Development of The Cubesat FITSAT-1

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We have developed a 10cm 1U cubesat FITSAT-1, which is released from ISS in September 2012. FITSAT-1 is orbiting around the earth about 100 days. The main mission of the FITSAT-1 is to demonstrate a high speed transmitter module developed by our group. It can send a VGA (640x480pix) resolution jpeg image data at 115.2kbps FSK in 5 to 6 seconds using 5.8GHz ham band. The second mission is to make the satellites twinkles as an 'artificial star' using high-output 50 green LEDs in flash mode. This LED light will be observed by binoculars. This paper introduces the detailed structure and the system of FITSAT-1.

Key Words: cubesat, FITSAT, 5.8GHz high speed transmitter, LED, Optical communication

1. Introduction

We have developed a 10cm 1U cubesat FITSAT-1 shown in Figure 1. It also has the nickname "NIWAKA". FITSAT-1 is released from ISS in September 2012. FITSAT-1 was carried to ISS by HTV in July 2012. We started up the FITSAT-1 project in April, 2011. The main mission of this satellite is to demonstrate the high speed transmitter developed. It can send a jpeg VGA-picture (480x640) within 6sec. FITSAT-1 has another experimental mission to test the possibility of optical communication by satellite. It will actually twinkle as an artificial star. FITSAT-1 high power LEDs will be driven with more than 200W pulse to produce extremely bright flashes. These, we hope, will be observable by the unaided eye or small binoculars.

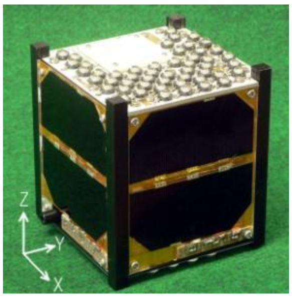

Fig. 1: Outside view

Structure

FITSAT-1 is a 10cm cube, and the weight is 1.33kg. The FITSAT-1 body is made by cutting a section of 10cm square aluminum pipe. Both ends of the cut pipe are covered with aluminum plates. The aluminum pipe and the inside sticks are made of aluminum alloy A6063 and the plates are made of aluminum alloy A6061. The cubesat slide rails and side plates are not separate; they are made as a single unit. The thickness of the square pipe is 3mm, but the surfaces attached by solar cells are thinned to 1.5mm because of weight limit. In order to make the 8.5mm square cubesat rails, 5.5mm square aluminum sticks are attached to the four corners of the square pipe(Figure2).

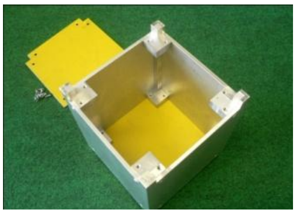

Fig. 2: Square pipe and plates

The solar cells are attached to the four sides of X and Y plane. The top (+Z plane) has a 5.8GHz patch antenna, green LEDs, and hole for the camera lens. The bottom (–Z plane) has the deployment switches, separation springs, 1.2GHz patch antenna, red LEDs and a hole for the 430MHz band antenna. Figure 3 shows the top plane and the bottom plane.

Fig. 3: Top plane and bottom plane

3. Electrical Power Subsystem

The FITSAT-1 electrical power system consists of solar cells, DCDC-converters, single lithium ion battery, three lithium ion batteries connected in series (Hitachi Maxell INR18650PB2, 1450mAH), battery controllers (SII S-8233BAFT, Linear Technology LTC4054-4.2), two deployment switches, and a flight pin switch. Each of these three switches controls electronic switches. Figure 4 shows these lithium ion batteries. Both single battery and three batteries in series are connected with these three electronic switches in series. So they never supply power until all three switches turn on. As solar cells also connected with two electronic switches and a physical switch in series, they never generate power until all three switches turn on.

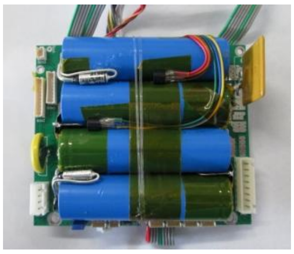

Fig. 4: Battery

Table. 1: Specification of battery

Battery type		Li-ion
Size	Diameter	18.3mm
	Height	64.95mm
Nominal voltage		3.7V
Rated capacity		1450mAh
Mass		41g

The single lithium ion battery supplies the power for communication and data handling system except high speed communication system and camera. While three batteries in series supply power for experiments of 5.8GHz high speed transmission and flashing LEDs.

