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The Effect Analysis of Compression Method on KOMPSAT Image Chain

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Abstract : Multi-Spectral Camera(MSC) on the KOMPSAT-2 satellite was developed and launched as a main payload to provide 1m of GSD(Ground Sampling Distance) for one(1) channel panchromatic imaging and 4m of GSD for four(4) channel multi-spectral imaging at 685km altitude covering 15km of swath width.

Since the compression on MSC image chain was required to overcome the mismatch between input data rate and output date rate JPEG-like method was selected and analyzed to check the influence on the performance. In normal operation the MSC data is being acquired and transmitted with lossy compression ratio to cover whole image channel and full swath width in real-time. In the other hand the MSC performance have carefully been handled to avoid or minimize any degradation so that it was analyzed and restored in KGS(KOMPSAT Ground Station) during LEOP (Launch and Early Operation Phase). While KOMPSAT-2 had been developed, new compression method based upon wavelet for space application was introduced and available for next satellite. The study on improvement of image chain including new compression method is asked for next KOMPSAT which requires better GSD and larger swath width

In this paper, satellite image chain which consists of on-board image chain and on-ground image chain including general MSC description is briefly described. The performance influences on the image chain between two on-board compression methods which are or will be used for KOMPSAT are analyzed. The differences on performance between two methods are compared and the better solution for the performance improvement of image chain on KOMPSAT is suggested.

Key Words : KOMPSAT, MSC, EOS, Image chain.

1. Introduction

KOMPSAT-2 was developed to continue the earth observation after KOMPSAT-1. The MSC on KOMPSAT-2 has the improved capability compared to 6.6m GSD of EOC(Electro-Optic Camera) on KOMPSAT-1. 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, composition of printed and digitized maps for the territories, balanced development of Korean territories, and survey of natural resources. MSC is a main payload on KOMPSAT-2 to comply with the mission requirements and to images the earth.

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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.

KOMPSAT-2 were verified through IST (Integrated Satellite Test) and ETE (End-to-End) tests including environmental tests since MSC was integrated and was launched on July 28th 2006. The aliveness and function on KOMSAPT-2 was verified or validated and confirmed through planned IAC (Initial Activation and Checkout) during LEOP. After that, the next stage, Cal/Val (Calibration and Validation) phase was started and all planned activities, such as performance analysis, all kinds of calibration and validation were conducted.

Since the JPEG like compression method on MSC image chain was selected to overcome the mismatch between EOS input rate and PDTS output data rate, the no influence on the performance by selected compression method was analyzed and notified. In practice, the image data was acquired with lossy compression ratio to simultaneously transmit image data from Pan and MS channels within X-Band beam width. In parallel the MSC performance was also carefully handled to avoid or minimize any degradation so that it was analyzed and restored in KGS (KOMPSAT Ground Station) during LEOP and Cal/Val phase. While KOMPSAT-2 was developed, new compression method based upon wavelet for space application was announced and available for next KOMPSAT satellite (Schiewe, 1998).

In this paper, general descriptions on MSC itself and KOMPSAT-2 image chain which consisted in on-board and on-ground, including chosen performance measurement methods are briefly described. The influences on image performance between two on-board compression method, JPEG like and wavelet method which is or to be used for KOMPSAT are measured and analyzed. The differences on performance between two methods are compared and the better solution for the performance improvement of image chain on KOMPSAT is suggested.

2. General Description

The MSC have been designed and developed to meet all the requirements including system performance specified in Table 1. Theses requirements were clearly tested or analyzed and verified since they were carefully assigned and controlled with mentioned hardware configuration and property at the beginning.

MSC images the earth using a push-broom motion with a swath width of 15 km and a ground sample distance of 1m over the entire field of view at nadir and is designed to have an on-orbit operation duty cycle of 20% shown in Fig. 1. The MSC also requires

Table 1. The system performance requirements of MSC.

Band	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
SNR	≥ 100	≥ 100	≥ 100	≥ 100	≥ 100

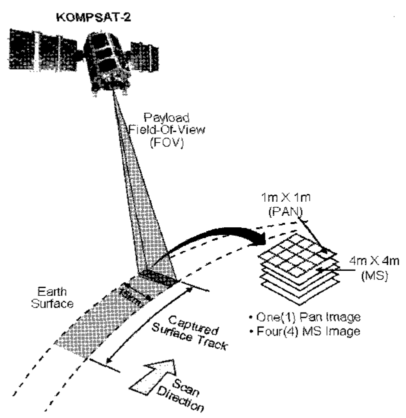


Fig. 1. MSC Operation Concept.

the functions of programmable gain and offset, on-board compression and storage, and the dark and white calibration by OBRC (On-Board Radiometric Calibration light source) (Yong and Heo, 2000).

