THE ANALYSIS OF THE INFLUENCE OF THE COMPRESSION ON THE LOW EARTH ORBIT SATELLITE PAYLOAD SYSTEM

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The mission of the EO(electro-optical) based low earth orbit satellite is provision of the high-resolution images required for GIS(Geographical Information Systems) establishment and the applications for environmental, agriculture and ocean monitoring. AEISS(Advanced Earth Imaging Sensor System) which is the main payload on the satellite consists of EOS(electro-optical subsystem) and PDTS(Payload Data Transmission Sub-system). IDHU(Image Data Handling Unit) which is one of the major unit in PDTS is capable of compression, storage, encryption and encoding. In this paper, the payload system of the EO based satellite is briefly introduced and the influence of the compression on AEISS is analyzed.

KEY WORDS: Compression, Satellite, MTF, PSNR, Payload

1. INTRODUCTION

The EO based satellite has the payload of AEISS(Advanced Earth Imaging Sensor System) to provide the high-resolution images. AEISS can provide 4 channel image covering the spectral range from 450nm to 900nm using TDI CCD Focal Plane Array(FPA). AEISS consists of EOS(electro-optical subsystem) and PDTS(Payload Data Transmission Sub-system). PDTS is divided into IDHU(Image Data Handling Unit), XAA(X-band Antenna Assembly), XTX(X-band Transmitter), etc.

The satellite image data taken by EOS can't be transmitted to the ground within the time limit without compression because of the data size. The lossy compression method is used to reduce the amount of the data size but the perceived satellite image is affected by the compression. The effect of the compression on the overall AEISS can be analyzed by measuring MTF (Modulation Transfer Function). MTF(Modulation Transfer Function) is usually used to evaluate the overall system resolution. The AEISS attenuation mechanism can be characterized in the spatial frequency domain by its MTF. The overall system MTF at all spatial frequencies is the multiplication of all MTFs of the different degradation sources. The total system's MTF at a given scenario of operation, is composed of atmospheric MTF terms, (Turbulence, Aerosol, Boundary Layer) and of specific MTF terms of the imaging systems's module (Optics, Detector, Data Processing, Line-of-Sight In-Stability, etc.). In this paper, AEISS and the degradation resources are introduced and the effect of compression unit on the EO based satellite overall system is studied.

2. PAYLOADS OF THE SATELLITE

2.1 AEISS(Advanced Earth Imaging Sensor System) overview

AEISS functional block diagram is below. The satellite image is captured by EOS and processed by PDTS. The light energy by the optical module falls onto TDI CCD FPA and is converted into the digital signal data by CEU (Camera Electronics Unit). CEU is composed of FPA, CEUP(CEU Powersupplier), CC(Camera Controller). The satellite image is generated from the digital signal data and sent to PDTS. The satellite image is compressed, encrypted, stored and transmitted by radio in PDTS. The compression method is based on a CCSDS lossless to lossy image compression standard. This CCSDS standard is a discrete wavelet transform (DWT) transform coder.

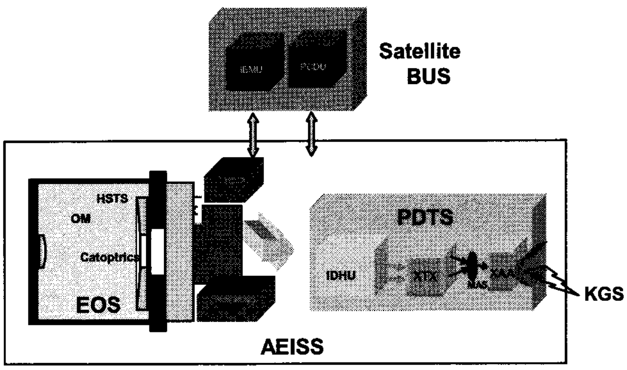

Figure 1. AEISS block diagram

AEISS is designed to operate at the altitude of 685km and to have TDI linear detector, pushbroom imaging, X-band Antenna.

