KRUSHISAT

Power System Design for a Pico Satellite

A major project report submitted by

D. AKHIL KRISHNA 15J41A0212

K. BHAVANI 15J41A0226

N. MAMATHA 15J41A0239

In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

In

ELECTRICAL AND ELECTRONICS ENGINEERING

Under the esteemed guidance of

Dr K. EZHIL VIGNESH

Associate Professor, Dept. of EEE

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

MALLAREDDY ENGINEERING COLLEGE (Autonomous)

(An Autonomous Institution, Approved by UGC and Affiliated to JNTUH, Approved by AICTE, Accredited by NAACwith ‘A’ Grade (II Cycle) and NBA, Recipient of World Bank Assistance under TEQIP phase – II S.C.1.1) Maisammaguda, Dhulapally (Post. Via. Kompally), Secunderabad – 500 100, Telangana State.

2015-19

MALLA REDDY ENGINEERING COLLEGE(Autonomous)

(An Autonomous Institution, Approved by UGC and Affiliated to JNTUH,
Approved by AICTE, Accredited by NAAC with 'A' Grade (II Cycle) and NBA,
Recipient of World Bank Assistance under TEQIP phase – II S.C.1.1)
Maisammaguda, Dhulapally (Post. Via. Kompally), Secunderabad – 500 100, Telangana State

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

CERTIFICATE

This is to certify that this major Project work entitled **"KRUSHISAT-Power System Design for a Pico Satellite"** is the bonafide work of **D. Akhil Krishna (15J41A0212), K. Bhavani (15J41A0226), N. Mamatha (15J41A0239) and** in partial fulfillment for the award of **Bachelor of Technology** in **Electrical & Electronics Engineering** to the **Jawaharlal Nehru Technological University, Hyderabad** during the academic period **2015-2019** under my guidance and supervision. The results embodied in this project have not been submitted to any other University or Institute for the award of any degree or diploma.

SIGNATURE	SIGNATURE
Dr. K. EZHIL VIGNESH	**Dr. N. RAJESWARAN**
PROJECT GUIDE	**PROFESSOR & HEAD**
Department of EEE	Department of EEE
MREC(A)	MREC(A)
Secunderabad – 500100.	Secunderabad – 500100.

Submitted for the Major project viva voce held on……………………..

-------------------------	----------------------
Internal Examiner	External Examiner

ACKNOWLEDGEMENT

We are very grateful to our major project guide **Dr. K. EZHIL VIGNESH,** Associate Professor, Department of Electrical & Electronics Engineering, Malla Reddy Engineering College (Autonomous), for his extensive patience and guidance throughout our project work and for having provided the freedom to use all the facilities available in the department.

We would like to thank **Mr. V. GANESH KUMAR,** Associate Professor & Major Project Coordinator, Department of Electrical & Electronics and Engineering, Malla Reddy Engineering College (Autonomous), for the timely suggestions and motivation during the course of this work.

We sincerely thank **Dr. N. RAJESWARAN,** Professor and Head, Department of Electrical & Electronics Engineering, Malla Reddy Engineering College (Autonomous), for his valuable suggestions to make our project successful.

We are happy to express our deep sense of gratitude to **Dr. S. SUDHAKARA REDDY,** Principal, Malla Reddy Engineering College (Autonomous), for having provided us with adequate facilities to pursue our project.

We sincerely thank to all the teaching and non-teaching staff of the Department of Electrical and Electronics Engineering for their constant support during the course of this work.

We thank parents for their moral support and the Almighty for his bountiful mercy and graces showered on me during the period of my project, without which nothing could have been possible.

Finally, we express our immense gratitude with pleasure to the other individuals who have either directly or indirectly contributed to my need at right time for the development and success of this work.

D. AKHIL KRISHNA 15J41A0212

K. BHAVANI 15J41A0226

N. MAMATHA 15J41A0239

CONTENTS

ABSTRACT

In the era of development of space technology, miniaturization plays a vital role in low cost small satellite missions. The versatile application capabilities and low cost of Pico/Nano satellites missions make them attractive for a wide scope exploration projects. This paper is drawn by taking reference of 'STUDSAT' which was taken up by few engineering colleges from South India. This paper outlines the steps involved in design, development and fabrication of a Pico-satellite 'KRUSHISAT'. It elaborates upon the different subsystems in the satellite. The overall dimension of the satellite is (10*10*10) cm and a mass of less than 1 KG. The satellite is capable of transmitting point to point messaging (continuous communication between transmitting and receiving stations), monitoring the space environment, determines 3D orientation of satellite, detecting the presence of greenhouse gases in low earth orbit, measuring the magnetic strength of the low earth orbit, measuring the atmospheric pressure above the earth surface. The main objective of this paper is to promote space technology in educational institutions and enabling students and faculty to gain knowledge and experience in the field of satellite and space technology. Further, this project elaborates on the detailed explanation of fabrication and the steps followed in order to achieve the above objectives.

LIST OF FIGURES

LIST OF TABLES

CHAPTER-1

SATELLITES

1.1 INTRODUCTION:

A Satellite is something that goes around the earth or another planet. Some satellites are natural, like the moon, which is a natural satellite of the earth. Other satellites are made by scientists and technologists to go around the earth. Some satellites send and receive television signals. The Signal is sent from a station on the earth's surface. The satellite receives the signal and rebroadcasts it to other places on the earth. With the right number of satellites in space, one television program can be seen all over the world. Some satellites send and receive telephone, fax, and computer communications. Satellites make it possible to communicate by telephone, fax, Internet, or computer with anyone in the world. Other satellites observe the world's weather, feeding weather information into giant computer programs that help scientists know what the weather will be. The weather reporters on your TV news program get their information from those scientists. Some satellites take very accurate pictures of the earth's surface, sending back images that tell scientists about changes that are going on around the world and about crops, water, and other resources. A launch vehicle is a rocket that places a satellite into orbit. Usually, it lifts off from a launch pad on land. Some are launched at sea from a submarine or a mobile maritime platform, or aboard a plane.

Fig 1.1 Satellite

1.2 TYPES OF SATELLITE:

Satellites are used for many purposes. Among several other applications, they can be used to make star maps and maps of planetary surfaces, and also take pictures of planets they are launched into. Common types include military and civilian Earth observation satellites, communications satellites, navigation satellites, weather satellites, and space telescopes. Space stations and human spacecraft in orbit are also satellites. Satellite orbits vary greatly, depending on the purpose of the satellite, and are classified in a number of ways. Well-known (overlapping) classes include low Earth orbit, polar orbit, and geostationary orbit.

1.2.1 COMMUNICATION SATELLITES:

The Indian National Satellite (INSAT) system is one of the largest domestic communication satellite systems in Asia-Pacific region with nine operational communication satellites placed in Geo-stationary orbit. Established in 1983 with commissioning of INSAT-1B, it initiated a major revolution in India's communications sector and sustained the same later. GSAT-17 joins the constellation of INSAT System consisting 15 operational satellites, namely - INSAT-3A, 3C, 4A, 4B, 4CR and GSAT-6, 7, 8, 9, 10, 12, 14, 15, 16 and 18.

1.2.2 EARTH OBSERVATION SATELLITES:

Starting with IRS-1A in 1988, ISRO has launched many operational remote sensing satellites. Today, India has one of the largest constellations of remote sensing satellites in operation. Currently, *thirteen* operational satellites are in Sun-synchronous orbit – RESOURCESAT-1, 2, 2A CARTOSAT-1, 2, 2A, 2B, RISAT-1 and 2, OCEANSAT-2, Megha-Tropiques, SARAL and SCATSAT-1, and *four* in Geostationary orbit-INSAT-3D, Kalpana & INSAT 3A, INSAT -3DR. Varieties of instruments have been flown onboard these satellites to provide necessary data in a diversified spatial, spectral and temporal resolutions to cater to different user requirements in the country and for global usage. The data from these satellites are used for several applications covering agriculture, water resources, urban planning, rural development, mineral prospecting, environment, forestry, ocean resources and disaster management.

1.2.3 NAVIGATION SATELLITES:

Satellite Navigation service is an emerging satellite based system with commercial and strategic applications. ISRO is committed to provide the satellite based Navigation services to meet the emerging demands of the Civil Aviation requirements and to meet the user requirements of the positioning, navigation and timing based on the independent satellite navigation system. To meet the Civil Aviation requirements, ISRO is working jointly with Airport Authority of India (AAI) in establishing the GPS Aided Geo Augmented Navigation (GAGAN) system. To meet the user requirements of the positioning, navigation and timing services based on the indigenous system, ISRO is establishing a regional satellite navigation system called Indian Regional Navigation Satellite System (IRNSS).

1.2.4 SMALL SATELLITES:

The small satellite project is envisaged to provide platform for stand-alone payloads for earth imaging and science missions within a quick turnaround time. For making the versatile platform for different kinds of payloads, two kinds of buses have been configured and developed. SARAL(IMS-2) and YOUTHSAT(IMS-1) are the two small satellites developed by ISRO.

1.2.5 SPACE SCIENCE AND EXPLORATION SATELLITES:

Indian space programme encompasses research in areas like astronomy, astrophysics, planetary and earth sciences, atmospheric sciences and theoretical physics. Balloons, sounding rockets, space platforms and ground-based facilities support these research efforts. A series of sounding rockets are available for atmospheric experiments. Several scientific instruments have been flown on satellites especially to direct celestial X-ray and gamma-ray bursts. Astrosat, chandhrayan-1 and 2 comes under this type of satellites.

1.2.6 UNIVERSITY/ ACADEMIC INSTITUTE SATELLITES:

ISRO has influenced educational institutions by its activities like making satellites for communication, remote sensing and astronomy. The launch of Chandrayaan-1 increased the interest of universities and institutions towards making experimental student satellites. Capable Universities and institution can venture into space technology on-orbit with guidance and support from ISRO in following ways.

