NON-UNIFORMITY CORRECTION SYSTEM ANALYSIS FOR MULTI-SPECTRAL CAMERA

Jong-Euk Park*, Jong-Pil Kong**, Haeng-Pal Heo***, Young Sun Kim****,
Young Jun Chang*****

Korea Aerospace Research Institute
305-333 Eoeun-Dong 45, Yuseong-Gu, Daejeon, Korea,
E-mail ; *pje@kari.re.kr, **kjp123@kari.re.kr, ***hpyoong@kari.re.kr, ****yskim1203@kari.re.kr,
*****yjchang@kari.re.kr

ABSTRACT:

The PMU (Payload Management Unit) is the main subsystem for the management, control and power supply of the MSC (Multi-Spectral Camera) Payload operation. It is the most important function for the electro-optical camera system that performs the Non-Uniformity Correction (NUC) function of the raw imagery data, rearranges the data from the CCD (Charge Coupled Device) detector and output it to the Data Compression and Storage Unit (DCSU). The NUC board in PMU performs it. In this paper, the NUC board system is described in terms of the configuration and the function, the efficiency for non-uniformity correction, and the influence of the data compression upon the peculiar feature of the CCD pixel. The NUC board is an image-processing unit within the PMU that receives video data from the CEU (Camera Electronic Unit) boards via a hotlink and performs non-uniformity corrections upon the pixels according to commands received from the SBC (Single Board Computer) in the PMU. The lossy compression in DCSU needs the NUC in on-orbit condition.

KEY WORDS: KOMPSAT, NUC, IMAGE, CORRECTION, CAMERA

1. INTRODUCTION

The purpose of the MSC in KOMPSAT-2 is to obtain data for high-resolution images by converting incoming light (analog data) into digital data. The OM (Optical Module) of EOS (Electro-Optical Subsystem) includes an optical objective, in order to image the objects on its detectors. The objective consists of two optical channels, a Panchromatic channel (PAN) and a Multi-Spectral channel (MS). Each detector has four output modes. Every output from CCD port has a separate video-processing channel that incorporates CDS (correlated double sample), PGA (programmable gain amplifier) and a 10 bits A/D (analog to digital converter). The outputs of the A/Ds are digitally driven out using differential line drivers, converted to 8 bit bytes, serialized and transmitted to the NUC (Non-Uniformity Correction) module for pre-processing to correct for non-uniformity.

The ideal CCD has to give uniform signal level for the uniform light source. It is necessary to overcome the non-uniformity of the CCD's photo-response.

The correction is performed with multiplying gain value and adding offset value according to the predefined NUC table. The NUC is a high speed and high throughput image processing unit. It performs the correction of 8 video channels for pixel gain and offset, the rearranging pixels of the MS Camera, the combining video data with uploaded headers, and the receiving and adding ancillary data to imagery heads. The video data that is processed by the NUC is transmitted to the DCSU board for further handling and transmitted to the Ground Station. This characteristic can usually be compensated in the ground station after receiving image data from satellite. But, the loss compression due to real time image transmission in MSC needs the NUC operation.

2. IMAGE DATA FLOW SYSTEM IN SATELLITE

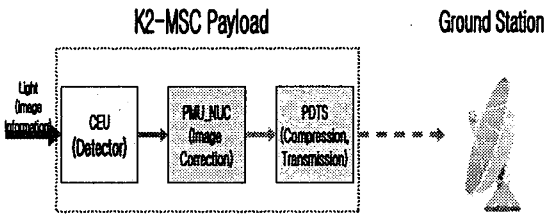

Figure 1. Image Data Flow.

The MSC system is a space-borne Electro-Optical system. The OM of MSC includes an optical objective, in order to image the objects on its detectors.

The PAN channel has a high-resolution image and produces a black-white picture at the spectral region of 500nm-900nm. The MS channel consists of four spectral bands and its resolution is four times greater in comparison to the PAN channel. The PAN channel has up to 1m ground resolution and the MS channel has up to 4m ground resolution in each of the 4 spectral bands.