2.2 AEISS overall performance definition

AEISS total performance can be defined as MTF in the spatial frequency domain. The MTF is the magnitude response of the optical system to sinusoids of different spatial frequencies. Besides the optical system, other factor can affect MTF such as the atmospheric factors (turbulence, aerosol, boundary layer) given by a operational scenario and the imaging system modules (optics, detector, data processing, etc.). The overall system MTF at all spatial frequencies is the multiplication of all MTFs of the different degradation sources. But, our major concerns about the degradation factors are the imaging system modules.

First, the optics MTF can be considered to be a result of a number of factors.

a. Diffraction limit due to finite aperture size of the optical system
b. Aberrations of the optical system
c. Optical design, the reduction of design to a physical optical system
d. The effect of the local operational environment upon the optical system

Especially, an optical system with a finite-sized aperture can never form a point image because of the wave nature of light. There is a characteristic minimum blur diameter formed, even when other image defects (aberrations) are absent. The best performance that the system is capable of is thus called "diffraction limited."

Also, the detector degrades MTF because of static terms and dynamic terms. Static terms include the sampling nature of a detector multi-element array, pixel's finite size (aperture), cross-talk due to the absorption depth of the charge in the silicon photo-element and the charge diffusion between adjacent pixels in the CCD chip. The cross-talk MTF exists in on direction only in linear CCD chips. Dynamic terms include charge transfer inefficiency, dynamic charge transfer smears as linear smear (CCD, TDI), electronics circuits transfer function such as amplifiers, read-out, sampling, TDI, etc (Clair L. Wyatt, 1991; Gerald D. Holst, 1995; Glenn D. Boreman, 2001).

As to the data processing, the compression unit is considered. IDHU receives the satellite digital image data from CEU and is compressed using CCSDS standard compression. Because CCSDS is the lossy compression algorithm based on DWT, it loses the original image data information. So, it influences the image quality. And the effect of the compression on the total system performance needs to be analyzed by the experiments (Smith, J.L, 1995).

3. EXPERIMENT

3.1 Test and result

In this experiment, the effect of the compression on the overall MTF performance is tested. For the test, the QuickBird panchromatic images are used. Figure 2 is the urban satellite image of Daejeon and figure 3 is the rural area image of Dangjin. QuickBird is a high-resolution commercial earth observation satellite, owned by DigitalGlobe and launched in 2001. The satellite collects panchromatic (black & white) imagery at 60-70 centimeter resolution and multispectral imagery at 2.4 and 2.8 meter resolutions. It orbits at the altitude of 450km with 98 degree sun synchronous inclination.

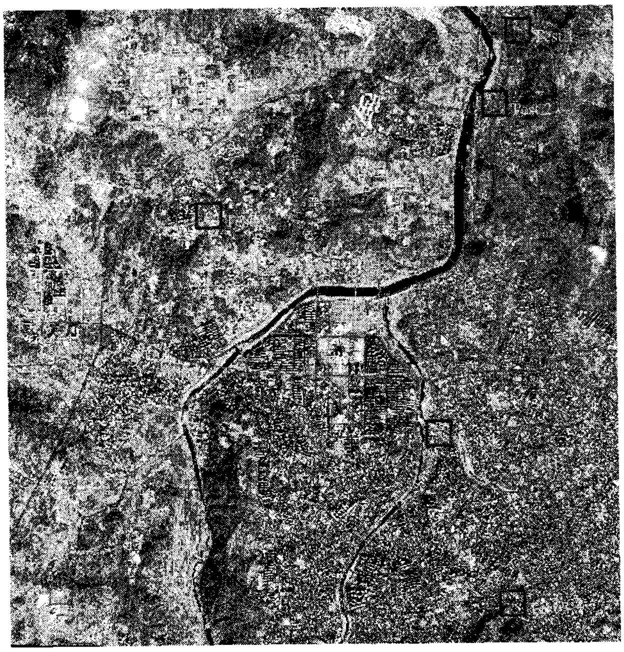

Figure 2. Urban area (Daejoen)

