

ShindaiSat : A Visible Light Communication Experimental Micro-Satellite

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Abstract— Shinshu University has been developing a visible light communication(VLC) system using Light Emitting Diode(LED) by modulating the light intensity. The data transmitting capability is a few hundred Mbps for short distance and will be expected a few kbps for very long distance. ShindaiSat, a 35kg micro-satellite, is the first satellite to demonstrate the VLC between satellite and ground station. It will be launched in 2014 by Japanese H-IIA launcher as a secondary payload. This paper describes the outline of the satellite.

Keywords- LED, Visible Light Communication, Micro-Satellite

I. INTRODUCTION

VLC is a wireless communication using visible wavelength (electromagnetic waves ranging from 360 to 830 nm, defined by JIS Z8120), different from a laser communication. LED is rapidly used as a lighting source with low power consumption. By modulating the lighting of the LED with high frequency, it can be used as data transmission and communication device. Some features of the VLC are as follows.

- (1) Safety for the naked eyes. Home/office high power lighting can be used directly as communication
- (2) Regardless of the indoor outside, all lighting areas cover visible light communication areas
- (3) Visibility of the communication. Prevention of the communication leakage by controlling the emitting area
- (4) At present, no legal regulation
- (5) The radio wave is limited to use in hospitals, aircraft and space station because of the bad effect to their precision instruments, on the other hand, VLC will be applicable
- (6) VLC has the potential of new application fields such as underwater communication and space

The service area of the VLC covers all our daily life environments under visible lightings. A few hundreds Mbps data transmission can be obtained in the short distance. Laser

is suitable for long distance communication, on the other hand, data transmission rate by VLC is limited and strongly depend on the distance and atmospheric conditions. The distance dependence is caused by the irradiation angle of the visible light, the feature of which is allowed to the rough pointing. Without precise pointing between transmitter and receiver, low bit rate data transmission will be obtained by VLC system.

Research and development on VLC technologies in Japan began in 2001 in the activities of the Institute of Electronics, Information and Communication Engineers(IEICE) and continued to the activities of VLCC(VLC Consortium). The purposes of these activities are to find new applications for visible light communication. Long distance communication is one of the new application fields. In 2008, 1 kbps data transmission via 2 km distance experiment has succeeded by using lighthouse. Outstanding Technology Company has succeeded to obtain 5 kbps communication rates via 13 km with 3 watts LED in 2009 and the communication distance is improved to 42 km in 2010 by using 10 watts LED.

Shinshu University has proposed a forest monitoring micro-satellite "COMOREBI" in 2010 at the 18th satellite design contest organized by JSASS(The Japan Society for Aeronautical and Space Sciences) with other two societies cooperation and received award from IEICE. "COMOREBI" has the capability of 5 m spatial resolution for forest remote sensing, especially for observing the tree crowns of *Cahmaecyaris obtuse*[1],[2]. The second mission of this satellite is a LED VLC. By controlling the precision attitude pointing, the light communication link between satellite and ground station is expected and high bit rate data transmission will be available. To realize the VLC, Shinshu university also proposed a 2U size cubesat releasing from the "KIBO", ISS(International Space Station), planed by JAXA in 2011. Another proposal of the VLC mission, we also applied a 30kg-class micro-satellite as a piggyback payload of GPM(Global Precipitation Measurement) spacecraft and obtained the launch opportunity in the FY 2013 by Japanese H-IIA launcher. The ShindaiSat, Shinshu University Satellite, is a visible light communication experimental satellite for on orbit technology demonstration between a very long distance, more than 400km, by using LED light as a communication link.

II. SATELLITE OVERVIEW

ShindaiSat is a 40cm size with a mass of 35kg micro-satellite, which will be launched by H-IIA rocket in FY 2013 as one of the secondary payloads of the US spacecraft, GPM. The overview of ShindaiSat is shown in Fig.1 and the main characteristics of it are shown in Table1. Two types of LEDs are onboard, one is a parabolic type high gain LED with the 35mm diameter parabolic mirror and mainly used for the downlink communication. 32 mirrors are mounted on the Earth pointing satellite panel(+Z_B). The another one is a low gain LED with broad irradiation angle and mainly used at the

critical phase after launching and also used at the search mode of the satellite acquisition by emitting CW signal. The ShindaSat has another communication link, amateur band RFs for up/down link and also for amateur service. The VLC operation is limited only at fine weather condition and at night, on the other hand, RF link is available at any time. The satellite is mainly operated by using RF link and commands/telemetry data are always transmit/receive at the ground station located Shinshu university in Nagano. Mobile station is planed as site diversity for VLC mission.