In addition MSC has also to satisfy satellite requirements with having a capability of automatic normal operation and stereo imaging capability by spacecraft tilting, that is, the compatibility of spacecraft roll tilting of +/- 56 degrees and pitch tilting of +/- 30 degrees.

Several major parameters, such as line-rate, gain & offset, number of sector for recording, compression ratio, Huffman & quantization table, encryption key and so on was implemented to achieve good quality image data and effective mission control (Yong *et al.*, 2002).

3. MSC Image Chain of KOMPSAT-2

1) On-board image chain in MSC

The electrical interface of MSC image data was analyzed and decided by the data rate and the hardware configuration as shown in Fig. 2.

Around 1.3Gbps digital image data in CEU are transferred to DCSU via NUC(Non-Uniformity Correction) in PMU by 8 channels in parallel, primary or redundant respectively. I & Q data channel in parallel, primary or redundant respectively are assigned between DCSU and CCU, and each dedicated line to QTX1 and QTX2 to transmit modulated data to KGS.

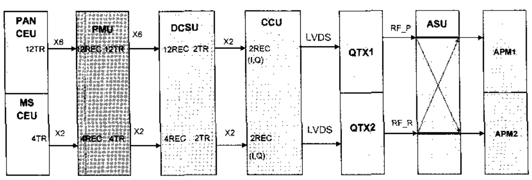


Fig. 2. MSC electrical interface for image data.

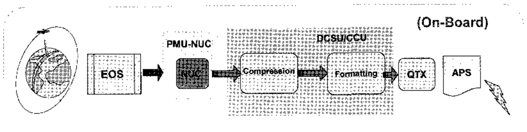


Fig. 3. On-board MSC image chain.

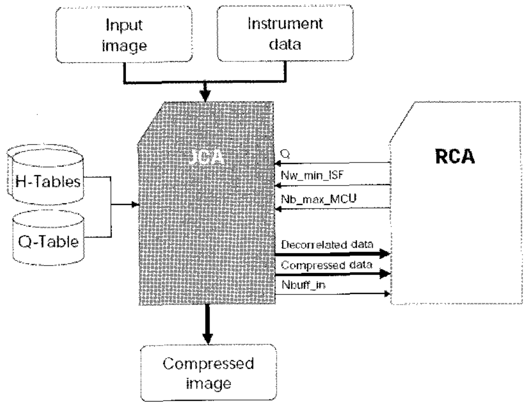


Fig. 4. MSC data compression algorithm.

After Optical information created by earth albedo is detected and converted with optimal TDI, gain and offset in EOS, non-uniformity among pixels in CCD sensor are corrected to minimize any degradation by loss compression which is necessary to match to output data rate of 320 Mbps as depicted in Fig. 3.

The selected JPEG-like compression method for MSC is the rate controlled JPEG algorithm which is combined with rate control algorithm and JPEG based compression algorithm. The sequence of compression is similar to normal JPEG algorithm shown in Fig.4 and the insignificant influence on payload performance was analyzed and reported before the launch (Yong and Ra, 2004).

2) On-ground Image Chain on KGS

The received MSC data is processed in reverse way of on-board data handling. The first step is to receive and preprocess raw data in DIS (Data Ingest system). And then radiometric and geometric corrections are applied including restoration and enhancement if required. The major activity of restoration is to apply the deconvolution filter which comes from MSC PSF (Point Spread Function) with or without smoothing filter as shown in Fig. 5.

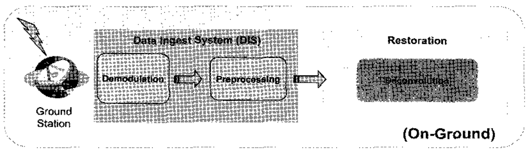


Fig. 5. On-ground MSC image chain.

Since KOMSPAT-2 has successfully been launched and finished IAC phase as a part of LEOP lots of Cal./Val. activities were planned and conducted to have all necessary parameters for better performance in KGS. And the normal calibration activity is periodically continuing as planned (Yong *et al.*, 2006).

4. The Effect Analysis of Data Performance

As mentioned in previous section, the influence of compression on image chain performance was analyzed and reported to insignificant results. But, in substance the performance is mixed with atmosphere condition, parameter setting and calibration status as well as compression and as a result, better quality image data is continually requested as well as the preparation of new demands with higher requirements. Therefore the analysis on whole image chain from on-board to ground station is needed.