Development of Payload (by Universities/Institutions):

Every satellite carries a payload that performs the intended function to achieve the mission goal and the main bus that supports the payload function. The Development of payloads may comprise of detectors, electronics and associated algorithms, which can be an experimental piggy back payload on the ISRO’s on-going (Small or operational) satellite projects.

Design and development of detectors, payload electronics, and associated algorithm / experiments that enhance the application of space services to mankind is a continuing R&D activity in several educational institutions all over the world. Educational institutions can propose the payloads developed by them to be flown on ISRO’s small satellites.

Under this option, payload only is developed by the Universities or Institutions and launched with ISROs satellite missions which has other ISRO’s payloads. Data Handing and data transmission is done by ISRO as the part of satellite bus. After launch ISRO will acquire payload data and disseminate it to Universities/ institutions further processing and analysis.

Satellite Design & Fabrication by Universities/Institutions:

Under this option Universities have to design, fabricate, test the satellite Bus & Payload and deliver the integrated spacecraft for launch. Technical guidance in designing, fabrication and testing will be provided by ISRO. Some critical materials for the space mission also will be provided by ISRO. The designs and test results will be reviewed by ISRO team.

Under this option more than one University/Institution may participate. One among them will be the focal point for the ISRO. After launch, the collected data will be archived and disseminated by university/Institution(s).

1.3 PROJECT INTRODUCTION:

Student satellite programs offer excellent opportunities for learning as they exhibit application of interdisciplinary system design and integration. Satellite design is a proposed technology with vast performance implications ranging from enhanced mission capabilities to radical reductions in operations cost. In recent years’ small satellites have proven great potential in scientific, communication and military applications. “Opportunities space” is the word for small satellite systems. Small satellite systems strive to identify future technological advancement to make successful programs. Low cost and quick development are essential for the proliferation of small satellite missions. A Satellite bus is a standardized module providing suitable locations for mounting of a variety of payloads and science instruments while retaining the basic infrastructure so as to allow rapid production of satellites for various purposes. To explore these possibilities and to enable its realization, we initiated the development of a simple, low cost, Pico satellite known as KRUSHISAT. It is a Pico-Satellite where it elaborates upon different subsystems in the satellite. It is a CubeSat where CubeSat’s are employed to demonstrate spacecraft technologies intended for small satellites or that present questionable feasibility and are unlikely to justify the cost of a larger satellite.

Fig:1.2 Cube satellite structure

1.4 OBJECTIVES:

- To promote space technology in educational institutions and enabling students and faculty to gain knowledge in the field of satellites.
- To Gain hands-on experience in design, development and fabrication of space mission at minimum cost.
- To create communication between the satellite and the ground station.
- To detect and transmit the temperature and humidity in the Low-Earth Orbit.

1.5 SUBSYSTEMS:

KRUSHISAT mainly elaborates upon five subsystems. They are:

1. Structure
2. Power Supply design
3. Payloads
4. Attitude Determination and Control
5. Antenna Deployment.

1.5.1 STRUCTURE:

The overall dimension of the satellite is (10*10*10) cm cube and a mass of less than or equal to 1 KG. CubeSat is mainly used in order to reduce the size and complexity of the structure.

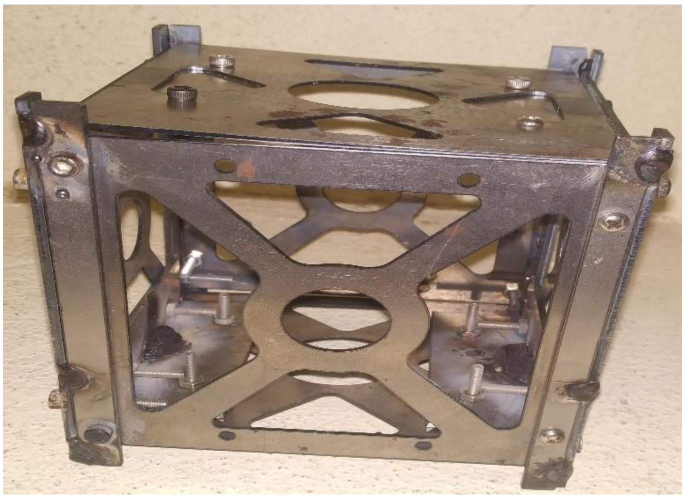


Fig:1.3 Structure used in the project

The Structure is an indispensable part of the spacecraft and serves to meet the following objectives:

(1) Enclose, protect and support the other spacecraft subsystems during launch and on orbit.

(2) Provide a robust body to accommodate all onboard components in their preferred orientations and locations.

(3) Provide a mechanical interface between the satellite and the launch vehicle.

(4) Qualify for all structural loads during launch and thermal loads on orbit.

(5) To have minimum Center of Gravity offset from geometric center so as to provide better attitude control capabilities in orbit.

1.5.2 POWER SUPPLY DESIGN:

With reference to the Electronic Power System Design of "SATHYABHAMA SAT", efficient power system is designed for this project. Brief explanation about the design and components used will be given in Chapter-3.

1.5.3 PAYLOADS:

Every satellite carries a payload that performs the intended function to achieve the mission goal and the main bus that supports the payload function. The Development of payloads may comprise of detectors, electronics and associated algorithms, which can be an experimental piggy back payload on the ISRO's on-going (Small or operational) satellite projects. Payloads for this satellite design is detecting Temperature, Humidity, Flux Density of the Low-Earth orbit. Its working will be explained in further chapters.

1.5.4 ATTITUDE DETERMINATION AND CONTROL:

With reference to SWAYAMSAT, Swayamsat hosts a passive magnetic attitude control system, achieving two axis stabilization and allowing the satellite to rotate about the antenna axis. As a result, power generated by the body mounted solar panels is variable and unregulated. The Magnetic rod suspended in the satellite aligns its magnetic field as per the earth's magnetic field. It aligns itself in the direction of Earth's magnetic field. So, that antennas always point towards the ground station and thus transmit the data i.e., healthy communication is carried out. Mainly, this attitude determination in satellites is introduced in order to stabilize the satellite. Because, when the satellite is suspended in Low earth orbit or in any orbit in the space satellite rotates in all directions there is no specific direction and stability.

1.5.5 ANTENNA DEPLOYMENT:

With reference to the IEEE paper of "Development of antenna deployment circuit for Nano satellites" antenna deployment circuit has been developed. Brief description of circuit, components and the materials used will be explained in Chapter-5.

CHAPTER-2

LITERATURE SURVEY

Literature Survey is a survey conducted in order to understand a topic in depth and finally get a reference to that particular topic. After making literature survey to get references or base for KRUSHISAT there are few papers which helped for design and construction of satellite. The reference papers for this are briefly discussed. They are as follows:

STUDSAT: India's First Student Pico-Satellite Project:

This paper serves a main reference to the project. It is a IEEE paper which is last updated in 2011. This paper mainly elaborates on the steps involved in design, development and fabrication of a Pico-satellite 'STUDSAT ': Student Satellite along with the development of ground station that is capable of communicating with STUDSAT. The STUDSAT satellite is capable of capturing images of ground resolution 90 meters at an altitude of 680 Kms.

Further, the paper elaborates on the beacon and telemetry data that were received from the satellite. The satellite mission was terminated officially after 3 months from its launch date. The paper also presents the analysis on failures that had caused early termination of STUDSAT mission. By making changes in the objectives of the project the rest will be referred from this paper.

Electronic Power Supply Design for Sathyabama University Nano Satellite:

This paper is taken as a base paper for the construction of Power System Unit (PSU) of KRUSHISAT. This paper presents the practical and theoretical design of the power supply unit (PSU) of the Sathyabama University Nano Satellite. The solar arrays are configured such that the cells of each side on the satellite are connected in series and the four sides are connected in parallel. This configuration has been chosen, because it was found that it is the best tradeoff between ease of maximum power point tracking(MPPT) and to improve the converter performance. The diodes protect the cells from conducting a reverse current. The battery charge controller acts as a central unit of the electronic subsystem, it takes care of charging the battery unit. It basically transfers power from solar panel to the battery at unregulated bus. By making slight changes in design the power system for this project is designed efficiently i.e., by averting the requirement of Maximum Power Point Tracking (MPPT) algorithm and has greatly reduced system complexity.

Novel Low Cost Standardized Nano-Satellite Structure Bus for LEO Missions:

This paper serves as a base paper for the construction and design of a CUBE of the satellite. In order to get knowledge regarding the materials used for constructing a cube and assembling all the subsystems in it. This paper focuses on SRMSAT STRUCTURE BUS which is a standardized Nano-Satellite structure bus. It provides a standard platform for a wide variety of missions in LEO and can be realized in a very short developmental period. Construction steps are followed but modifications are made to the dimensions and weight of the cube.

Antennas for Modern Small Satellites:

This paper is used as a reference for gaining knowledge regarding the types of antennas and selection of antennas. This paper gives an overview of antenna technologies for applications in modem small satellites. First, an introduction to modern small satellites and their structures is presented. This is followed by a description of technical challenges in the antenna designs for modern small satellites, and the interactions between the antenna and modern small satellites. Easy method of deploying the antenna has been utilized in this project by burning the nichrome wire.

Development of Antenna Deployment Circuit for Nano-Satellites:

This paper deals about the design and development of a highly efficient, smart and reliable control circuit prototype called the Antenna Deployment Circuit. This developed prototype is tested and the results are summarized in the paper. This paper is taken as base paper for developing antenna deployment of KRUSHISAT.

CHAPTER-3

POWER SYSTEM DESIGN

3.1 INTRODUCTION

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination. Photovoltaic cells convert light (photons) into an electric current using the photovoltaic effect. Photovoltaics are the best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons by the photovoltaic effect. Solar cells produce direct current electricity from sunlight which can be used to power equipment or to recharge a battery.