The detector consists of 5200 active elements with 32 TDI stages. The number of TDI stages is externally selectable in predefined stages. This control module shall be included in the FPE (Focal Plane Electronics) of CEU. The FPE board receives operating voltages from an external source. The FPE board supplies voltages (required power) as well as clocks (timing) to the CCD detector. Precise timing is supplied to the detector to ensure optimal operation in each operational mode (Figure 2).

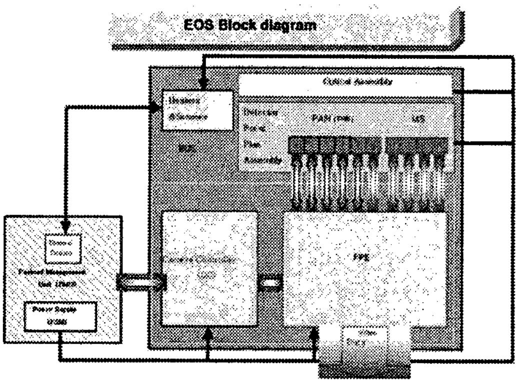

Figure 2. EOS Block Diagram

The MSC consists of two Electro-optical channels. A single internally CC (Camera Controller) that performs the communication and control functions and serves both the PAN-CEU and the MS-CEU. The incoming light is converted to electronic analog signals by the detectors. The analog signals are amplified, biased and converted into digital signals (pixel data stream) in the FPEs. Each of the detectors is supported separately with the required timing and power supply circuitry. The FPE assembly shall support the detector with the required power and timing. It shall process the analog signals which come out of the detector and convert them to digital form. The FPE assembly shall consist of a single detector, up to six video channels, clock drivers, voltage regulators and control lines.

The digital data is transmitted to the NUC for pre-processing to correct for non-uniformity and to add header data for identification and synchronization.

The figure 3 is the PAN FPE data output block diagram. As the figure 3, the acquisition video signals from the detector (four-output, each mode Primary and Redundant) are amplified, converted, mixed, and transmitted. The figure 4 is the MS FPE data output block diagram. In the MS mode, the video data output mode has only one channel, because of the slower video data rate for MS channel.

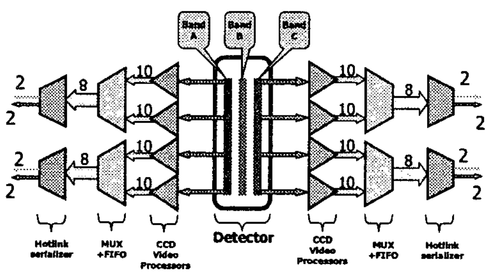

Figure 3. PAN FPE Data Output Block diagram.

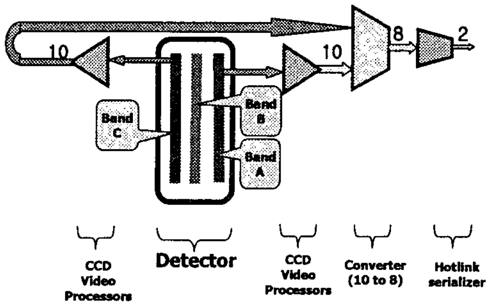

Figure 4. MS FPE Data Output Block diagram.

3. NON-UNIFORMITY CORRECTION SYSTEM

The PMU shall be capable of storing default NUC correction data in the non-volatile memory. The PMU shall be capable of loading NUC update for the currently used TDI level (for pixels of the active PAN band and for the MS bands). The PMU shall be capable of receiving the 10bit pixel data via 8bit serial Hot-link interface definitions, formatting the data back to 10bits. The PMU shall be capable of receiving the 10bit pixel data in 8bit per word (due to Hot-link interface definitions), formatting the data back to 10bits and rearranging the MS imagery data separating the multiplexed MS pairs of bands and ordering the two parts of each band pair in sequence. The PMU shall be capable of adding header data to each part of the PAN imagery data lines and each of the MS imagery channels.

