The Study for the KOMPSAT-3 Image Data Compression

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Abstract: Satellite payload on-board date compression unit are use for saving date storage space and reducing time to transmit payload data to the ground station. The KOMPSAT-3 payload will generate higher data rate than KOMPSAT-2 due to its better ground sample distance capacity. High input data rate and limited output transmission data rate might lead excessive compression and degraded image quality. This paper presents a trade-off study about data storage capacity and compression parameters for estimated KOMPSAT-3 system.

Keywords: DCSCU, KOMPSAT-3.

1. Introduction

On-board compression function is required to save data storage and to reduce time to transmit payload data to the ground station. But if the input data rate is much higher than downlink data rate, excessive compression is unavoidable and image degradation might be happen.

The KOMPSAT-3 has better GSD(ground sample distance) capacity than the KOMPSAT-2. It will generate higher data rate. The normal compression ration of the KOMPSAT-2 for PAN(panchromatic camera) only is around 3.8 and the normal comp-ression ratio for PAN + MS(multi-spectral camera) is around 5.08. Actual real-time compression ration can be varied by compression regulation function. Design of compression system for the KOMPSAT-3 is quite different from those of the KOMPSAT-2. The main purpose of the KOMPSAT satellite is the observation of the Koran Peninsular. It can take image for 132.24 seconds using 128 Gbits memory and it's enough time to image the Republic of Korea without compression. It takes 7 minutes 43 seconds to download 128 Gbits to the ground station and it can be achieved in one normal pass. Because the KOMPSAT-3 has more than two times faster input rate than the KOMPSAT-2, it's not possible to take image the Republic of Korea and transmit to the ground station in a normal pass. The KOMPSAT-3 system needs different data storage and compression ratio.

2. KOMPSAT-3 Compression System

1) Image data Input

To calculate the image input data rate we have to know some characteristics of the satellite and characteristics of payload cameras. It's assumed that the orbit and mass of KOMPSAT-3 is similar to these of KOMPSAT-2. Below values are basic characteristics of the satellite used in the calculation.

- Satellite Altitude : 685 Km
- Satellite Orbit Cycle : 5910 sec
- Ground Speed : 6784 Km/h
- Contact Nadia : 2285 Km
- Max. Contact Time : 11 min 13 sec

The KOMPSAT-3 has two cameras. One is for panchromatic image with resolution 0.7 m and the other is for 4 color multi-spectral images with 2.8 m resolution. The used characteristics of the cameras are below.

- GSD for PAN : 0.7 m
- Swath Width for PAN : 15000 m
- No. Pixel per Line for PAN: 21429
- Normal Line Rate for : 9691.43 line/sec
- GSD for MS : 2.8 m
- No of color for MS : 4
- Swath Width for MS : 15000 m
- No. Pixel per Line for MS: 5357
- Normal Line Rate for : 2422.86 line/sec

Another major variable needed to estimate the input data rate is number of bits per pixel. The more number of bits per pixel, the better image quality we will get. But we have to pay more data storage and more RF bandwidth to transmit image data. In KOMPSAT-2 every pixels are represented by 10 bits. The NUC(Non-Uniformity Correction) unit in the PMU(Payload Management Unit) aligns 10 bits pixel data to 8 bits serial data to transmission through Hot-Link interface. And interface board in the DCSU(Data Compression & Storage Unit) re-aligns 8 bits serial data to 10 bits pixel data for image compression. These days most CCD manufacturers offer 12 bits pixel output.

On the assumption that number bit per pixel is 10, input data rate for PAN is 2.076 Gbps and input data rate for MS is 519 Mbps. Total image input data rate will be 2.595 Gbps.

On the assumption that number bit per pixel is 12, input data rate for PAN is 2.493 Gbps and input data rate for MS is 623 Mbps. Total image data input rate will be 3.115 Gbps.

The table 1. shows the major difference of image data input characters between KOMPSAT-2 and KOMPSAT-3.