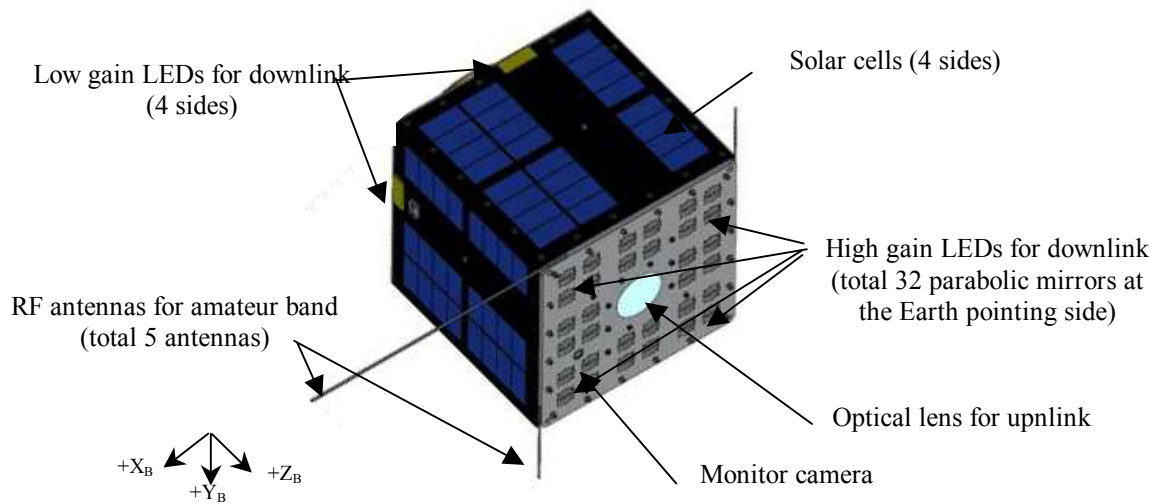


Figure 1 Overview of ShindaiSat

TABLE 1 MAIN CHARACTERISTICS OF SHINDAISAT

Dimension (mm)		400 x 400 x 450(include satellite attach fitting)
Mass (kg)		35
Orbit	Altitude (km)	400
	Inclination (deg.)	65
Attitude Control	Mission Mode	3-axis stabilization with reaction wheels and magnetic sensor and Fiber Optical Gyros
	Power	
Power	Power Consumption (W)	6~100
	Power Generation (W)	10 (mean value), 24 (maximum at one panel)
RF Communication	Amateur Band Up/Down Bit Rate (bps)	1200 (Up) 145MHz 1200 (Down) 430MHz
	Mission	1. VLC
a.High Gain LED for VLC		a. 32-Parabolic mirrors with 6 deg. irradiation angle. Earth pointing side(+Z axis)
b.Low Gain LED for CW and Acquisition		b. LED with 110 deg. irradiation angle. 4 sides attached on the CFRP panels
c.Optical lens to receive Command Signal	c. 80mm diameter, 200mm focal length lens	
3. Monitor Camera	2. Amateur Service	Open for amateur use
	3. Monitor Camera	CMOS camera for Earth image and pointing

III. SYSTEM

System block diagram of ShindaiSat is shown in Fig.2. The satellite is composed of data management system, attitude control system, power system, communication system and VLC mission. The satellite operation is managed by the central onboard computer, attitude control and VLC mission are managed by the SH-4 microprocessor and by the mission control microprocessor using FPGA board, respectively. At VLC mission mode, high gain LED panel(+Z_B axis) points to the Earth direction by stabilizing attitude control system using three reaction wheels and magnetic torquers. The satellite attitude is determined by the compound navigation system using magnetic sensor, sun sensor, GPS receiver and FOG(Fiber Optical Gyro) or MEMS gyro. GaAs solar cells generate about 24 watts electric power at maximum and stored it in lithium ion batteries. Amateur bands are used for basic satellite communications and VLC is demonstrated as experimental communication.