The NUC board is an image-processing unit within the PMU that receives video data from the FPE boards via a hotlink and performs non-uniformity corrections upon the pixels according to commands received from the SBC. The figure 5 is the NUC block diagram. As the figure 5, the NUC board is an image-processing unit that receives video data from the FPE boards via a hotlink.

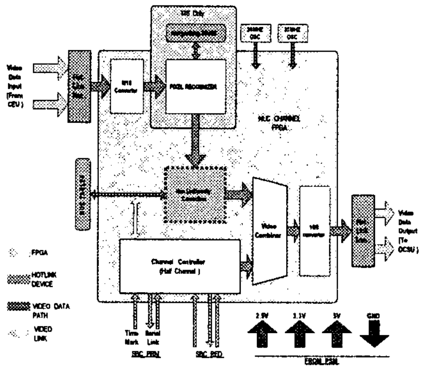

Figure 5. NUC Block diagram.

4. NON-UNIFORMITY CORRECTION FUNCTION

The CCD correction function is the most important function for image quality. The NUC correction will discard the CCD non-uniformity characteristics. The non-uniformity correction is common to all video channels. It is implemented in order to overcome the inherent variances of the detector's photo-response, and blacklevel signal. The NUC unit stores correction tables in the SRAM. Simply, the NUC block operates on input data as in

$$Px_{out} = Px_{in} \times (1 + Gain/1024) + Offset \qquad (1)$$

Eq. (1) shows the basic correction method using the gain and offset table. The NUC function itself is implemented in an FPGA using several stages of pipeline. One set of the TDI NUC tables is loaded to SRAM memory when the unit is turned on, or a new TDI mode is needed.

5. NUC INFLUENCE ANALYSIS FOR IMAGE COMPRESSION

The figure 6 is the detector output (about 15,000-pixel) that is half level of detector saturation from the uniform light source. The figure 7 is the raw data of the figure 6 and the figure 8 is the FFT (Fourier Transform) result of the figure 7.

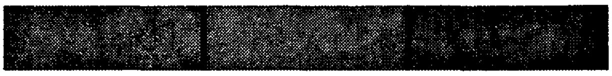

Figure 6. Detector Output (Saturation 50% Level)

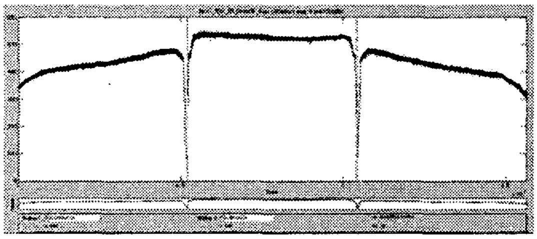

Figure 7. Raw data of the figure 6

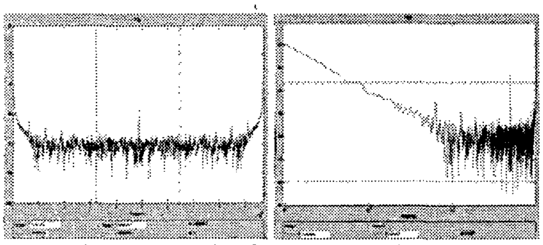

Figure 8. The FFT result of the figure 7 (Left linear scale, Right Log scale)

The figure 9 is the designed LPF filter frequency response diagram. This filter uses the equi-ripple FIR algorithm. The pass frequency (Fp) of pass-band is 50KHz and the stop frequency (Fs) of stop-band is 100KHz.