Each side of the solar cells generates 2.3W (4.74V x 0.487A) of electrical power. The generated power is extracted by maximum power point tracking DCDC-converter and supplied to 5V load, single lithium-ion battery, and three lithium-ion batteries. The charging of the single lithium-ion battery is controlled by a battery protection IC (Liner Technology LTC4054-4.2), and the three lithium-ion batteries are controlled by a battery protection IC (SII: S-8233BAFT). The battery control IC LTC4054-4.2 controls only charging because no over discharge state is assumed. While the battery protection IC S-8233BAFT also controls discharging to protect the three batteries from over consumption of high power experiments. This IC monitors the voltage of each battery cell and controls the charging and discharging. If the voltages of all the three batteries are in the range from the over discharge detection voltage to the overcharge detection voltage, and the current flowing through the batteries is lower than a specified value, the charging and discharging circuits (FETs) remains on.

Normally, the electrical system will operate at 5V under 0.13A. When the solar cells face to the sun, excess currents charge the single battery. When the single battery is charged enough, the three batteries are charged. When the FM transmitter (437.445MHz, 0.8W RF-output) operates for replying to remote commands, a discharge current (0.3-0.7A) will be drawn for 10 minutes from the single battery.

When the high speed transmitter operates, a 1.5A current will be drawn for 5 minutes from the three batteries. The current will rise to 2-2.5A during the 4 minutes of the "artificial star" experiment from the three batteries. The high speed transmitter and artificial star experiments need optimal battery conditions and times when the orbit of FITSAT-1 passes over the home base. Therefore those experiments will be performed once every three days.

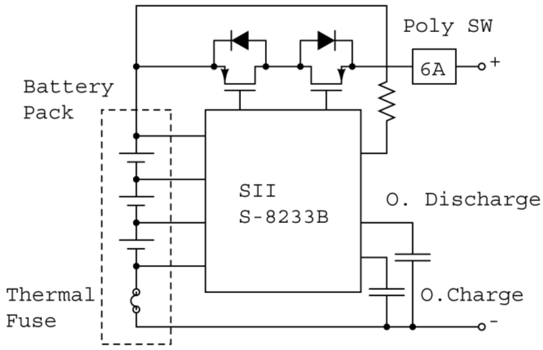

Fig. 5: Circuit for battery controller

Not only the battery protection IC, but also each battery cell (Hitachi Maxell INR 18650PB2) has, to protect against excessive pressure due to heating, a gas release vent with a current cutoff mechanism. The external thermal fuse will also cut off the current on overheating by short circuit. The two deployment switches and the flight pin connected in series also protect short circuits before deploying.

4. Communication and Data handling subsystem

Figure 7 shows the block diagram for the FITSAT-1 communication and data handling system. When the deployment switches turn on, 430MHz TXRX-controller, the main CPU (RX-CPU, TX-CPU) and the backup CPU start operating. Thirty minutes after deployment, timer of the 430MHz TXRX-controller turns on the switch of the servomotor for extending the 430MHz antenna (Figure 6).

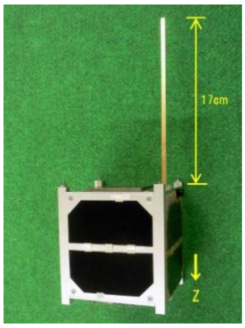

Fig. 6: 437MHz antenna

The communication system consists of a low speed system and a high speed system. Using the low speed system, FITSAT-1 always sends a CW beacon signal at 437.250 MHz with 100mW. This signal includes telemetry data such as internal voltages, currents, temperatures, timestamp, and other FITSAT-1 states. The low speed system accepts remote commands from the ground station between beacon signal intervals. The remote commands are sent by AX.25 packets at 1200bps from the ground station. The packet signals are received by the 430MHz band FM receiver and decoded by the AX.25 TNC (AXELSPACE HVU-301). The RX-CPU executes the commands and outputs signals on the bus line which connects between CPUs and peripherals. The results of the remote commands are monitored by the TX-CPU and sends to the FM transmitter through the AX.25 TNC. The FM transmitter sends the AX.25 packet at 437.445MHz with 800mW. The specification is listed in Table 2.

If the 430MHz receiver does not work, the ground station can send remote commands with DTMF signals using a 1.2GHz transmitter. The DTMF signal is received by the 1.2GHz band receiver and sent to the DTMF decoder. The backup CPU executes the commands and outputs signals on the bus line.