A. Structure

Fig.3 shows the satellite structure and components layout. Main structure is 25x25 mm aluminum flame and CFRP panels are attached on the four sides. Four aluminum double cross panels are fixed inside the structure, on which components are assembled. Optical lens system for receiving modulated LED

light from the ground station is fixed at the center of the satellite.

B. Attitude Control System

After the separation from the launcher, the attitude of the ShindaiSat is roughly controlled by magnetic torquer, +Z_B axis of which is aligned parallel to the geomagnetic line and also the oscillation is damped by B-dot control. Three axes are controlled by three reaction wheels and magnetic torquers for VLC mission(Earth pointing). At waiting mode, or electric power generation mode, the attitude is controlled for sun pointing, i.e. one solar panel is oriented to the sun.

C. Power System

Solar cells are mounted on the four CFRP panels orthogonal to the +Z_B axis. 4 series and 6 parallel cells are mounted on the one satellite panel, the total amount is 96 GaAs cells. The size of the cell is about 40x80 mm and the efficiency is about 27 % at maximum. Lithium ion batteries, NCR-18650A by Panasonic Corp. are used to store the generated electric power. The nominal capacity is 3,100 mAh with 3.6 voltages. The size of which is 18.6 mm diameter and 65.2mm length with 45.5 grams. As a battery unit, 12 cells with 2 series 6 parallels are packaged and three units are onboard for electric power supply.

