International Journal of Recent Research and Review, Vol. XIII, Issue 2, June 2020
ISSN 2277 – 8322

Satellite Design and Communication with Ground Station for CanSat

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***Abstract*- The objective of the manuscript is to explain the design and development of a pico-satellite AabiSpace 1.0(or CanSat), and its communication mechanism with its ground station. Like an artificial environmental satellite, AabiSpace 1.0 will collect environmental data from an altitude and send it to the ground station. AabiSpace 1.0 was developed by me to promote and foster innovation in space technology and space robotics. The satellite is designed in cylindrical shape with dimension 80mm (diameter)*200mm (height), and has a weight of ~300g. It establishes communication with the ground station, and after receiving the commands from the ground station, it sends the collected data to the ground station; the ground station then uses an application and User Interface design to display the data graphically and make it legible for technical/non-technical people.**

***Keywords*- Satellite, Communication, data transmission, CanSat, telemetry, AabiSpace 1.0.**

I. INTRODUCTION

Satellite refers to an object that orbits around a bigger object. There are two kinds of satellites: artificial satellites (like international space station orbiting in low earth orbital) and natural satellites (such as the moon orbiting the earth) [1,2]. This study includes information about the design of a pico-sized artificial satellite, and communication mechanism with its ground station.

People have built and launched a variety of artificial satellites into space using a rocket for specific purposes. The size, altitude, and design of a satellite depend upon its purpose. For instance, there are artificial satellites such as Earth Observation Satellite for military and surveillance, Navigation Satellite for navigation, Communication Satellite for telecommunication, Weather Satellite for weather forecasting, Astronomical Satellite for astronomical observations and so on[7].

A CanSat (can-sized μ-satellite) is a simulation of a real satellite, integrated within the volume and shape of a can. Generally, CanSat that I built is an Environmental Satellite that communicates the basic information about the environment such as pressure, temperature, humidity, latitude, longitude, altitude, and acceleration along X-axis, Y-axis, and Z-axis at a particular location [7].

CanSat consists of sensors, a storage module, wireless transmission, and control. Measurement data of all sensors are stored in the SD card module and are sent to the ground station for further analysis and processing. CanSat establishes its communication after its deployment from the deploy box when the crash sensor is activated up to the landing zone. Tracking of the satellite is done by a ground station that uses a personal computer to run an application. The application is connected with Arduino Mega and communication module for communication with CanSat and displays the measured data with a user interface, each second after the satellite is deployed from the deploy box attached to the Quadcopter.

II. DESIGN AND SYSTEM OVERVIEW

At first, I sketched the design of the satellite using pen and paper then researched the locally available materials that I could use to build it.

A. Mechanical Design and Parts

My goal was to constraint the satellite within the dimension of 80mm diameter, 200 mm height, and approx.300gm weight. To reduce the weight of the satellite, I used fiberglass of radius 39mm and two aluminum stands (of height 170mm and diameter

4mm) nut bolts to attach three glasses. In the Upper first and second plate, I made a hole at the center to bind the satellite with a parachute. A transmitter module and a nine-axis accelerometer to precisely measure the acceleration across axes were attached to that plate. The third plate contains sensors to measure temperature, pressure, humidity, and a timestamp clock module along with an ATmega328 processor (which performs overall operation of the satellite) of Arduino Uno as shown in fig.1. To balance satellite while in a phase of descent with the parachute as shown in fig.2, the fourth or the last plate contains a power source for the satellite.

Fig 1. Descending phase of the Satellite

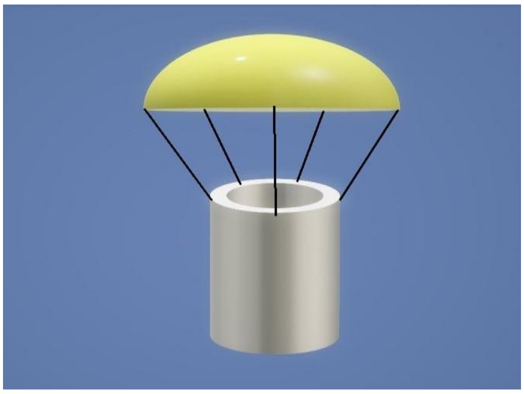

Fig 2. CanSat with its Ground Station.