3.2 COMPONENTS USED:

1. Solar Panels.
2. Diode.
3. Battery Protection Circuit.
4. Boost Converter.
5. Buck converter.

3.2.1 Solar Panels:

Fig 3.1 Solar Panels

Solar panels absorb the sunlight and serves as a source of energy to generate electricity. Solar panels get energy from the sun for people to use. There are two types of solar panels, those that collect heat (thermal), and those that produce electricity (photovoltaic). Heat from solar panels is often used for space heating and for hot water. Solar panels collect renewable energy. In the 20th century some used the heat of the sun to make steam for a steam engine to turn a generator. Nowadays producing electricity from the sun's light is cheaper. This is a solid state way of producing electricity, meaning that it has no moving parts. Home solar panels are often mounted on rooftops. Commercial or industrial installations are often on trackers mounted on the ground. The trackers point the panel towards the sun as the sun moves across the sky. Photovoltaic panels are also commonly used in outer space, where they are one of the few power sources available.

3.2.2 DIODE:

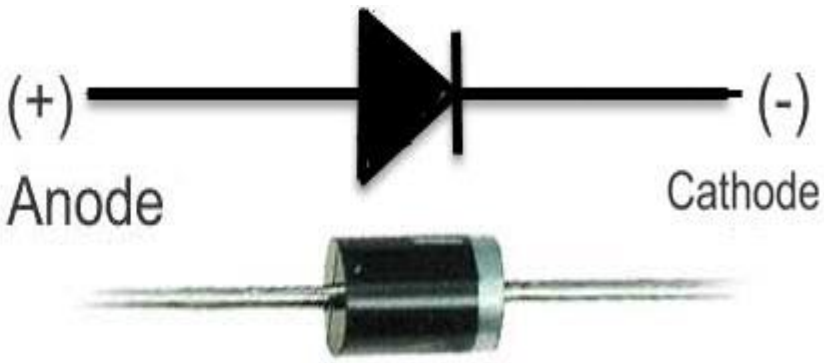


Fig 3.2 Diode representation

A diode is a two-terminal electronic component that conducts current primarily in one direction (asymmetric conductance); it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other. A diode vacuum tube or thermionic diode is a vacuum tube with two electrodes, a heated cathode and a plate, in which electrons can flow in only one direction, from cathode to plate. A semiconductor diode, the most common type today, is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals. Diodes are connected in order to prevent the flow of reverse current and protects the solar cells from conducting a reverse current.

3.2.3 BATTERY PACK:

Li-Polymer battery are made of soft aluminum-plastics compound packaging. Internal is half solid polymers. Discharge stability, high efficiency, the internal resistance small.

Safety performance is better, and has overcurrent, overvoltage protection devices. The

Fig 3.3 Lithium polymer battery pack

lithium-polymer differentiates itself from conventional battery systems in the type of electrolyte used. The original design, dating back to the 1970s, uses a dry solid polymer electrolyte. This electrolyte resembles a plastic-like film that does not conduct electricity but allows ions exchange (electrically charged atoms or groups of atoms). The polymer electrolyte replaces the traditional porous separator, which is soaked with electrolyte. The dry polymer design offers simplifications with respect to fabrication, ruggedness, safety and thin-profile geometry. With a cell thickness measuring as little as one millimeter (0.039 inches), equipment designers are left to their own imagination in terms of form, shape and size. Unfortunately, the dry lithium-polymer suffers from poor conductivity. The internal resistance is too high and cannot deliver the current bursts needed to power modern communication devices and spin up the hard drives of mobile computing equipment. Heating the cell to 60°C (140°F) and higher increases the conductivity, a requirement that is unsuitable for portable applications.

Advantages:

- Very low profile - batteries resembling the profile of a credit card are feasible.
- Flexible form factor - manufacturers are not bound by standard cell formats. With high volume, any reasonable size can be produced economically.
- Lightweight - gelled electrolytes enable simplified packaging by eliminating the metal shell.
- Improved safety - more resistant to overcharge; less chance for electrolyte leakage.

3.2.4 BATTERY PROTECTION CIRCUIT:

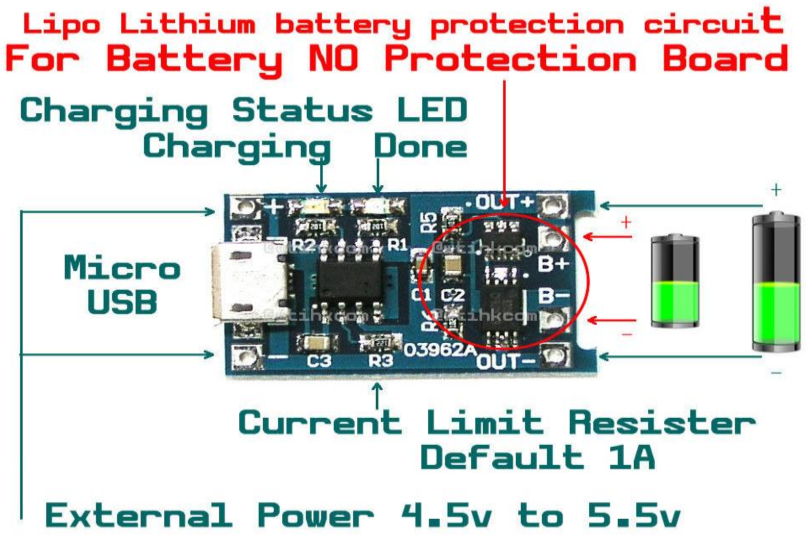


fig 3.4 TP4056 module with connections

Battery charger or a Battery protection circuit acts as an intermediate between solar panels and the battery pack. The main function of battery charger is to transfer the power generated by the solar panels to the battery pack at unregulated bus. Here, 3.7V capacity batteries are used. Battery pack stores the power generated by solar panels.

3.3 BLOCK DIAGRAM:

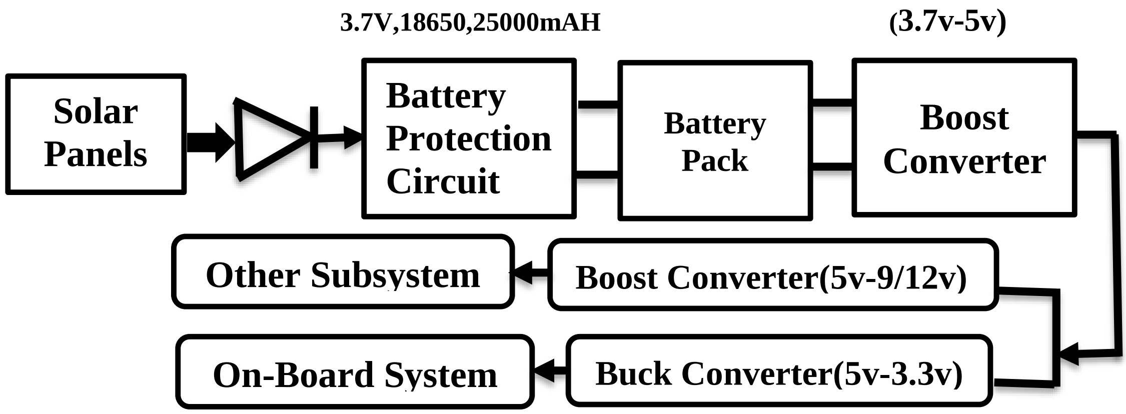


Fig.3.5 Block Diagram representation of Power System Unit

A Boost converter steps up the unregulated battery voltage +3.7V to +5V bus in order to provide supply to the on-board computer system and other subsystems. This power supply unit (PSU) has two Boost converters. One boost converter steps up battery voltage +3.7V to +5V which is given to two buses A and B. Another boost converter is used in bus A which steps up the +5V bus to (9-12) V bus in order to provide supply to antenna deployment circuit which will be discussed in further chapter. A Buck converter is used in bus B in order to step down voltage from +5V bus to +3.3V bus for the on-board computer system.

The PSU has been optimized for two stages of power conditioning:

- To harvest and regulate the solar power and utilize it for battery charging at 5V. This is performed with the help of a step up (Boost) regulator.
- To provide a stable 3.3V bus for the entire system and on board electronics. This is achieved through a step down (Buck) regulator.

In order to ensure that the outputs from the boost and buck converters simulation is also done and the values of both theoretical and practical are compared. The Simulation Software used for this is “MATLAB”.

3.4 MATLAB:

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and proprietary programming language developed by Math Works. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

USES OF MATLAB:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building.

3.5 BOOST CONVERTER

Fig 3.6 boost converter module

A boost converter (step-up converter) is a DC-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power must be conserved, the output current is lower than the source current. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage.

3.5.1 Theory of operation:

(a) When the switch(Mosfet) is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

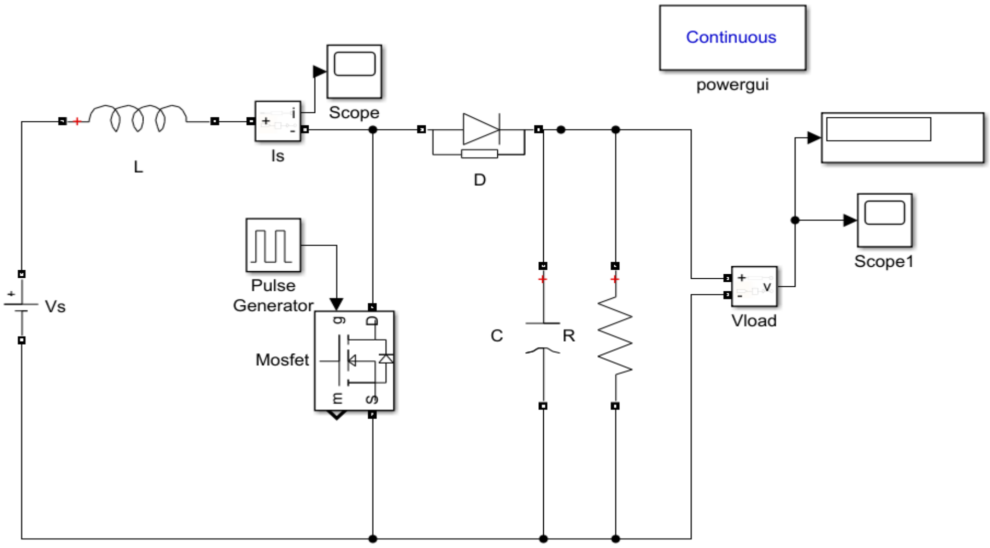


Fig 3.7 Boost converter circuit in MATLAB

(b) When the switch(Mosfet) is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

The basic principle of a Boost converter consists of 2 distinct states in the On-state, the switch is closed, resulting in an increase in the inductor current;

- In the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

3.5.2 THEORETICAL CALCULATION

1. In order to find T_{ON} and T_{OFF} of the boost converter firstly, find the duty ratio using the following formula.

Duty Ratio=1-V_s/V_o x ŋ

Where V_s= supply voltage

V_o= output voltage

Ŋ= efficiency

2. The value of inductance required in order to get desired output voltage of the boost converter can be calculated by using the following equation.