Table.1 Input characters of the KOMPSAT-2 and the KOMPSAT-3

	KOMPSAT-2	KOMPSAT-3
resolution of PAN	1.0 m	0.7 m
swath-width of PAN	15 km	15 km
#pixel per line of PAN	15,168	21,429
line rate of PAN*	6800	9691
Bits per pixel of PAN	10	12
output rate of PAN	1039 Mbps	2492 Mbps
Resolution of MS	4.0 m	2.8 m
Swath-width of MS	15 km	15 km
#pixel per line of MS	3,792	5,357
line rate of MS*	1700	2423
Bits per pixel of MS	10	12
output rate of MS	259 Mbps	623 Mbps
total output rate	1298 mbps	3115 Mbps

* for normal operation

2) Memory Capacity

Now, we have input data rate. The last variables needed to calculate required memory space are total recording time to store and compression ratio. Depending on compression algorithm, compression ratio is quite variable. So we only take recording time into account for minimum requirement of memory space. If the satellite speed is constant, it means the satellite altitude is quite stable, recording time is proportioned to the length of image.

Fig 1. shows required memory space to image length. Another assumption is that the data storage unit is using RS FEC coding. The storage unit records 239 bytes data with 16 bytes RS symbol within 256 bytes memory space. The storage unit detects 16 bytes error detection and corrects 8 bytes error on 255 bytes RS code.

This paper proposes using 10 bits per pixel to save memory space and to reduce time to transmit data to the ground station. It's same value as the KOMPSAT-2. It is required to study more about using 12 bits per pixel due to unknown benefit per its cost.

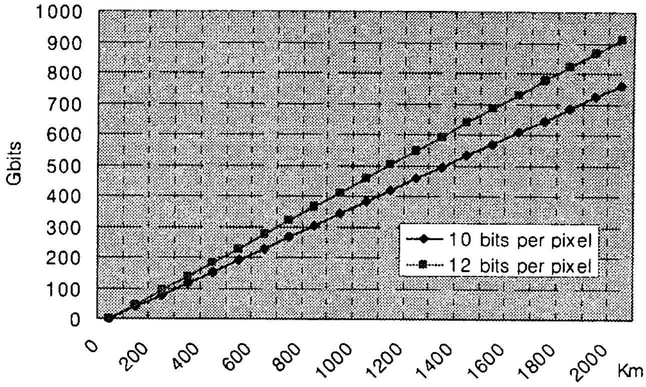

Fig. 1. Required Memory Capacity per Length of Image

Proposed required memory capacity is minimum space for both recording the half of Korean Peninsular and for storage previous image of the half of Korean Peninsular as a backup for retry downlink when unsuccessful real-time transmission. It's required 191.7 Gbits memory to recording the half of the Korean Peninsular, so that total 384 Gbits memory capacity is suggested.

3) Compression Algorism

Data compression function is required due to high input data rate and limited downlink capability. Lossless compression is the best way to compress in a point of data transmission without any loss of information. But most lossless compression is hard to implement. Compression performance is very depending on input image contents. Its normal compression ratio is 1.5:1 and worst case compression ration is 1:1. No one guarantees its compression performance and it's difficult to make mission plan such as total amount of memory required to save the mission data and required time to send this data to the ground station.

The data transmitter, next stage of data storage unit in PDTS, is sending payload data through limited RF channel bandwidth. So the input rate of the data transmitter should always be less or equal to RD bandwidth. This is the reason why the KOMPSAT-2 has a data regulation function in a compression unit. Using lossless compression, this requireement can not gratified unless using big enough buffer size(ex. equal to total amount of data to transmit) in front of the data transmitter. The SPOT5 and Pleiades are using lossy compression

There are several candidates for lossy compression. Wavelet, JPEG2000 and JPEG-like compression used in the KOMPSAT-2. Wavelet compression is quite well known for its good performance on commercial market but few heritages on space program. The most wavelet compression chip developed for space use can process only 20~30 Mbps input. JPEG-like compression ASIC used in the KOMPSAT-2 DCSU process 200 Mbps per channel. If we use wavelet compression, we need about ten times more channels for data interface.