B. *Electronics and Unknown Calculation*

For a small size and easy fabrication, I used an Arduino with ATmega328 processor and connected all other sensors and modules with the Arduino. I used DHT22 sensor to measure humidity and temperature; MPU-9250 (nine-axis accelerometer) to measure acceleration along X-axis, Y-axis, and Z-axis; DS-3231(Real-Time Clock module) to calculate date and time-dependently or independently using power given by power supply and cell within the module; BMP180 to accurately measure pressure. To calculate the altitude using pressure and temperature measured by BMP180 and DHT22 respectively, I used the barometric formula. I wrote an algorithm for the barometric formula and coded it in the internal coding of the processor, which after receiving the value of pressure and temperature will return the value of the altitude [5].

$$h = -\frac{RT\ln(\frac{P}{Pa})}{Mg} \qquad (1)$$

Where, Temperature (T) and Pressure (P) are measured by DHT22 and BMP180 respectively, where h represents altitude as shown in table I.

TABLE I

Representation of unknown parameters in Eq. (1)

Parameter	Symbol	Value	Unit
Universal gas constant	R	8.3142	mole*Kelvin
Average sea level pressure	Pa	101.325	Kilopascal
The Molar mass of Earth's air	M	0.02896	kg/mole
gravitational acceleration	g	9.807	m/s^2

I used two SD cards with SD card modules (an SPI communication based device): one within the satellite, and another in the ground station, to store all the measured or calculated data.

C. *Communication with Ground Station*

Generally transmitting, receiving and processing of any data is via a specific medium or channel is communication. The process of satellite communication begins at the ground station. A single satellite can communicate with more than one ground station. An installation is designed to transmit and receive signals from a satellite in an orbit around the ground station. Ground Stations send the information to satellites in the form of high powered, high frequency (GHz range) signals [6].

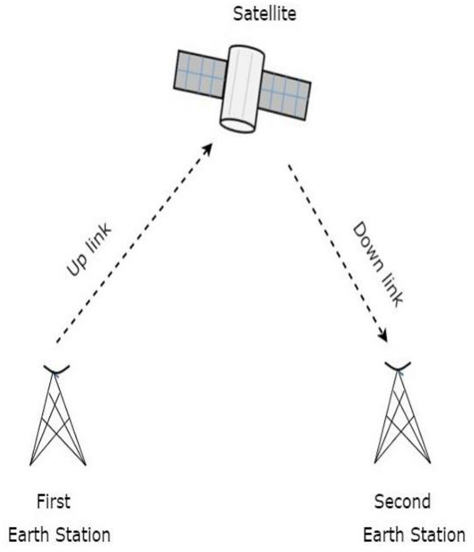

Fig.4 Communication of satellites with earth stations [6].

The satellite receives and retransmits the signals back towards the ground station where they are received by other stations within the coverage area of the satellite. Satellite's footprint is the area, within which a signal of useful strength from the satellite can be received [6].

D. Electrical Architecture of Satellite

The CanSat requires an electrical system for communication telemetry and landing. In choosing the electrical system, I considered the basic requirements of the satellite. The electrical architecture includes sensors, microcontrollers, batteries, memory card modules, and other circuits. To provide enough power to the microcontroller (ATmega328) and other sensors and modules, I used a battery of 7.4 V and a 2600 mAh current capacity. 7.4 V was supplied to the Arduino while other sensors and modules were powered from the Arduino pins of 5V and 3.3V [7]. The MPU-9250 9-axis Accelerometer, DHT22 humidity sensor, BMP180 pressure sensor, and the SD card module were supplied with 5V. The RTC Clock module and transmitter/receiver were supplied with 3.3V. Besides, we can make a measurement system for the battery's voltage level using a voltage divider [7].

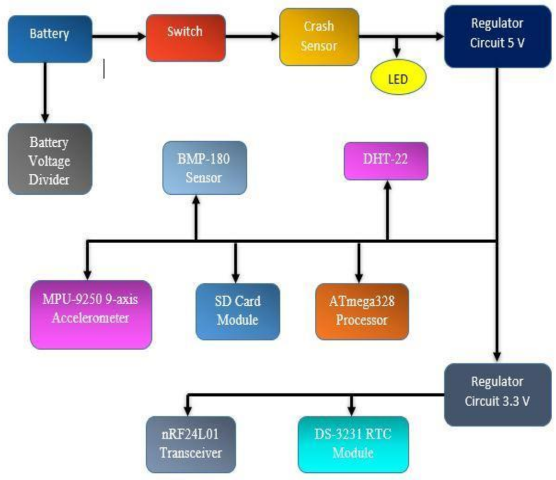

Fig 5. Electrical Architecture Block Diagram.