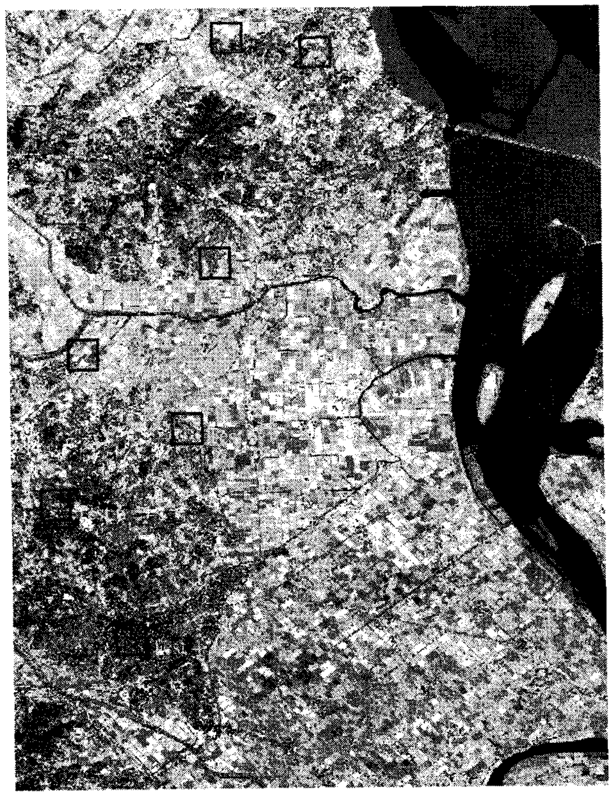

Figure 3. Rural area (Dangjin)

For each figure, five different areas are selected in urban area and seven different areas are chosen to test the satellite images having a variety of characteristics. In order to test the effect of the compression, MTF value of the original test image before compression is compared with MTF value of the decoded test image after compression. The decoded test image after compression lost some information of the original image and the image quality degraded. The MTF value variation is observed depending on the compression ratio. To measure the MTF value, Imatest digital image quality test software is used. The measured MTF values are plotted below.

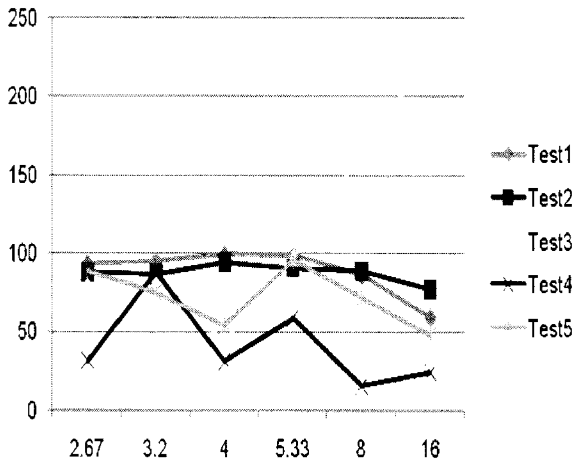

Figure 4. MTF variation according to compression ratio (Daejeon)

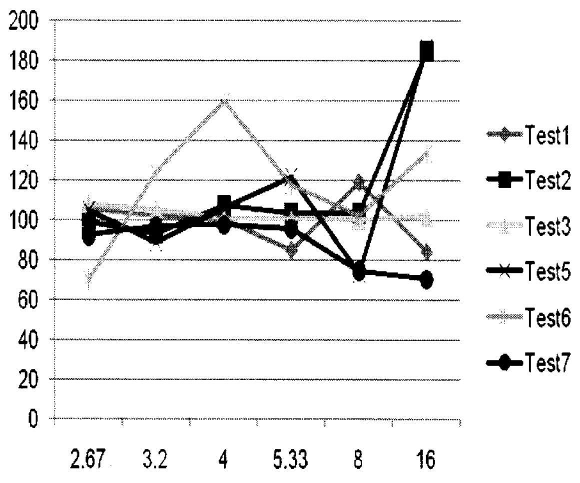

Figure 5. MTF variation according to compression ratio (Dangjin)