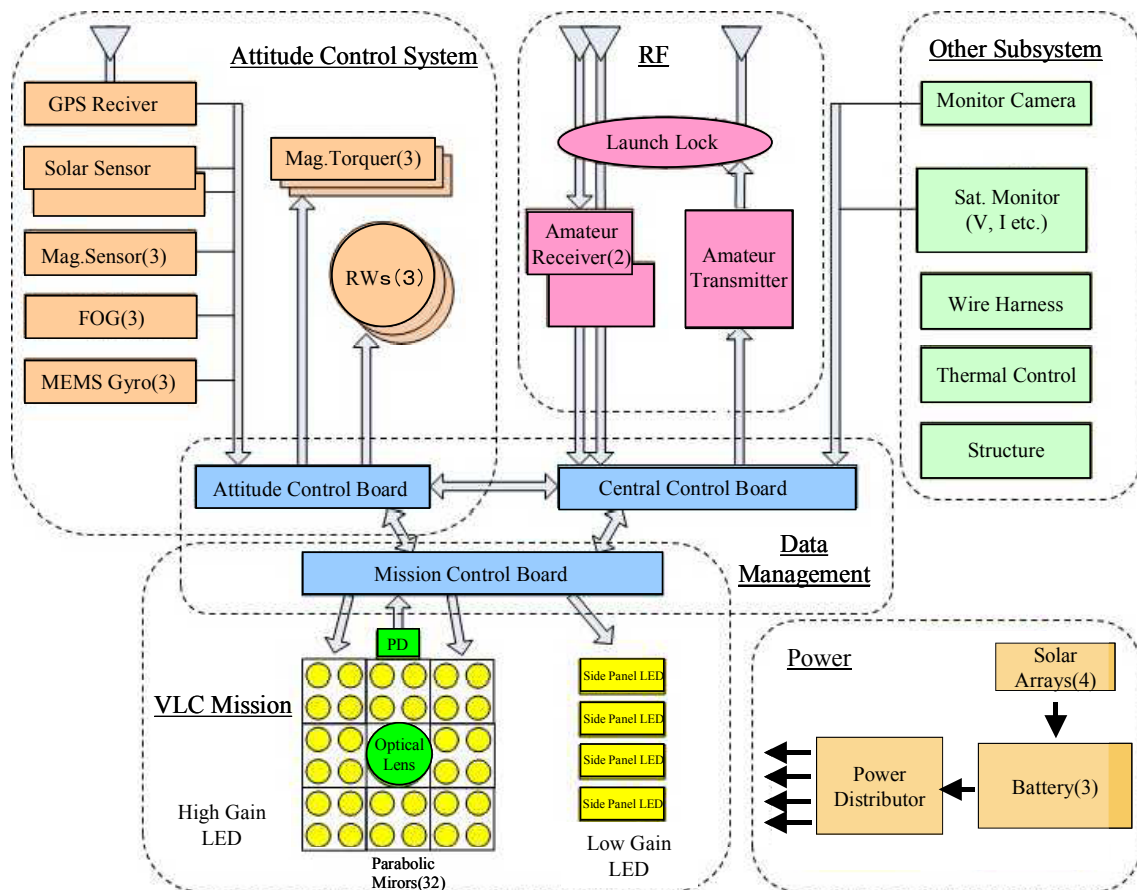


Figure 2 System Block Diagram of ShindaiSat

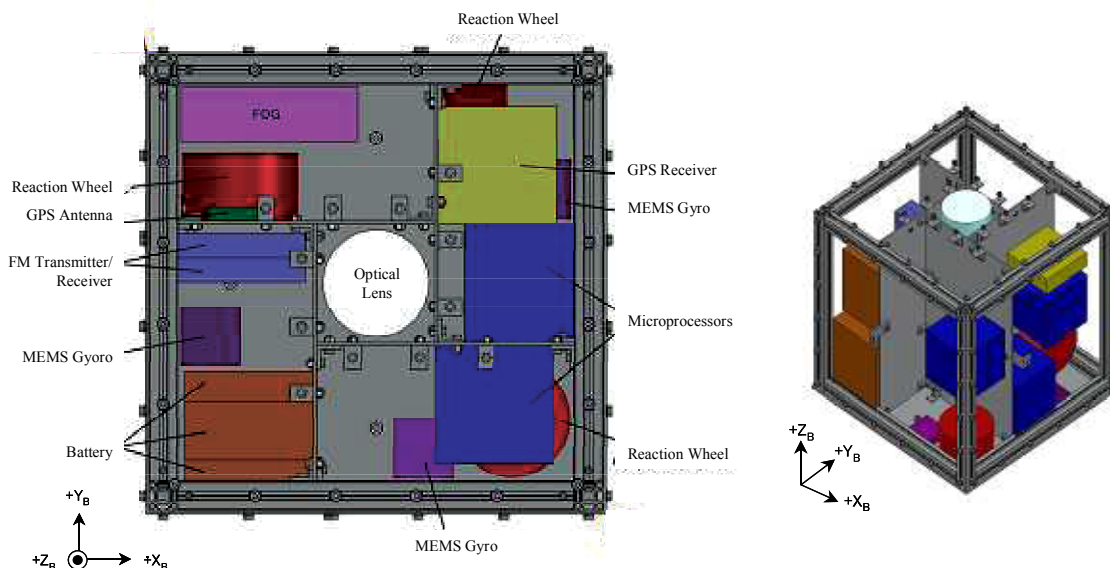


Figure 3 Components Layout of ShindaiSat

IV. VLC MISSION

High gain and low gain LEDs are used for VLC experiments as shown in Fig.4. One LED device is mounted at the focal plane of each parabolic mirror and the irradiation angle is about 6 degrees. The heat sink of the LED energy consumption is the 40cm x 40cm satellite panel with 10 mm thickness aluminum and the temperature of which will be limited under the design value at high power mode. 32 parabolic mirrors in which one LED is mounted for each mirror emit the total light flux about 9,600 lumen for the VLC communication with bit rate of 1,200 bps or 9,600 bps. 9,600 bps will be available under the precise attitude control stabilization. Low gain LED composed of 4 LEDs emits about 1,920 lumen for CW communication. NVSW119A LED, which has the capability of 140 lumen/W, is used for high and low gain LED units.

Fig.5 shows the brightness and irradiation area for high gain and low gain LED lighting. The irradiation angle is about 6 degrees and the irradiation area on the ground is about 40 km from 400 km altitude. The maximum brightness will be estimated as -2 star magnitude, the light of which pass through the area about 5 seconds for satellite nadir pointing. For VLC communication, the satellite points continuously to the ground tracking station, the maximum communication time will be calculated about 5 minutes, depending on the satellite orbit.. The brightness of the low gain light will be estimated as 8 star magnitude. Some optical device is necessary to find the light. This low gain LED with broad irradiation angle is used for the satellite acquisition just after the separation from launcher and unexpected attitude disappearance.