$L \geq V_{S(MIN)} \times D / F_s \times \Delta I_l$ (HZ)

Where L= inductance

D= duty ratio

F_s= supply frequency

ΔI_l= ripple current in inductor (20% to 40% of I_l)

3. Power $P= I_s \times V_s = I_o \times V_o$

$I_o = P/V_o$

4. The Value of capacitance required in order to get desired output voltage of the boost converter can be calculated by using the following equation.

$$C \geq I_{o(max)} \times D/F_s \times \Delta V_c$$

Where C= Capacitance

Since $V_c = V_o$

ΔV_c= 1% to 5% of V_o

5. Load at rated power

$$P= V^2/R$$

$$R= V^2/P$$

Where R= load resistance

V= output voltage

P= rated power

3.6 BUCK CONVERTER:

A Buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semi

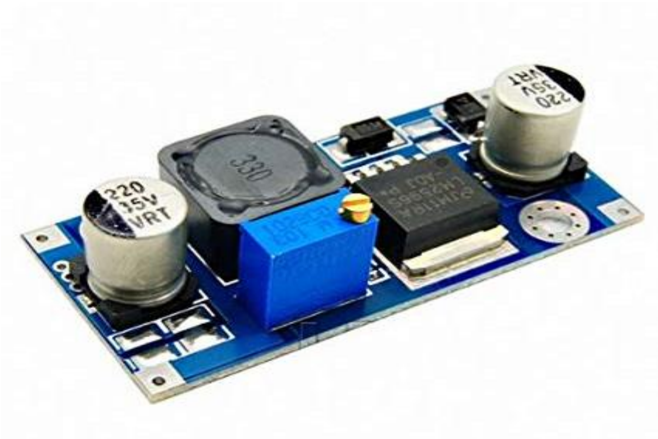


fig 3.8 Buck converter module

-conductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current. Buck converters can be highly efficient (often higher than 90%), making them useful for tasks such as converting a computer's main (bulk) supply voltage (often 12 V) down to lower voltages needed by USB, DRAM and the CPU (1.8 V or less).

3.6.1 Theory of operation:

The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized converter, all the components are considered to be perfect. Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off, and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance as being infinite).

The conceptual model of the buck converter is best understood in terms of the relation between current and voltage of the inductor. Beginning with the switch open (off- state), the current in the circuit is zero. When the switch is first closed (on-state), the current will begin to increase, and the inductor will produce an opposing voltage across its terminals in response to the changing current. This voltage drop counteracts the voltage

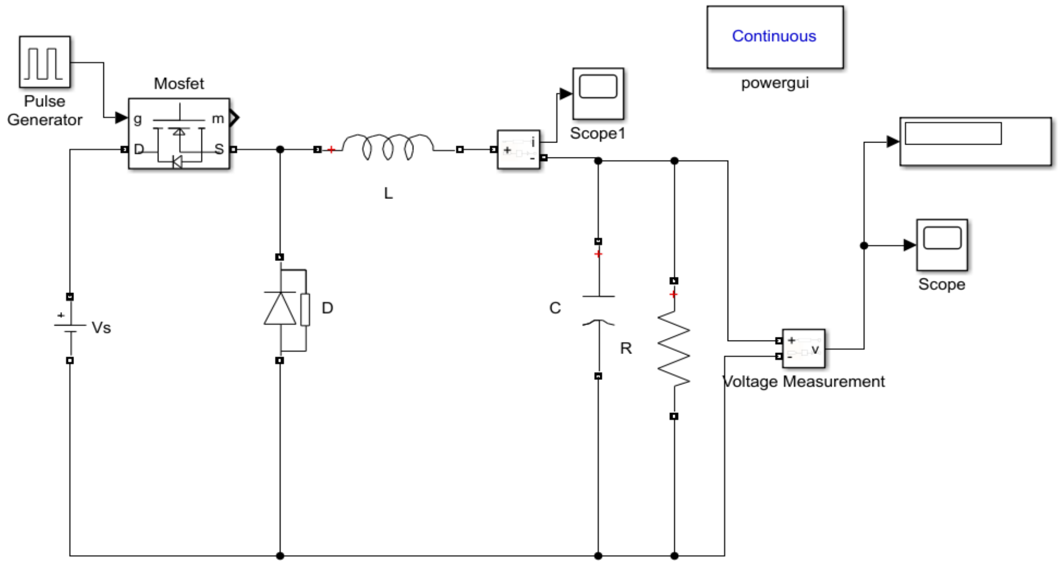


Fig 3.9 Buck converter design in MATLAB

of the source and therefore reduces the net voltage across the load. Over time, the rate of change of current decreases, and the voltage across the inductor also then decreases, increasing the voltage at the load. During this time, the inductor stores energy in the form of a magnetic field. If the switch is opened while the current is still changing, then there will always be a voltage drop across the inductor, so the net voltage at the load will always be less than the input voltage source. When the switch is opened again (off-state), the voltage source will be removed from the circuit, and the current will decrease. flowing while the input voltage source is disconnected, when concatenated with the current flowing during on-state, totals to current greater than the average input current (being zero during off-state). The "increase" in average current makes up for the reduction in voltage, and ideally preserves the power provided to the load. During the off-state, the inductor is discharging its stored energy into the rest of the circuit. If the switch is closed again before the inductor fully discharges (on-state), the voltage at the load will always be greater than zero. In a Buck converter, the output voltage is always lower than the input voltage.

3.6.2 Theoretical calculation:

1. In order to find the TON and TOFF of the Buck converter we need to find the Duty Ratio using the formula.

$D = V_0/Vs$ $[0 \leq D \leq 1]$

Where D= duty ratio

V_0= output voltage

Vs= supply voltage

2. Il(max)= I_0=V_0/R_0, min

Where Il(max)= maximum inductance current

I_0= output current

R, min= minimum load resistance

3. The value of inductance required in order to get desired output voltage of the Buck converter can be calculated by using the following equation.

L =D(1-D) VS/ΔI_L X f

Where L= inductance

D= duty ratio

Vs= supply voltage

ΔIL= ripple current in inductor (20% of Il, max)

f= frequency

4. ΔV_0=Vs(1-D) D/8LCf^2

C= Vs(1-D) D/8Lf^2 ΔV_0

ΔV_0 =±2% to 4% of V_0

Where C= capacitance

D= duty ratio

L= inductance

f = frequency

V_0= output voltage

Vs= supply voltage

5. I_1= I_0 =ΔI_1/2

R_0= R_{load} = V_0/I_0.

CHAPTER-4

COMMUNICATION SYSTEM

4.1 INTRODUCTION:

The primary goal of the communication subsystem of any satellite is to establish a communication link between the satellite and the ground station to relay payload and housekeeping data. The geometry of a satellite's orbit dictates a schedule of when, and for how long, the satellite is able to communicate with a fixed ground station. Low earth orbits are characterized by their short range, high orbital velocity and non-geosynchronous nature. A satellite is basically a self-contained communications system with the ability to receive signals from Earth and to retransmit those signals back with the use of a transponder—an integrated receiver and transmitter of radio signals. The main components of a satellite consist of the communications system, which includes the antennas and transponders that receive and retransmit signals. A communication satellite is nothing but a microwave repeater station in space that is helpful in telecommunications, radio, and television along with internet applications. A repeater is a circuit which increases the strength of the signal it receives and retransmits it. But here this repeater works as a transponder, which changes the frequency band of the transmitted signal, from the received one.

The frequency with which the signal is sent into the space is called Uplink frequency, while the frequency with which it is sent by the transponder is Downlink frequency.

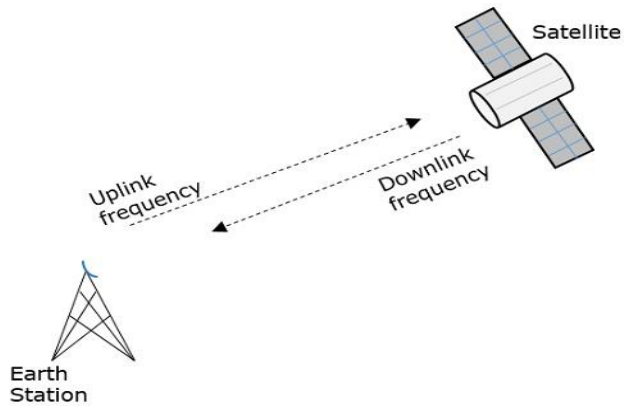


Fig 4.1 Communication between ground station and satellite

Communication between the satellite and ground station in "KRUSHISAT" is created by the transceiver module i.e., NRF24L01 module. It creates two-way communication and records the health conditions of satellite every second.

4.1.1 NRF24L01 MODULE:

It uses the 2.4 GHz band and it can operate with baud rates from 250 kbps up to 2 Mbps. If used in open space and with lower baud rate its range can reach up to 100 meters. 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 6 addresses, or each unit can communicate with up to 6 other units at the same time.

