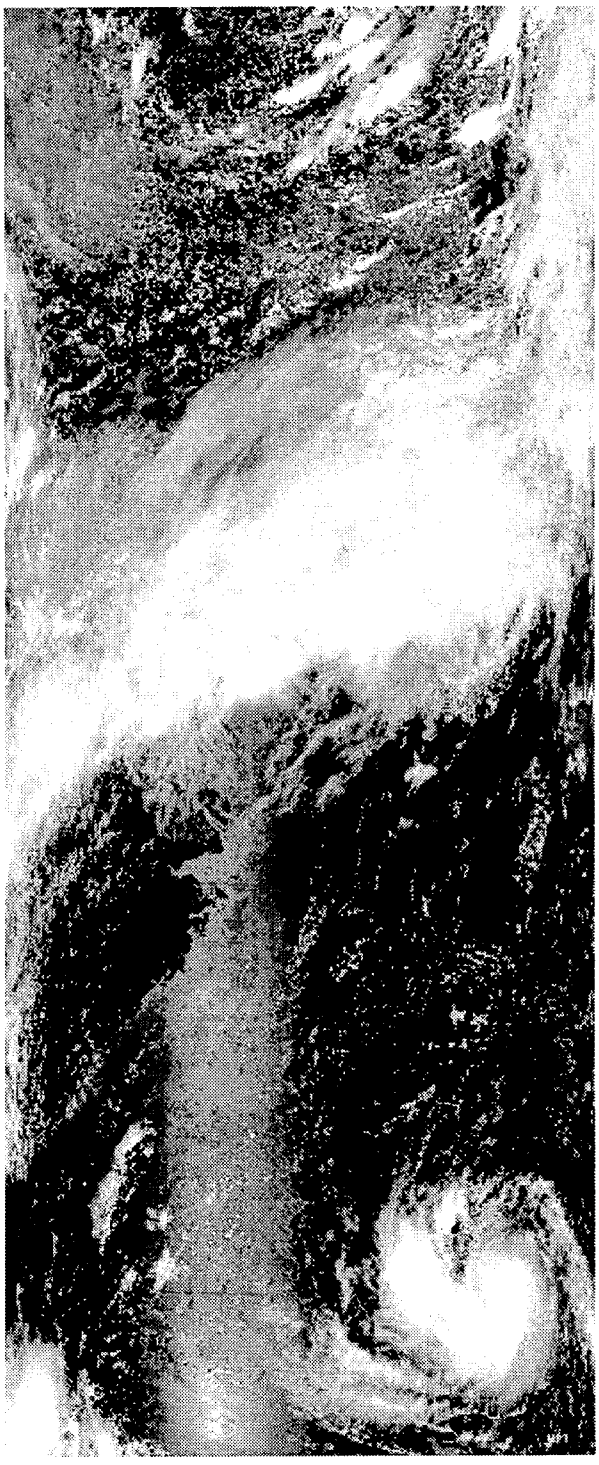

Figure 3 AQUA level-0 MODIS Image

23, July, 2002

6. Conclusion

The overall description of EOS DB receiving system developed by KARI was covered in this paper. KARI implemented EOS DB processing system by both adding receiver, in-house controller and developing level-0 processing software. Level-1 processing is achieved by IMAPPW, available in public and upgraded version of IMAPPW will be installed when available for processing other DB sensors.

Since July, 2002 KARI EOS DB system has provided a successful operation.

KARI has a plan to reduce processing time by adopting PCI interface serial card in level-0 processing system in 2003 and prepare the subsequent DB services, which will be available in future. Also, efficient product distribution and archive system developments will be started in soon future.

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