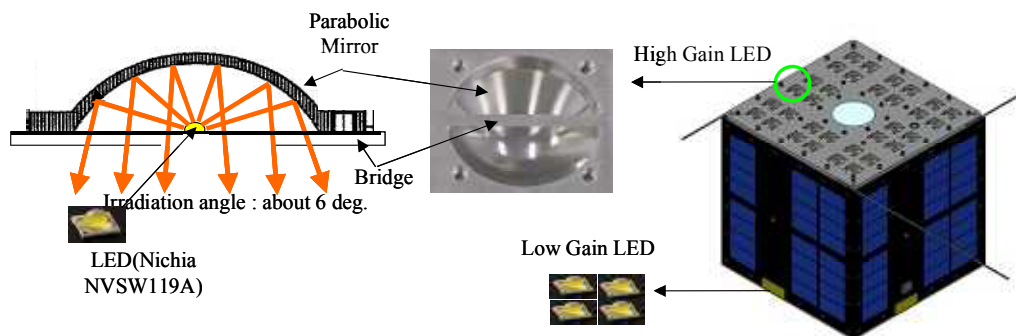


Figure 4 High and Low Gain LED Unit

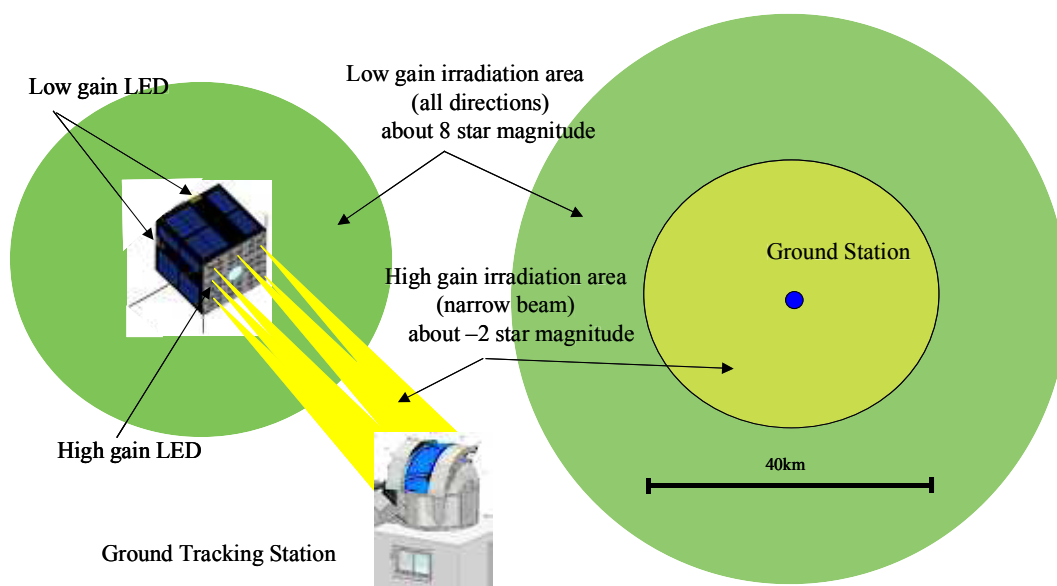


Figure5 LED light Irradiation Area

V. DEVELOPMENT ORGANIZATION

ShindaiSat has been developed by Shinshu University collaborated with the Shinshu Satellite Workshop(SSWS), which was organized in 2011 for the information exchange and manufacturing ShindaiSat. The members of the SSWS are academic organizations and their students, innovative small-midsize companies located at Nagano prefecture(mainly, no restriction for companies outside of Nagano).

The phase 0/1 PDR was held in August 2012, and the flight model is planed to manufacture in August 2013 and will be transferred to Tsukuba Space Center, JAXA in November 2013.

VI. CONCLUSION

ShindaiSat is the first technology demonstration micro-satellite on LED visible light communication between satellite and ground. Command and telemetry operation is controlled by ground tracking station located at Shinshu University in Nagano for the both RF and light communication. Mobile tracking station will be prepared to decrease the influence of weather condition. During the experiments, some technical data will be obtained and some parameters for designing the very long LED visible light communication system will be determined.

Because of the easy LED light recognition from the ground, young people will join some events to receive the messages involved in the light without any special instruments by using CW(Morse code).

ShindaiSat is expected to contribute the academic training of satellite development and operation for young people and

will exploit new applications of visible light communication in the fields of our daily lives, underwater and space communication. ShindaiSat will become a forerunner of a very long distance VLC commercialization by using micro-satellite.

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