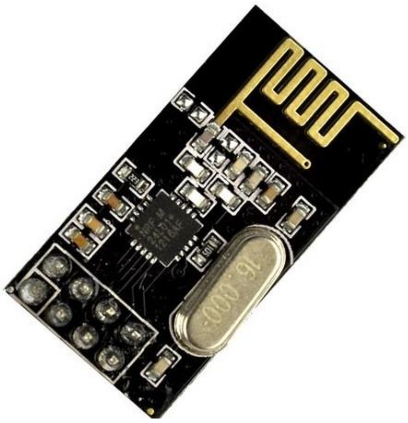


Fig 4.2 Transceiver Module

The power consumption of this module is just around 12mA during transmission, which is even lower than a single LED. The operating voltage of the module is from 1.9 to 3.6V, but the good thing is that the other pins tolerate 5V logic, so we can easily connect it to an Arduino without using any logic level converters.

4.1.2 DHT-22 SENSOR:

DHT22 capacitive humidity sensing digital temperature and humidity module is one that contains the compound has been calibrated digital signal output of the temperature and humidity sensors. Application of a dedicated digital modules collection technology and the temperature and humidity sensing technology, to ensure that the product has high reliability and excellent long-term stability. The sensor includes a capacitive sensor wet components and a high-precision temperature measurement device, and connected with a high-performance 8-bit microcontroller. The product has excellent quality, fast response, strong anti-jamming capability, and high cost. Standard single bus interface, system integration quick and easy. Small size, low power consumption, signal transmission distance up to 20 meters, making it the best choice of all kinds of applications and even the most demanding applications. DHT22 has higher precision and can replace the expensive imported SHT10 temperature and humidity sensor. It can measure the environment temperature and humidity to meet the high demand. The product has high reliability and good stability. If it's used and combined with special sensor Arduino expansion board, it will be easily implemented the interactive effect which related to the temperature and humidity perception.

Fig 4.3 DHT22 Sensor

- Low cost
- 3 to 5V power and I/O
- 2.5mA max current use during conversion (while requesting data)
- Good for 0-100% humidity readings with 2-5% accuracy
- Good for -40 to 80°C temperature readings ±0.5°C accuracy
- No more than 0.5 Hz sampling rate (once every 2 seconds)
- Body size 15.1mm x 25mm x 7.7mm
- 4 pins with 0.1" spacing

4.2 PAYLOADS:

Payloads involved in the satellite are as follows:

- Transmitting Point to point messaging.
- Determining Losses and other factors
- Monitoring Atmospheric Conditions Temperature, Humidity of the Low Earth Orbit.
- Flux Density of the Low Earth Orbit.

There are various factors and losses involved while transmitting and receiving the data. Those losses are recorded every second. Point to point messaging involves the lapse of time in which satellite is transmitting the data to ground station. Temperature and Humidity in the Low Earth orbit are also recorded. While revolving around the earth every time it reaches the ground station data is transmitted in the form signals. These signals are displayed in the digital form. These digital signals may contain the data of atmospheric conditions, flux density, health conditions etc. of the satellite. It depends upon the variation of the values of above mentioned parameters.

4.3 ARDUINO UNO BOARD:

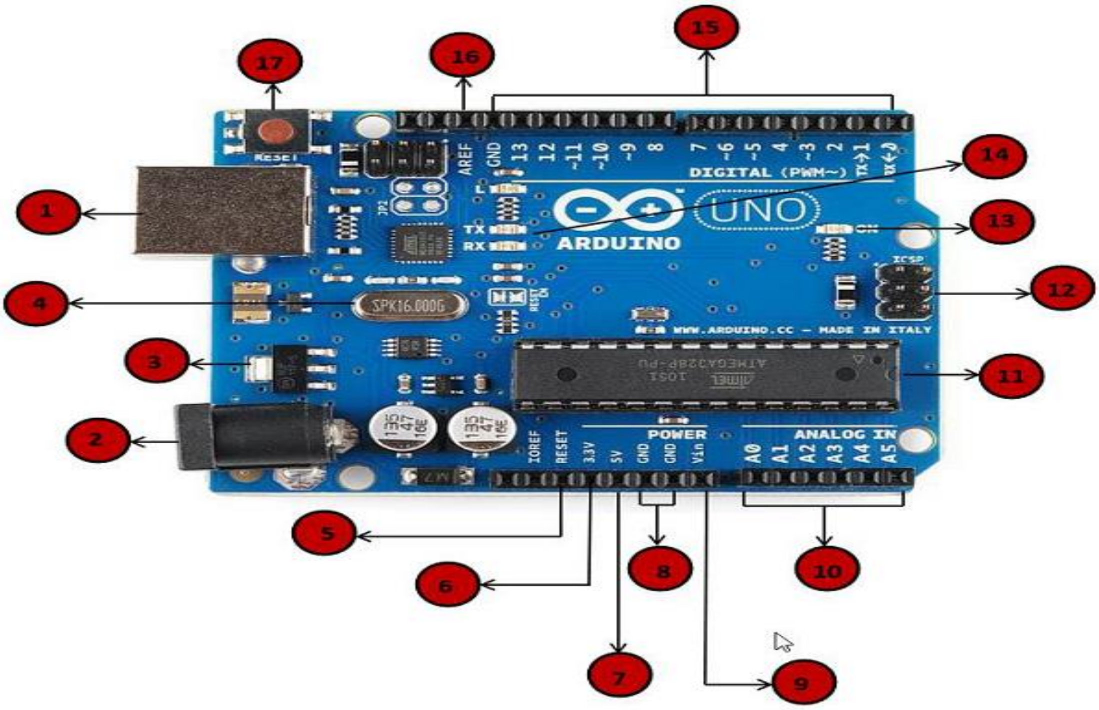


Fig 4.4 arduino uno with pin description

1	**Power USB** Arduino board can be powered by using the USB cable from your computer. All you need to do is connect the USB cable to the USB connection (1).
2	**Power (Barrel Jack)** Arduino boards can be powered directly from the AC mains power supply by connecting it to the Barrel Jack (2).
3	**Voltage Regulator**

	The function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.
4	**Crystal Oscillator** The crystal oscillator helps Arduino in dealing with time issues. How does Arduino calculate time? The answer is, by using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.
5,17	**Arduino Reset** You can reset your Arduino board, i.e., start your program from the beginning. You can reset the UNO board in two ways. First, by using the reset button (17) on the board. Second, you can connect an external reset button to the Arduino pin labelled RESET (5).
6,7 8,9	**Pins (3.3, 5, GND, Vin)** • 3.3V (6) − Supply 3.3 output volt • 5V (7) − Supply 5 output volt • Most of the components used with Arduino board works fine with 3.3 volt and 5 volts. • GND (8) (Ground) − There are several GND pins on the Arduino, any of which can be used to ground your circuit. • Vin (9) − This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.
10	**Analog pins** The Arduino UNO board has six analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity

	sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.
11	**Main microcontroller** Each Arduino board has its own microcontroller (11). You can assume it as the brain of your board. The main IC (integrated circuit) on the Arduino is slightly different from board to board. The microcontrollers are usually of the ATMEL Company. You must know what IC your board has before loading up a new program from the Arduino IDE. This information is available on the top of the IC. For more details about the IC construction and functions, you can refer to the data sheet.
12	**ICSP pin** Mostly, ICSP (12) is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an "expansion" of the output. Actually, you are slaving the output device to the master of the SPI bus.
13	**Power LED indicator** This LED should light up when you plug your Arduino into a power source to indicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.
14	**TX and RX LEDs** On your board, you will find two labels: TX (transmit) and RX (receive). They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led (13). The TX led flashes with different speed while sending the serial data. The speed of flashing

	depends on the baud rate used by the board. RX flashes during the receiving process.
15	**Digital I/O** The Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled “~” can be used to generate PWM.
16	**AREF** AREF stands for Analog Reference. It is sometimes, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

Table 4.1 Arduino UNO pins description

4.4 SOFTWARE PROGRAMMING:

Arduino programs are written in the Arduino Integrated Development Environment (IDE). Arduino IDE is a special software running on your system that allows you to write sketches (synonym for program in Arduino language) for different Arduino boards. The Arduino programming language is based on a very simple hardware programming language called processing, which is similar to the C language. C is a high-level and general-purpose programming language that is ideal for developing firmware or portable applications. C belongs to the structured, procedural paradigms of languages. It is proven, flexible and powerful and may be used for a variety of different applications. Although high level, C and assembly language share many of the same attributes. C provides constructs that map efficiently to typical machine instructions, and it has therefore found lasting use in applications that were previously coded in assembly language. Such applications include operating systems, as well as various application software for computers ranging from supercomputers to embedded systems. After the sketch is written in the Arduino IDE, it should be uploaded on the Arduino board for execution. The first step in programming the Arduino board is downloading and installing the Arduino IDE. The open source Arduino IDE runs on Windows, Mac OS X, and Linux. Download the Arduino software (depending on your OS). The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino compatible boards, but also, with the help of 3rd party cores, other vendor development boards. The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

4.5 BLOCK DIAGRAM:

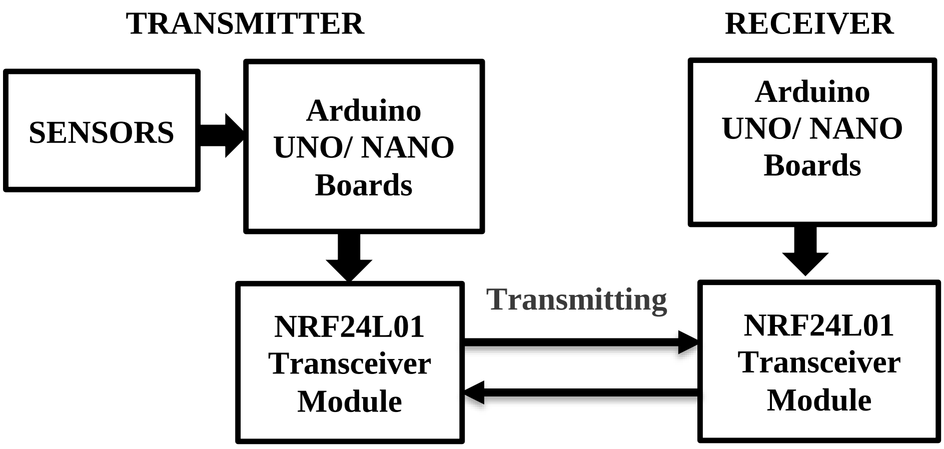


Fig 4.5 Block diagram representation of Communication System

First, the connections are made as per the circuit diagrams. Arduino Board is supplied with 5V from the power booster which is connected to the buck converter with output of 3.3V. Once the Arduino is supplied required code is dumped into the Arduino board and then transceiver module is also connected to the Arduino. Common data pin is given between the transceiver and the sensor so that communication path is created between both. Therefore, the data of the sensor will be transmitted through the transceiver module.