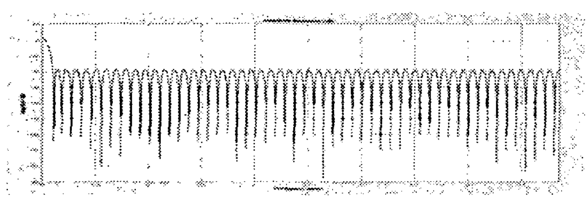

Figure 9. LPF, Fp = 50KHz, Fs = 100KHz

The figure 10 is the result of the pass through LPF (figure 9) of the raw data (figure 7). The figure 11 is the FFT results of the figure 10 (the left side is the linear frequency scale and the right side is the log frequency scale).

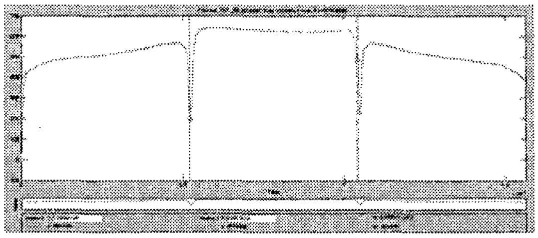

Figure 10. The LPF result of the figure 7.

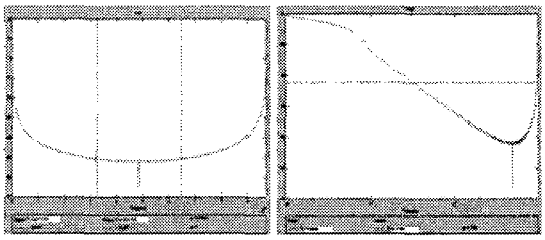

Figure 11. The FFT result of the figure 10.

The figure 12 is the NUC operation result of the raw data (figure 7) and the figure 13 is the FFT result of the figure 12.

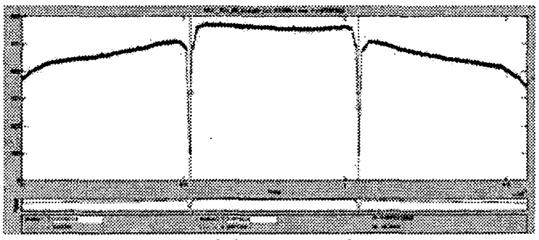

Figure12. The result of the NUC of Raw data (figure 7)

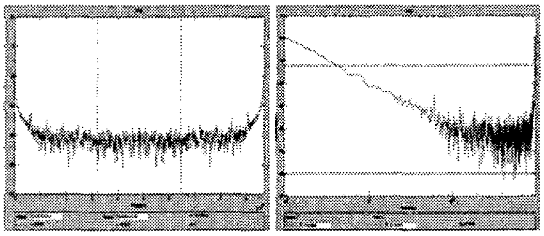

Figure 13. The FFT result of the figure 12.

The figure 14 is the filtered data after NUC operation and the figure 15 is the FFT result of the figure 14.

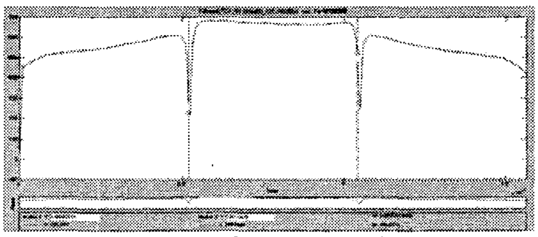

Figure 14. The filtered data after NUC

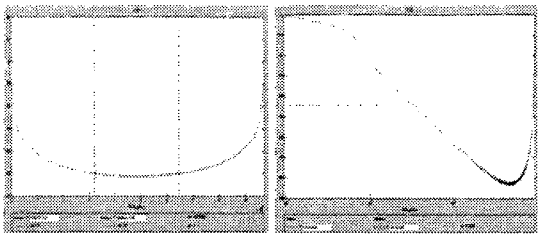

Figure 15. The FFT result of the figure 14.

The figure 16 shows the JPEG result of the No-NUC. The figure 17 is the raw data of the figure 16 and the figure 18 is the FFT result of the figure 17.

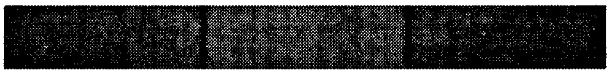

Figure 16. The JPEG result of the No-NUC.