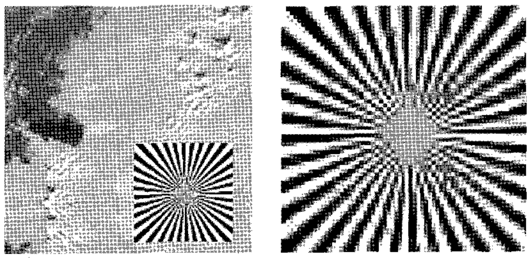
In this paper, the influence by compression method between JPEG-like and wavelet which is the first and major stage for whole image chain is analyzed and discussed although all necessities are defined on the basis of above design and experience and divided to several tasks to check the real influence.

1) The feasibility study

In advance of the preparation and activation, the feasibility study for clear understanding and seeing the necessity was considered and conducted. The well characterized image data for the major performance with a reference image, simulated Siemens star, is selected to check the difference between JPEG and wavelet algorithms.

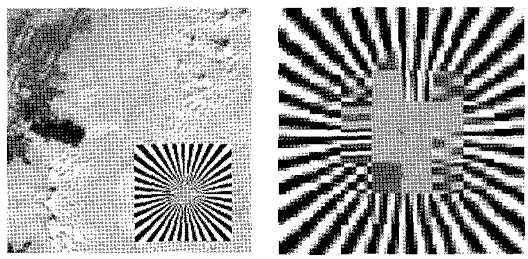
The original data and simulated result which is decompressed data for wavelet and JPEG-DCT(Discrete Cosine Transform) are shown in Fig. 6 and Fig. 7 respectively.

The difference between original data and simulated data can be observed, such as smoothing in the center of Siemens star, blurring in narrow stream lines and block artifact, etc. It is a good pre-study to continue further analysis with the expected results (Yong and Ra, 2007).



(a) Original (b) Wavelet(Stretched)

Fig. 6. The result on Wavelet (CCSDS 122.0) CR=6.5.



(a) Original (b) JPEG-DCT (Stretched)

Fig. 7. The result on JPEG-DCT extended mode CR=5.98.

2) The analysis of KOMPSAT compression methods

In the influence analysis of compression method on image chain of KOMPSAT, no compression sample image data which was captured by KOMPSAT-2 is used and the visual inspection and quantitative measurement, PSNR, MTF and CC (Correlation Coefficient) are considered to make clear and objective conclusion after compression with nominal compression ratio of KOMPSAT-2.

The selected PSNR measurement is most commonly used as a measure of quality of reconstruction in image compression. It is most easily defined via the mean squared error (MSE) for two m × n monochrome images, I and K as follows. It means that the K image is considered a noisy approximation of I image.

$$\mathrm{MSE} = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\|I(i,j)-K(i,j)\|^2 \qquad (1)$$

The PSNR is defined as:

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \qquad (2)$$

where, MAX_I is the maximum pixel value of the image. When the pixels are represented using 8 bits per sample, MAX_I is 255.

In case of MTF measurement on image it is not so easy to make a common value because there are a lot of methods announced and used. Therefore ImaTest software supplied by Applied Image Inc is selected and used.

CC is analysis way to find the difference of spatial resolution between two image data. Both images are convolution with high pass filter which is 3 × 3 mask as defined in equation (3) and generate the coefficient through equation (4) for the analysis.

$$HF = [\,-1\ -1\ -1;-1\ 8\ -1;-1\ -1\ -1] \qquad (3)$$

$$r_{xy} = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{(n-1)s_x s_y} \qquad (4)$$

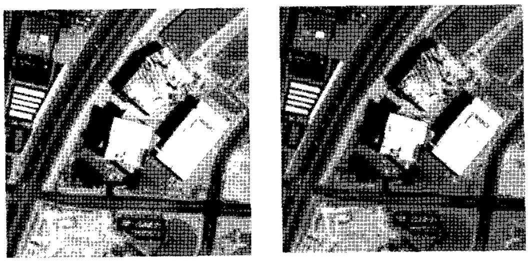
Where, $\bar{x}$ and are the sample means of X and Y, s_x and s_y are the sample standard deviation of X and Y and the sum is from i=1 to n.

The expectation result is that small deviated processed imaged data would show closed '1' CC value.

For the simulation of KOMPSAT-2 and next KOMPSAT compression, the simulator provided by each relevant hardware developer was used to have close and accurate simulation results.

The original image and compressed/decompressed image data with different compression ratio which is usually used for nominal operation in KOMPSAT-2 are shown Fig. 9 and Fig. 12 with CR = 1:4, and Fig. 10, and Fig. 13 with CR=1:8 based on original image in Fig. 8 and Fig. 11.