The connection for transceiver module on receiver side is same as that on transmitter side. Connections will be explained through the following diagram:

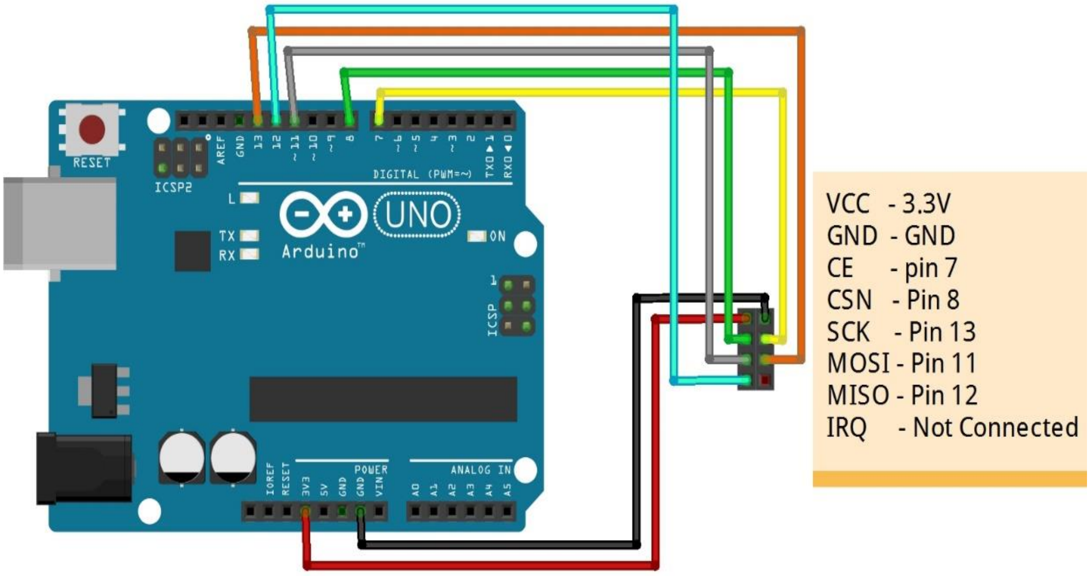


Fig 4.6 Connection of Arduino Uno/Nano with NRF24L01

Temperature and Humidity are the payloads of the system. These can be achieved by using DHT22 Sensor. DHT22 capacitive humidity sensing digital temperature and humidity module is one that contains the compound has been calibrated digital signal output of the temperature and humidity sensors. Application of a dedicated digital modules collection technology and the temperature and humidity sensing technology, to ensure that the product has high reliability and excellent long-term stability. The sensor includes a capacitive sensor wet components and a high-precision temperature measurement device, and connected with a high-performance 8-bit microcontroller. The product has excellent quality, fast response, strong anti-jamming capability, and high cost. Common Data Pin i.e., pin7 is taken in order to establish communication between the sensor and transceiver so that data will be updated every time and thus transmitted whenever the transmitter reaches the ground station. This transmission is only possible through antennas. Antennas enable satellites to transmit the data to more distances. Sensor Connection with Arduino board is as follows:

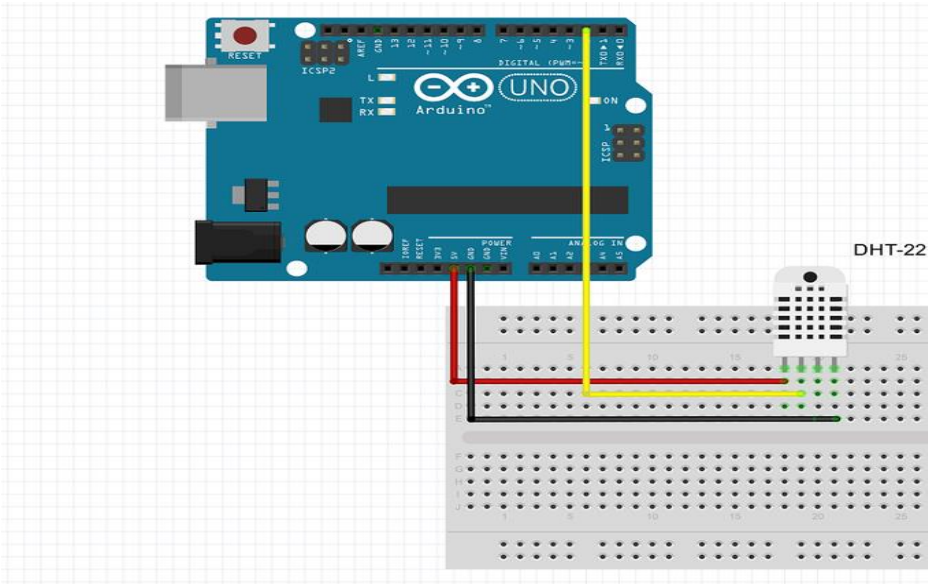


Fig 4.7 Arduino connection with DHT22 Sensor

4.6 ANTENNAS:

Modem small satellites need antennas for realizing different functions: 1.) telemetry, tracking, and command, which includes both uplink and downlink, at different frequencies; 2.) high-speed downlink for payload data, e.g., in Earth observation missions; 3.) GPS/GNSS receiver; and 4. inter-satellite cross links. These functions often require several different antennas. Typical coverages utilized for the antennas are from low-gain hemispherical, iso-flux, and fill-in to medium-gain antennas. The basic radiator designs used are normally helices, monopoles, patches, and patch-excited cups (PEC), depending on frequency range, coverage requirements, and application. Common for all helix designs is that they are lightweight designs, with broad coverage and low cross polarization. A major benefit of using quadrifilar-helix antennas (QHA) is that it is possible to shape the radiation pattern to obtain the desired coverage.

Depending on the coverage and bandwidth requirements, they are conical, or resonant, or something in between. Helices can be realized in different ways: self-supporting metallic wires, machined out of one metallic piece, metallic tubes or wires using dielectric supports, or etched on dielectric cones or tubes.

CHAPTER-5
ANTENNA DEPLOYMENT

5.1 INTRODUCTION

Generally, frequency range for Nano-satellites lies in VHF band. Therefore, the antenna length will lie in range of 10 - 150 cm (varies with frequency). In vibration, higher is the mass farther from the base (source of vibration), lesser is the natural frequency of the satellite. This means that if antennae are not deployable, but rather fixed the satellite body, then they are more vulnerable to damage due to resonance during launch, since the fundamental frequency will approach the lower limit imposed by the launch vehicle. This imposes the requirement of antenna deployment so as to keep mass closer to the base (source). Also if we keep antenna un-deployed then we have to increase its mass to increase stiffness. It can affect the mass budget constraint. Another major reason is that it covers larger space on launch vehicle. Side panel length is major determinant of antenna deployment. If the antenna length is larger than the side length, then we have roll or wind up the antenna. If power is an issue, then antenna should be deployed in such way that the shadow on the solar panels should be minimized to maximize the power for charging. Deployment of antenna is usually done on different sides to avoid the collision or entangling of antennae while deployment. If all the antennas are to deploy on same side they should not be deployed in the same plane, else there can be collision of antennae.

The major challenge faced while operating at these frequencies is the design of the on-board communication. antennas. While designing antennas for the optimum performance, the sizes of the antennas become larger than the dimensions of the Nano-Satellite. Thus housing the on-board antennas on the satellite becomes a major concern. Typically, Linear Wire Antennas are used on-board Nano-Satellites due to their good performance and the ease of their housing. The antennas concerning this text are the Monopole and the Dipole antennas. These antennas are coiled into a stowed position and secured using a strong fiber. A heating element, generally a wire, is used to break the fiber and release the antennas from their stowed position into their deployed position. This heating element is activated only when the satellite is ejected from the deployed module into its specified orbit. The entire process of the antennas being deployed is very crucial in the functioning of Communication Subsystem, the failure of which would lead to the failure of the Communication Subsystem on a whole. Hence this process will have to be reliable, automated and also smart such that minimum on-board power is expended. The Antenna Deployment System was designed, prototyped and tested with this objective.

5.2 COMPONENTS USED:

1. Structure- Cube
2. Nichrome Wire
3. IRF540 Power MOSFET
4. Power Supply
5. Switch
6. Resistor

5.2.2 NICHROME WIRE:

Nichrome (NiCr, nickel-chromium etc.) is any of various alloys of nickel, chromium, and often iron (and possibly other elements). The most common usage is as resistance wire, although they are also used in some dental restorations (fillings) and in a few other applications. nichrome is the oldest documented form of resistance heating alloy. A common nichrome alloy is 80% nickel and 20% chromium, by mass, but there are many other combinations of metals for various applications. Nichrome is consistently silvery-grey in color, is corrosion-resistant, and has a high melting point of about 1,400 °C (2,550 °F). Because of its low cost of manufacture, strength, ductility, resistance to oxidation, stability at high temperatures, and resistance to the flow of electrons, nichrome is widely used in electric heating elements in applications such as hair dryers and heat guns. Typically, nichrome is wound in coils to a certain electrical resistance, and when current is passed through it the Joule heating produces heat.