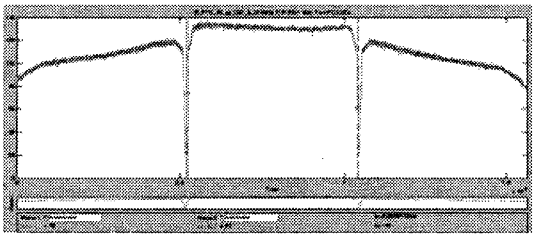

Figure 17. The Raw data of the No-NUC JPEG result.

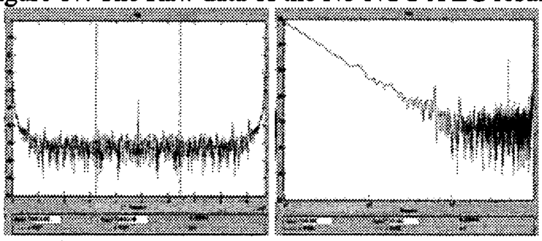

Figure 18. The FFT result of the figure 17.

The figure 19 shows the JPEG result of the after NUC operation. The figure 20 is the raw data of the figure 19 and the figure 21 is the FFT result of the figure 20.

Figure 19. The JPEG result of the NUC opeation

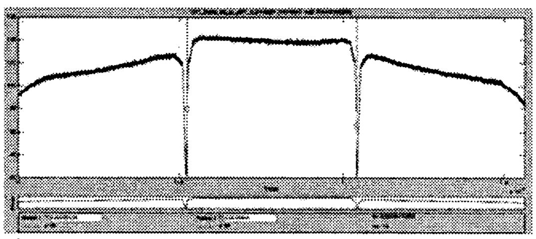

Figure 20. The Raw data of the NUC JPEG result.

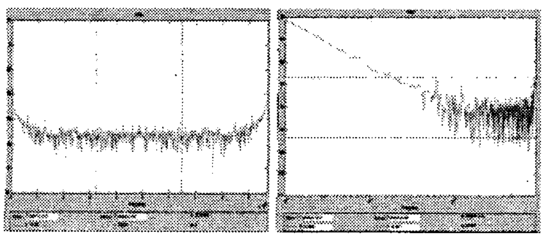

Figure 21. The FFT result of the figure 20.

6. CONCLUSIONS AND FURTHER WORK

In this paper, the NUC sub-system is described in terms of H/W (Configuration and Function operation). The purpose of the MSC is to obtain data for high-resolution images by converting incoming light into digital stream of pixel data. The NUC performs pre-processing to correct for non-uniformity and adding header data for identification and synchronization. The MSC has more high resolution than other satellite camera. It's used by very accurate observation and other multi-purposes.

The satellite electronic system has the restriction of the image processing because of the power consumption, speed limitation and the capacitance of the payload system. For the advanced image processing in ground station, it's very importance that lossless data processing is used in payload system.

In the future, it is needed that the multi-purpose satellite camera has the fast speed, the high confidence, the low power consumption, and the small size. These image data processing and correction system will be used for high resolution image acquisition.

References from Journals:

J.E Park, 2003. Video data output system design for CEU of satellite, ACRS, pp. 435-438.

J.P Kong, 2003. Payload Management Unit design of MSC, ACRS, pp. 443-446.

Y.S Kim, 2003. FGI (Frame Grabber Interface) Design for MSC Image Data Test, ACRS, pp. 426-428.

Y.S Kim, 2004. SNR Analyses for MSC and Camera Electronics Design for its Improvement, ISRS, pp. 444-447.

J.E Park, 2004. Image Data Processing System Design for Satellite , ISRS, pp. 486-488.

References from Books:

A. P. Malvino, 1995, Electronic Principles, Los Angeles: McGraw-Hill..

References from Other Literature:

Camera Controller Software Requirement Specification.

Camera Controller Software Design Document.