The MTF variation according to compression ratio for each test image in the urban and rural area is shown in Figure 4 and figure 5. The x-axis represents compression ratio and y-axis represents the ratio of the original image MTF value and the decoded image MTF value. When the y-axis value is 100, it means MTF value doesn't change. The MTF characteristic gets worse as the compression ratio goes high but doesn't change so much until the compression ratio reaches 5.33 in Figure 4. In Figure 5, the MTF value changes more than Figure 4 after compression. But it keeps the high ratio value. So when the MTF value of the original image meets the MTF performance requirement, the MTF value of the compressed satellite image data can satisfy the performance requirement. Beside of MTF, PSNR test is shown below (Ahmet M. Eskicioglu and Paul S. Fisher, 1995).

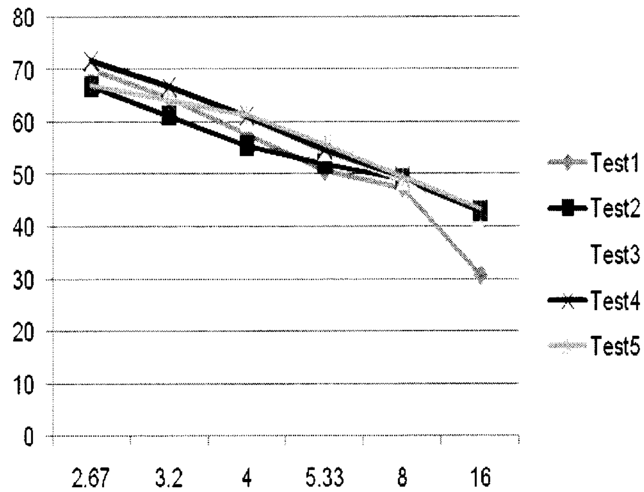

Figure 6. PSNR variation according to compression ratio (Daejeon)

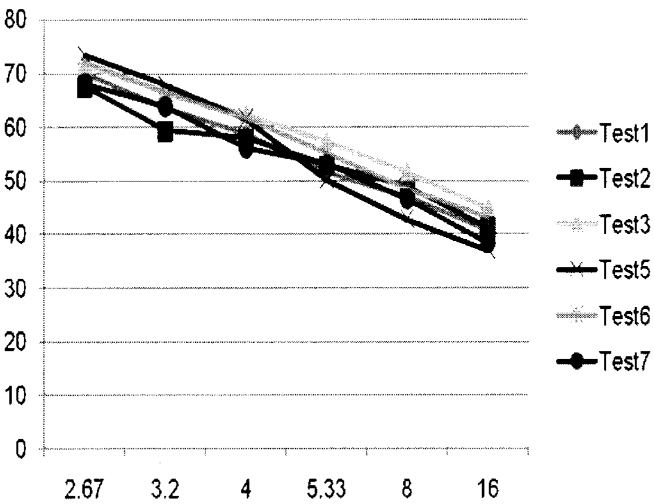

Figure 7. PSNR variation according to compression ratio (Dangjin)

In the PSNR test, the PSNR value decrease as the compression ratio increase until the compression ratio goes high. But, high PSNR values are retained until compression reaches 8.

4. CONCLUSION

The effect of the compression on the AEISS total performance concerning the MTF value variation was analyzed by comparing the MTF and PSNR value of the original image with the MTF and PSNR value of the decoded image after compression. The test images are sampled from the commercial QuickBird satellite panchromatic image. As the compression ratio increase, the MTF and PSNR characteristic become worse but it can satisfy the required performance until the compression ratio reaches a certain compression ratio.

5. REFERENCES

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