CCD Signal Processing for Optimal Non-Uniformity Correction

Jong-pil Kong* and Song Jae Lee**†

*Korea Aerospace Research Institute, 45 Eoeun-Dong, Daejeon, 305-333, Korea
**Dept. of Electronics Engineering, Chungnam National University, Daejeon, 305-764, Korea

Abstract: The performance of the payload Electro-Optical System (EOS) in satellite system is affected by various factors, such as optics design, camera electronics design, and the characteristics of the CCD (Charge Coupled Device) used, etc. Of these factors, the camera electronics design is somewhat unique in that its operational parameters can be adjusted even after the satellite launch. In this paper, the effect of video gain on the non-uniformity correction performance is addressed. And a new optimal non-uniformity correction scheme is proposed and analyzed using the data from real camera electronics unit based on a TDI (Time Delayed Integration) type of CCD. The test results show that the performance of the conventional non-uniformity correction scheme is affected significantly when the video gain is added. On the other hand, in our proposed scheme, the performance is not dependent on the video gain. The insensitivity of the non-uniformity performance on the video-gain is mainly due to the fact that the correction is performed after the dark signal is subtracted from system response.

Key Words: EOS, CCD, NUC, DNSU, PRNU.

1. Introduction

The Electro Optical System (EOS) as a payload in a satellite system consists of Optical Module (OM) and CEU (Camera Electronics Unit) which uses CCD (Charge Coupled Device) as a key component. In general, the performance of the EOS is largely dependent on the design of both OM and CEU. In the case of OM, it is almost impossible, once the satellite is launched, to modify its design. In the case of CEU, however, various operational parameters can be adjusted, even after the launch, to compensate the performance degradation resulting mainly from the aging effect of the electronics (Srour 1988). The correction parameters are often uploaded by ground station using operational command. The most important correction parameters among them are the video gain, offset, and non-uniformity correction parameters required to obtain optimized images. It is noted that the non-uniformity correction should be done in orbit because, when the non-uniformity performance is poor, the subsequent data compression removes dominantly the high spatial frequency components and thereby changes the
characteristics of the original image (Majid and Raul 1991). In this paper, we discuss the in-orbit non-uniformity correction with video gain applied and propose the optimized correction scheme to avoid the adverse effect due to the applied video gain. For the verification we analyzed the real measurement data from the CEU, which was built based on the CCD module from Fairchild Imaging. The test result shows that the non-uniformity performance is degraded significantly in the conventional scheme by the video gain but is not affected in the proposed scheme. The improved performance in the proposed scheme is mainly due to the fact that the non-uniformity correction is performed after the dark signal correction, in which the dark signal is subtracted from the measured data so that the system response is more linear and thus the adverse effect of the offset on the non-uniformity correction is minimized.

2. Overview of the CEU

As shown in Fig. 1, the CEU block consists of a 4K CCD and its peripheral electronics. The CCD from Fairchild Imaging is TDI (Time Delay Integration) type. The two key components of the peripheral electronics are the CSP (CCD Signal Processor, AD9824) from Analog Device, Inc. with input range of 1V and LVDS (Low Voltage Differential Signal) data serializer. Most of the functional units in the CEU including the DSNU and PRNU (Photon Response Non-uniformity) correction, and the interface with EGSE (Electronic Ground Support Equipment) are implemented inside a FPGA. The EGSE, the CEU controller for the ground test, sends the commands for imaging, and receives both the raw image data and telemetry from CEU. The conceptual signal flow from the CCD output to the CEU output is depicted in Fig. 2. The analog output from the CCD is transferred to the CSP, in which the CDS (Correlated Double Sampler) samples the reset noise and signal sequentially and then subtract reset noise from the signal (Albert 1996, Gerld 1998). The VGA (Video Gain Amplifier) in the Fig. 2 often works to balance the output level differences among the output ports due to different CCD amplifiers. At the same time it also works to amplify the signal level as well. It is noted, however,