Fig. 8. Original test image#1.



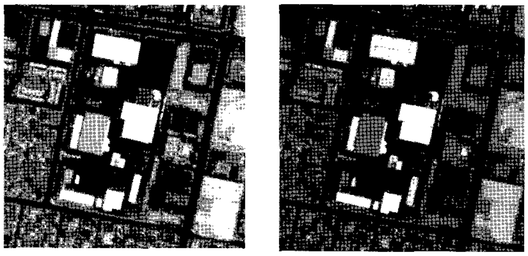
(a) JPEG-like (b) Wavelet

Fig. 9. The results on test image#1 CR=1:4.

(a) JPEG-like (b) Wavelet

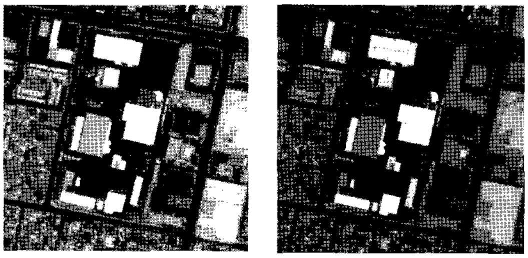
Fig. 10. The results on test image#1 CR=1:8.

Fig. 11. Original test image#2



(a) JPEG-like (b) Wavelet

Fig. 12. The results on test image#2 CR=1:4.



(a) JPEG-like (b) Wavelet

Fig. 13. The results on test image#2 CR=1:8.

The wavelet method is around 2 times higher results than JPEG-like results method on PSNR measurement as shown in Table 2.

In case of MTF measurement, the JPEG-like method shows slightly higher number than wavelet method and original image data as shown in Table 3.

Table 2. PSNR measurement Results.

Image	Compression Ratio(CR)	JPEG-like (KOMPSAT-2)	Wavelet (next KOMPSAT)
1	1:4	25.88	56.17
	1:8	25.56	45.07
2	1:4	21.84	22.01
	1:8	48.14	58.15

Table 3. MTF measurement Results.

Image	CR	Origin	JPEG-like (KOMPSAT-2)	Wavelet (next KOMPSAT)
1	1:4	18.6	26.8	19.6
	1:8		26.3	18.9
2	1:4	8.51	27.3	9.1
	1:8		25.0	7.82

Final understanding on analyzed results of MTF measurement is that more deviation comes out higher MTF values and it means more degradation by compression method.

The CC measurement shows the same results with PSNR which means higher value by the wavelet method in Table 4.

Table 4. CC measurement Results.

Image	Compression Ratio(CR)	JPEG-like (KOMPSAT-2)	Wavelet (next KOMPSAT)
1	1:4	0.990994	0.999279
	1:8	0.977565	0.993412
2	1:4	0.988164	0.999360
	1:8	0.976725	0.994383

Based on analysis results using three different kinds of measurement methods, wavelet compression which will be used for next KOMPSAT shows better performance than JPEG-like which is adapted for KOMSPAT-2.

5. Conclusion

The demands of imagery data from earth observation satellite have dramatically been increased for the survey of natural resource, the information of surveillance of large scale disaster and its countermeasure, GIS and so on. Furthermore required systems are expected with better GSD and larger swath which resulted to higher input data rate. On one hand, the technical status can not be equal to the desired transfer and recording rates. The solution of this limitation is the lossy compression as a JPEG-like compression in KOMPSAT-2.

New compression based on wavelet method was announced for space application during MSC development phase and the study on improvement of image chain including new compression method is asked for next KOMPSAT which requires better GSD and larger swath width.

In this paper, the performance effects of compression method on satellite image chain are tested and analyzed to make a improved system.

In advance of actual test and analysis, the feasibility study was performed by the well characterized image data with simulated Siemens star. It is really good results to continue further analysis by showing the difference between original data and simulated data, such as smoothing in the center of Siemens star, blurring in narrow stream line and block artifact so on.

The simulated image data by the KOMPSAT-2 compression method, JPEG-like and next KOMPSAT compression method, wavelet are not clearly distinguished by visual inspection although there are observed some differences between methods.

On the other hand the selected three measurements, PSNR, MTF and CC shows clear results between JPEG-like and wavelet compressions methods. In PSNR measurement wavelet showed two times better results.

In conclusion, wavelet compression method would be expected in better performance results than JPEG-like and it will be used for next KOMPSAT to overcome real difficulties which come from the demand on large amount of data and high data rate.

The effect analysis of the different compression methods on the image chain will be extended to on-ground image chain to cover whole image chain for best final product from KOMPSAT satellite in future.

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