Fig 5.1 Nichrome wire

PROPERTIES:

Nichrome alloys are known for their high mechanical strength and their high creep strength. The properties of nichrome vary depending on its alloy. Figures given are representative of typical material and are accurate to expressed significant figures. Any variations are due to different percentages of nickel or chromium.

Material property	Value	Unit
Modulus of elasticity	2.2×10^{11}	Pa
Density	8400	$kg \cdot m^{-3}$
Melting point	1400	°C
Electrical resistivity at room temperature	$(1.0–1.5) \times 10^{-6}$	$\Omega \cdot m$
Specific heat	450	$J \cdot kg^{-1} \cdot K^{-1}$
Thermal conductivity	11.3	$W \cdot m^{-1} \cdot K^{-1}$
Thermal expansion	14×10^{-6}	K^{-1}

Table 5.1 properties of nichrome wire

USES:

Almost any conductive wire can be used for heating, but most metals conduct electricity with great efficiency, requiring them to be formed into very thin and delicate wires in order to create enough resistance to generate heat. When heated in air, most metals then oxidize quickly, become brittle, and break. Nichrome wire, however, when heated to red-hot temperatures, develops an outer layer of chromium oxide, which is thermodynamically stable in air, is mostly impervious to oxygen, and protects the heating element from further oxidation.

- Nichrome is used in the explosives and fireworks industry as a bridge wire in electric ignition systems, such as electric matches and model rocket igniters.
- Industrial and hobby hot-wire foam cutters use nichrome wire.
- Nichrome wire is commonly used in ceramic as an internal support structure to help some elements of clay sculptures hold their shape while they are still soft. Nichrome wire is used for its ability to withstand the high temperatures that occur when clay work is fired in a kiln.
- Nichrome wire can be used as an alternative to platinum wire for flame testing by coloring the non-luminous part of a flame to detect cations such as sodium, potassium, copper, calcium, etc.
- Other areas of usage include motorcycle mufflers, in certain areas in the microbiological lab apparatus, as the heating element of plastic extruders by the RepRap 3D printing community, in the solar panel deployment mechanism of spacecraft Light-Sail-A, and as the heating coils of electronic cigarettes.

5.2.3 IRF540 POWER MOSFET:

IRF540 is basically an N-Channel Power Metal Oxide Silicon Field Effect Transistor (MOSFET) and operates in enhancement mode. MOSFET is a lot sensitive in comparison to an FET (Field Effect Transistor) due to its very high input impedance. IRF540 can perform very fast switching as compared to the normal transistor. It is based on HEXFET technology and operates on the temperature ranging from -55 degrees Celsius to 175 degrees Celsius. If we need some switching application between different signals or to perform any of amplification process, MOSFET IRF540 will be the best option in this case because it can perform very fast switching as compared to the similar general transistors. It has a very wide range of applications in real life e.g. high power switching drivers for high speed, switching regulators, relay drivers, switching converters, motor drivers. IRF540 is an N-Channel powered MOSFET used for very fast switching operations as well as for amplification processes. It operates in enhancement mode. Its input impedance is quite high as compared to the general transistor so, it's a lot sensitive in comparison to them. It has a lot of applications in daily life for example, switching regulators, relay drivers, switching converters, motor drivers, high speed power switching drivers etc. You should also have a look at other MOSFETs and can compare their values with IRF540. IRF540 Power Mosfet schematic with pin description is as follows:

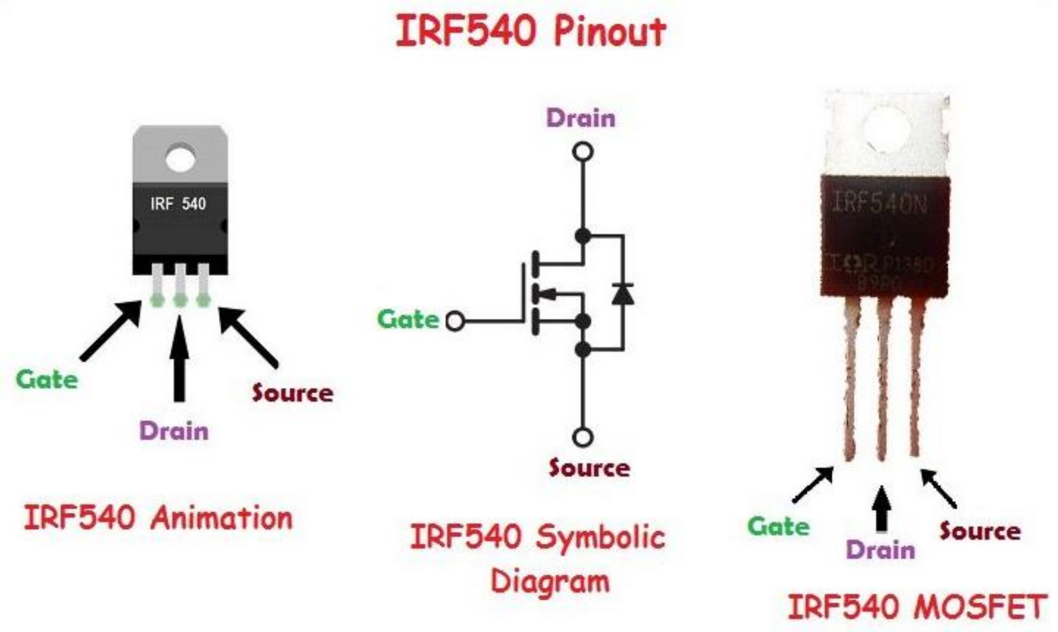


fig 5.2 IRF540 pin description

IRF540 Pinout:

- IRF 540 has three pins in total named as:
    1. Drain
    2. Gate
    3. Source
- So, when we apply signal at the Gate of IRF540, then its Drain and Source got connected.
- All of the IRF540 pins along with their names and symbol are given in the table shown below.

IRF540 Pinout				
Pin#	**Name**	**Symbol**	**Type**	**Function**

IRF540 Pinout				
1	Gate	G	P-Type	Controls the current between Drain & Source
2	Drain	D	N-Type	Electrons Emitter
3	Source	S	N-Type	Electrons Collector

Table 5.2 IRF540 pin description

5.3 DEPLOYMENT MECHANISMS:

There are several deployment mechanisms. The choice of the mechanism majorly depends on the antenna requirement and its implementation. Some mechanisms are better than the others for student satellites. We'll discuss one popular mechanism here

Burn Wire Release Mechanism:

It can be implemented in many ways. Mostly burn wire mechanism is used in case of Nano satellite because it is compact and more reliable and contains less number of moving parts.

The Mechanism:

Wind or roll flexible tape antenna around a rail and use nichrome wire to burn the dyneema wire (retention wire), this dyneema wire is the link between antenna and the nichrome. And when nichrome heats up the dyneema wire melts and the antenna deploys.

Design Takeaways:

- Burning of the securing thread for all antennas by a single burner is preferred in the interests of power and space.
- A modular system that can be integrated easily on the satellite without disturbing the internal framework is preferred.
- The antennas can be positioned at the top and the bottom of the satellite to incorporate the maximum number of antennas on one side without disturbing other side panel arrangements.

- A retention film can be used for stowing of antenna which is tied with Dyneema wire and goes to the burner circuit. This film is important because if we use only nylon wire then there is possibility of slippage of wire due to vibration.
- There should be a proper interface between the dyneema wire and the resistor. Also, the heating element shouldn't be in stress condition.
- The resistor should be properly insulated from the metallic body.
- Heating element can be covered with some thermal insulator with only some part of heating element kept open to environment on which retention wire is tied.
- Nuts and bolts used for attaching antenna should be taken into account when designing and analyzing the deployment mechanism.

5.4 CIRCUIT:

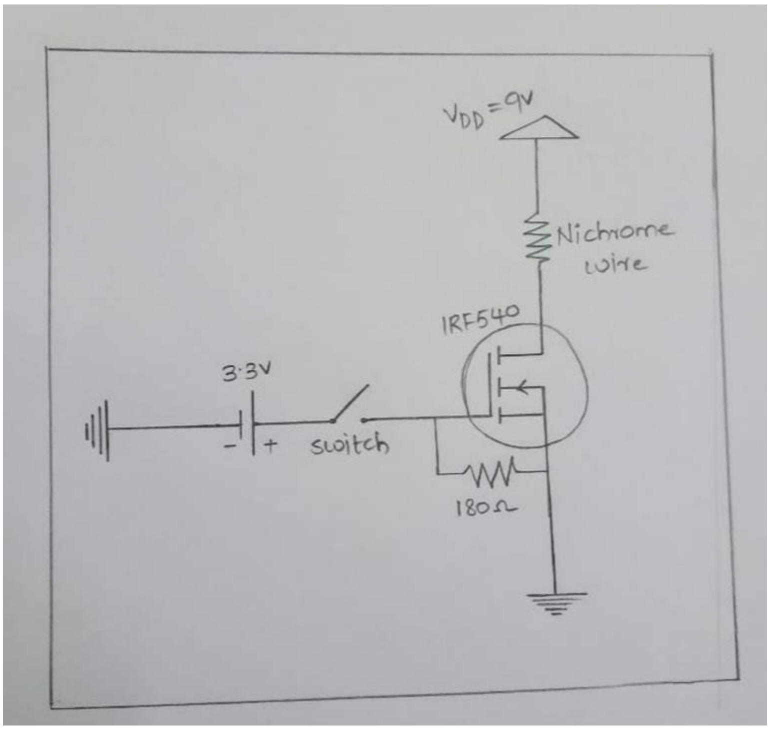


Fig 5.3 Circuit Diagram for antenna deployment

5.4.1 OPERATION:

As soon as the supply is "ON", the Switch is closed and the current flows through the nichrome wire. Nichrome is a non-magnetic alloy of nickel and chromium. Nichrome is widely used in heating elements. It is wound in wire coils to a certain electrical resistance, and current passed through to produce heat. As soon as the high current passes through the Nichrome wire it burns and frees the antenna. Thus, the antenna will be deployed.