4) Downlink Speed

Due to the remarkable increase of the KOMPSAT-3 data input rate, the KOMPSAT-2 transmitter is not good solution anymore. It takes 23 minutes to send 384 Gbits memory data. This means we can not send whole memory data within a pass. We need more powerful data transmitter. As a KOMPSAT-3 transmitter, several RF systems are under consideration.

The first one is 620 Mbps 8PSK RF subsystem. It has 4 155 Mbps 8PSK transmitter and 1 8PSK transmitter for redundancy. 4 transmitters are working together and their outputs flow together with single RF carrier. But this subsystem has much power consumption and no flight heritage yet. The ground station equipments also have to be changed to receive 8PSK RF signal.

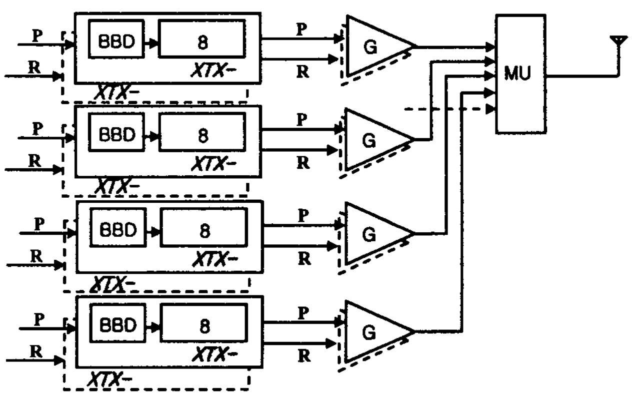

Fig. 2. 620 Mbps 8PSK Subsystem

The second one is using 1 800 Mbps 8PSK transmitter. This subsystem configuration is the most simple and has the best performance. But no heritage is existing.

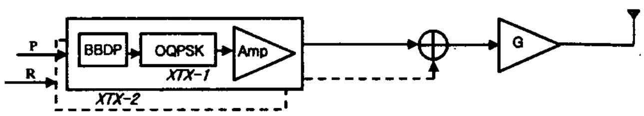

Fig. 3. 800 Mbps 8PSK Subsystem

The third one is using same type of 2 OQPSK transmitter used in the KOMPSAT-2 with dual polarization. It has the most reliable, acceptable power consumption, satisfiable performance and minor change necessary on the ground station. The main problem of this configuration is using two antennas. The KARI is under design to use one X-Band TX antenna to send two RF signal.

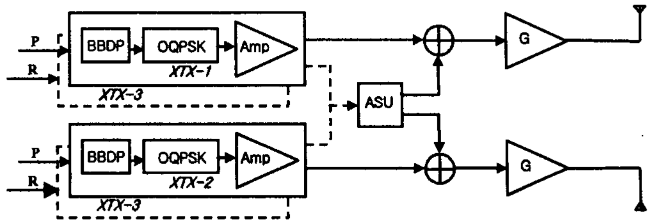

Fig. 4. 640 Mbps dual OQPSK Subsystem

Considering using dual OQPSK subsystem and RF channel coding overhead, here takes 600 Mbps data rate for RF downlink speed. The estimated time to transmit whole 384 Gbits memory data to the ground station is 10 min. 42 sec. It's enough time to downlink whole memory data to the ground station in one pass.

3. Conclusions

Assuming satellite orbit and mass as same as the KOMPSAT-1, 0.7 m PAN, 10 bits per pixel and 600 Mbps downlink band-width, this paper suggest 384 Gbits memory system and JPEG-like compression. Suggested system has enough performance to image and transmit two mission data of the half of the Korean Peninsular in one pass.

Further analysis about the benefit of using 12 bits per pixel and availability research to increase RF download band-width are necessary to finalizing system configuration.

Acknowledgement

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References

[1] S.G. Lee, 24/03/2005, KOMPSAT-3 PDTS Trade-off Study.

[2] John R. Schott, 1997, Remote Sensing The Image Chain Approach, Oxford University Press

[3] 8PSK X-Band Data Downlink Subsystem, http://www.alcatel.com/space/obeqpt/payload/obsmicro/p40 1.htm.

[4] http://www.l-3com.com/