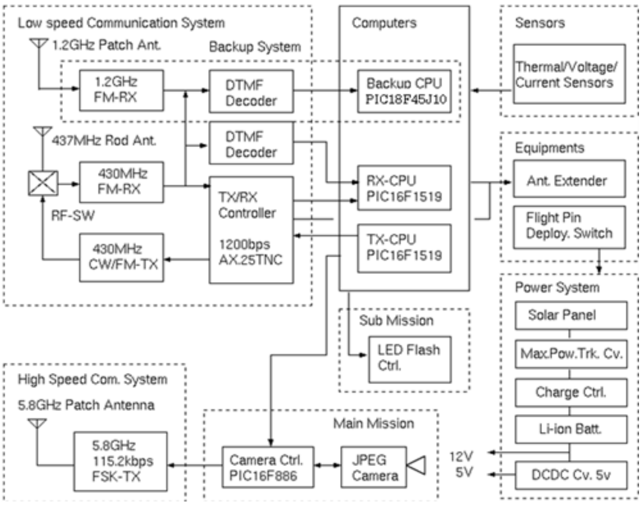

Fig. 7: Block diagram

Table. 2: Communication specification

Receiver	Frequency	Signal
430RX	436-438MHz	1200bps packet(AFSK)
1.2GTX	1260-1270MHz	DTMF

Transmitter	Frequency	Signal	Power
430CWTX	437.250MHz	CW	100mw
430FMTX	437.445MHz	1200bps packet(AFSK)	800mW
5.8GTX	5.84GHz	115.2kbps(FSK)	2W

5. Attitude Control Subsystem

Since a permanent magnet is mounted in FITSAT-1, the top (+Z plane) of the body will always face magnetic north. The top plane has a 5.8GHz patch antenna, LEDs, and a hole for the camera lens. The circle of the satellite in the Figure 8 shows the directivity of 5.8GHz patch antenna, the corner of the satellite shows the angle of front camera and green LED beam.

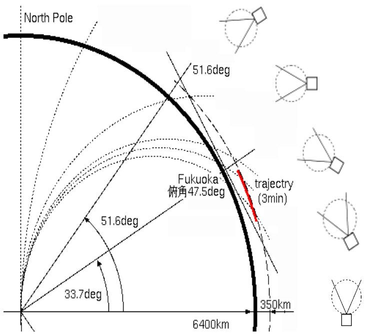

Fig. 8: Attitude of FITSAT-1

6. Missions of FITSAT-1

6.1 5.8GHz high speed transmission

The high speed radio system uses 5.8GHz ham band. The transmitter sends a VGA image data (640 x 480 pixels) at 115.2kbps FSK in 5 to 6 seconds. Bandwidth is 300KHz. The transmitter generates 2W RF power from 15W DC-input. The patch antenna generates the right circularly polarized wave. The camera of a FITSAT-1 is C1098 (Silent System) shown in Figure 9.

Fig. 9: Jpeg camera

Image data is packed and transmitted every 128byte. FITSAT-1 has two jpeg cameras inside of the body, and 20 pictures are stored. It takes about 3 minutes to transmit all the image data. Immediately after FITSAT-1 is deployed, 20 photographs are taken every 10 seconds, and stored. All commands can be set up with delay time, so it is possible to take pictures anywhere on the orbit.

6.2 Flashing LEDs

50 green LEDs are attached on the top (+Z plane) of the body. 32 red LEDs are attached on the bottom (-Z plane) of the body. Flashing 50 green LEDs is shown in Figure10.

Flashing LEDs has the two modes. One is Duty 30%, 10Hz signal is modulated with also duty 30%, 5kHz signal. So the average input power will be 220W x 0.3 x 0.3 = 20W. In order to detect the faint light, 5kHz filter may be useful. Flashing time is selected 2 minutes or 4 minutes with commands. Another mode is flashing by Morse code. The Morse code is modulated with duty 15%, 1kHz signal. So, the signal can directly drive a speaker with AF-amplifier to hear Morse sound. The dot of the Morse code is 0.2 second and a dash is 0.6 second. With a delayed execution of command, LEDs also can be flash anywhere on the orbit. Since attitude of the satellite is based on a magnet, flashing green LEDs is observed in the Northern Hemisphere and flashing red LEDs is observed in the southern Hemisphere.

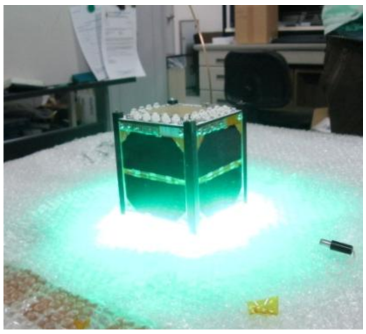

Fig. 10: Flashing green LED

7. Conclusion

We have developed the cubesat FITSAT-1, and it is released from ISS in September 2012. We are now preparing the ground station. As many ham equipments such as transceivers and antennas are available on 430MHz band, it is not so difficult to make the low speed communication system of the ground station at 430MHz band. But, neither antenna nor receiver was not available on 5.8GHz high speed communication system. So we had to develop 5.8GHz antenna and LNB which converts 5.84GHz to 440MHz. The LNB is mounted on the focal point of 1.2m parabolic antenna. Controlling 1.2m parabolic antenna is more difficult than 430MHz Yagi antenna. It needs accuracy of 3 degree. We have also developed the light detector for FITSAT-1. The controller of parabolic antenna and the light detector are presented by our colleagues.

References

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