III. TELEMETRY AND SYSTEM ANALYSIS

Architecture and Analysis are described separately in two subheadings.

A. TELEMETRY

The satellite AabiSpace 1.0 and Ground Station that I made communicate with each other using nRF24L01 as a transceiver module one of which is connected in the satellite and other in the ground stations. The Transceiver module nRF24L01 operates with 2.4 GHz band and baud rates from 250 kbps up to two Mbps. In an open space and with lower baud rate its range can reach up to 100 meters of radius. The module can use 125 different channels, which gives a possibility to have a network of 125 independently working modems in one place. Each channel can have up to six addresses, or each unit can communicate with up to six other units at the same time. Three of these channels are for the SPI (Serial Peripheral Interface) communication and were connected to the SPI pins of the Arduino Uno: MOSI (Master Out Slave In) to digital pin 11, MISO (Master In Slave Out) to digital pin 12, and SCK (Serial Clock) to digital pin 13. The chip-select pins CSN and CE were connected to the digital pins of the Arduino board. These chip-select pins were used to set the module in standby or active mode, as well as to switchbetween transmitting or command mode. The IRQ pin is an interrupt pin, which is not used [3,4].

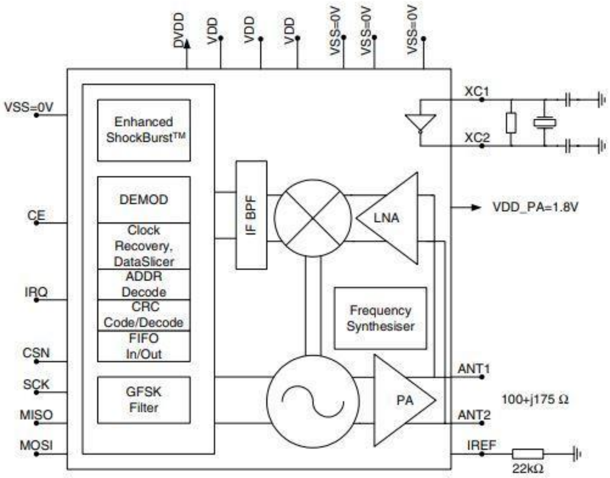

Fig 6. nRF24L01 with channels and external components.

The satellite sends all the data measured and calculated in the satellite in form of packets via the packet switching method. Packet switching is a method of grouping data that is transmitted over a digital network into packets that are made of a header and a payload. Data in the header is used by networking hardware to direct the packet to its destination whereas the payload is extracted and used by application software in the ground stations[8].

B. SYSTEM ANALYSIS

Before launching and after landing the satellite not only the payload but also the overall connections of the mechanical part, electronic sensors, and battery must be checked to see whether they are damaged or shifted from their position.

IV. RESULT AND DISCUSSION

The data received in the ground station and the data stored in the SD Card module in the AabiSpace 1.0 satellite are compared to each other, and the packet loss is calculated along with the errors in the data received in the ground stations. In an upgraded version of a satellite, I will try to overcome the errors, add more features, and increase precision.

V. CONCLUSION

In the study of this paper concludes that AabiSpace 1.0 possesses the basic features of an environmental satellite (pico-sized, can-shaped satellite). After launching the satellite when the crash sensor switches to active mode, the satellite starts to send measured data in the form of packets to the ground stations. An application to decode the packets is developed using Visual Basics. The nRF24L01 transceiver receives the data and sends commands to the satellite from the ground station. This paper is useful to those people who are interested in the field of satellite engineering and space science and want to understand the development and design of satellites. This paper gives basic ideas about the requirements of pico-satellites, their mechanical, electronics and electrical architecture, flight mechanics, application software, ground station, and communication.

VI. ACKNOWLEDGEMENT

I would like to thank my mentors Bajracharya Dibya and Subedi Deepak of Department of Physics, Sharma Prashant of Department of Chemistry, Pun Magar Pritam and Augi Raju of Department of Mathematics from Trinity International College Kathmandu Nepal. I am also thankful to my team The Robonauts, Bista Laxman brother, all my friends including Pudasaini Manish, Dhungana Animesh, Dulal Dajeel and those who helped me to complete this research project successfully.

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