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High-Definition Television System Onboard Lunar Explorer Kaguya (SELENE) and Imaging of the Moon and the Earth

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Abstract The High-Definition television (HDTV) system onboard the Japanese lunar explorer Kaguya (SELENE) consists of a telephotographic camera and a wide-angle camera that each have 2.2 M-pixel IT-CCDs (interline transfer charge-coupled devices) and LSIs (large-scale integrated circuits) of the several-million-gates class. One minute-long motion pictures acquired by the HDTV system at 30 fps (frames per second) are recorded in a 1 GB

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semiconductor memory after compression, and then transmitted to a ground station. In the development of the space-going HDTV system, a commercial ground-model HDTV system was extensively modified and evaluated for its suitability to withstand the harsh environment of space through environmental tests. The HDTV acquired a total of 6.3 TB of movies and still images of the Earth and the Moon over the mission period that started on September 29, 2007, and ended on June 11, 2009. Footage of an "Earth-rise" and an "Earth-set" on the lunar horizon were captured for the first time by the HDTV system. During a lunar eclipse, images of the Earth's "diamond ring" were acquired for the first time. The CCDs and the instruments used in the system remained in good working order throughout the mission period, despite the harsh space environment, which suggests a potential new approach to the development of instruments for use in space.

Keywords HDTV · Kaguya · Earth-rise · Earth-set · Diamond ring

1 Introduction

The High-Definition Television (HDTV) system has a resolution that is twice that of conventional television in terms of both vertical and horizontal resolution and a wider picture aspect ratio of 16:9. Research and development into HDTV was started in the 1970s by NHK (Japan Broadcasting Corporation) (Fujio et al. 1980, 1982). The HDTV system, characterized by its higher resolution and wider picture aspect ratio, appeals strongly to viewers thanks to the "presence" of its images, and has been adopted in many Japanese households.

HDTV was firstly carried into space in 1998 onboard the Space Shuttle. Imaging of the Earth from a spacecraft in an Earth-revolving orbit was conducted manually by an astronaut. In order to load the system into a manned spacecraft, the system was examined and improved with respect to toxic substances, fire prevention, and electromagnetic radiation in the communication frequency band (Yamazaki 2001). NASA's (National Aeronautics and Space Agency) evaluation was that a three-CCD type HDTV had a color representation closer to natural color than that of film or a single-CCD camera, and thus was most suitable for observations of the Earth (Robinson et al. 2000). However, a HDTV system had not been sent into deep space onboard an unmanned spacecraft.

The first still image of the Earth viewed from space was taken by the weather satellite TIROS-1 on April 1, 1960. The image of an "Earth-rise" from the lunar horizon was acquired by an Apollo 8 astronaut with a 70 mm film camera on December 22, 1968. The first movies of the Earth, the Moon and the lunar landing module were shot by Apollo 11 astronauts using a video camera on July 16, 1969. No other videos of the Earth and the Moon were acquired from a lunar orbit from the completion of the Apollo mission until 2006, although still images of Moon were acquired by Clementine's UV/VIS camera (Nozette et al. 1994) and SMART-1's AMIE multicolor micro camera (Josset et al. 2006).

The lunar-orbiting explorer Kaguya/SELENE (Selenological and Engineering Explorer) was developed by JAXA (Japan Aerospace Exploration Agency) to conduct scientific observations of the lunar surface and the environment around the Moon using 15 mission instruments while in a lunar-revolving orbit. The HDTV system was selected in 2001 as the last mission instrument to be carried onboard the Kaguya. The primary objective of adopting an HDTV system was the acquisition of high-resolution movies of the Earth and the Moon, in particular the Earth-set and the Earth-rise from the Moon, for public outreach purposes.

Following the launch of the spacecraft atop an HII-A rocket on September 14, 2007, from the Tanegashima Space Center in Japan, Kaguya' s HDTV system acquired clear moving