CHAPTER-6
SYSTEM TOOL KIT

6.1 INTRODUCTION:

STK is a physics-based modeling, simulation and analysis tool with an integrated 4D (X, Y, Z, Time) interactive globe. **Systems Tool Kit** (formerly **Satellite Tool Kit**), often referred to by its initials **STK**, is a physics-based software package from Analytical Graphics, Inc. that allows engineers and scientists to perform complex analyses of ground, sea, air, and space assets, and share results in one integrated solution. At the core of STK is a geometry engine for determining the time-dynamic position and attitude of objects ("assets"), and the spatial relationships among the objects under consideration including their relationships or accesses given a number of complex, simultaneous constraining conditions. STK has been developed since 1989 as a commercial off the shelf software tool. Originally created to solve problems involving Earth-orbiting satellites, it is now used in the aerospace and communities and for many other applications.

The STK interface is a standard GUI display with customizable toolbars and dockable maps and 3D viewports. All analysis can be done through mouse and keyboard interaction. In addition, there is a scripting interface named Connect that enables STK to act within a client/server environment (via TCP/IP) and is language independent. Users on Windows have the option of using STK programmatically via OLE automation. Each analysis or design space within STK is called a scenario. Within each scenario any number of satellites, aircraft, targets, ships, communications systems or other objects can be created. Each scenario defines the default temporal limits to the child objects, as well as the base unit selection and properties. All of these properties can be overridden for each child object individually, as necessary. Only one scenario may exist at any one time, although data can be exported and reused in subsequent analyses. For each object within a scenario, various reports and graphics (both static and dynamic) may be created. Relative parameters, between one object and another can also be reported and the effect of real-world restrictions (constraints) enabled so that more accurate reporting is obtained. Through the use of the constellation and chains objects, multiple child objects may be grouped together and the multipath interactions between them investigated. STK can be embedded within another application (as an ActiveX component) or controlled from an external application (through TCP/IP or Component Object Model (COM)).

Both integration techniques can make use of the connect scripting language to accomplish this task. There is also an object model for more "programmer oriented" integration methodologies. STK can be driven from a script that is run from the STK internal web browser in the free version of the tool. To control STK from an external source, or embed STK in another application requires the STK/Integration module.

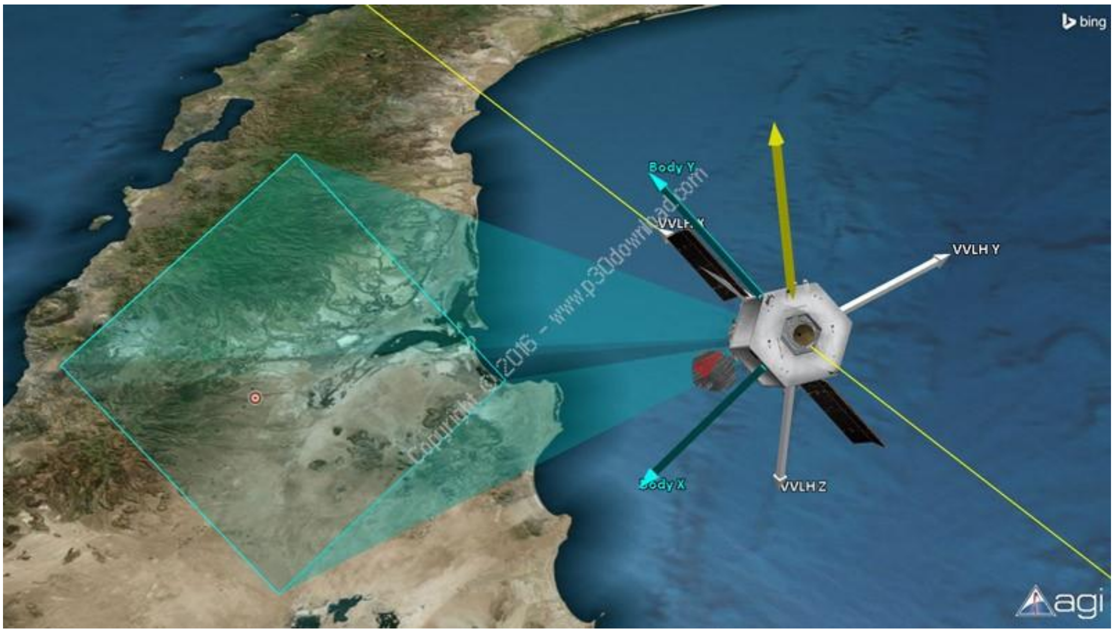


Fig 6.1 Showing the real-time environment of the satellite in STK

This software provides the real time environment of the satellite as it has a 3D view. Satellite provides the data regarding all the losses and factors related to satellite.

ADVANTAGES:

- Model with an accurate Earth representation in time and space.
- Support cloud and server-based architectures with flexible development kits and components.
- Add streaming imagery and terrain, or any kind of map and GIS data.
- Define realistic and accurate, idealistic, or user-ingested dynamic vehicles.
- Add vehicle orientation, pointing, and sensor fields of view.

- Report or define new points, vectors, angles, axes and coordinate systems.
- Run in real time or simulate in past or future time.
- Analyze complex physical relationships between all the vehicles, sensors and environment.
- Report, graph or export the results.
- Visualize the scenario in any way imaginable in a 3D environment.
- Create videos, custom views or images to clearly convey results.
- Integrate, customize or extend capability with the open API and file formats.

6.2 Losses in Satellite Communication:

Free Space Path Losses: In telecommunication, the **free-space path loss** (**FSPL**) is the attenuation of radio energy between the feed points of two antennas that results from the combination of the receiving antenna's capture area plus the obstacle free, line-of-sight path through free space (usually air).[1] The "Standard Definitions of Terms for Antennas", IEEE Std 145-1993, defines "free-space loss" as "The loss between two isotropic radiators in free space, expressed as a power ratio."[2] Despite this name and definition, the FSPL includes a receiving antenna aperture component in the total attenuation.[1] It does not include any path loss associated with hardware imperfections, or the effects of any antenna gains. A discussion of these losses may be found in the article on link budget. The FSPL is rarely used standalone, but rather as a part of the Friis transmission formula, which includes the gain of antennas.

Atmos Losses:

Losses occur in earth’s atmosphere because of the energy absorption by the atmospheric gases. These losses are quite different from those which results from adverse weather condition and are known as atmospheric losses. To distinguish between these, the weather related losses are known as atmospheric attenuation and the atmospheric losses are known as atmospheric absorption.

Attenuation occur at sufficient high frequencies and the interaction of electromagnetic waves with molecules of atmospheric gases, occur at resonance frequencies, and are apparent in plots of zenith (90-degree elevation angle).

Attenuation due to Precipitation and Clouds:

The strength of satellite signal may be degraded or reduced under rain conditions; in particular radio waves above 10 GHz are subject to attenuation by molecular absorption and rain. Presence of rain drops can severely degrade the reliability and performance of communication links. Attenuation due to rain effect is a function of various parameters including elevation angle, carrier frequency, height of earth station, latitude of earth station and rain fall rate. The primary parameters, however, are drop-size distribution and the number of drops that are present in the volume shared by the wave with the rain. It is important to note that, attenuation is determined not by how much rain has fallen but the rate at which it is falling.

Rain Attenuation:

This is the most important attenuation factor at frequencies above 10 GHz. The rain drops absorb and scattered energy. Rain drops are also heated by the radiation leading to an increase of the sky temperature. The amount of attenuation depends on the number of drops, the size and shape of the drops. For example, heavier rain tends to compromise larger droplets and then larger attenuation. Other important parameters are the frequency, antenna elevation, the rain height, rain type (strati-form or convective). Attenuation is the decibel difference between the power received P_r, at a given time t and the received power under ideal propagation condition (referred to as "clear sky" conditions). With all values in dB \, we have -

$$A(t) = P_{r(clear\ sky)} - P_r(t)$$

Attenuation, A(t) on satellite communication links operating at C, Ku, Ka-bands is primarily caused by absorption of the signal in rain. On most satellite links above 10 GHz rain attenuation limits the availability of the system and to develop an adequate link margin, the rain attenuation to be expected for a given time percentage needs to be calculated. This can be a complicated process, but there basically three steps –

a) Determine the rainfall rate for the time percentage of interest.
b) Calculate the specific attenuation of the signal at this rainfall rate in dB/km.
c) Find the effective length of the path over which this specific attenuation applies.

The difficult part of this process is part (c), because rainfall is to type:

1. Strati-form Rain

2. Convective Rain

Strati-form rain is generated in cloud layers containing ice and results in widespread rain or snow at rainfall rates of less than 10 mm/hour. Convective rain is generated by vertical air currents that can be very powerful, leading to thunder storms and high rainfall rate. Convective rainfall is very important for satellite communication system, because it is the major cause of link outages. Strati-form rain consists of a generally constant rainfall rate over a very large area, while convective rain is generally confined to a narrow, but tall column of rain.

Snow, Cloud and Fog attenuation:

They will also attenuate and scatter microwaves signals but not as much as rain. The attenuation magnitude of this factors depends on the cloud, fog or snow layer thickness, what kind of content and distribution these layers have (aerosol, ice particles), frequency and on the antenna elevation, too.

Tropospheric Scintillation:

At elevation angle below than 5 °, the tropospheric portion of the propagation path is so long that turbulence may cause rapid variations of amplitude and phase, and is known as atmospheric scintillation. This is fading phenomena and fading period is several tens as seconds. It is caused by the differences in the atmospheric refractive index, which in turn results in focusing and defocusing of the radio waves and follows different ray paths through the atmosphere. Simultaneously waves may arrive at the receiving antenna via several propagation paths and by integrating each other. It gives rise to multipath fading and known as frequency selective fading. For this reason, commercial links try to avoid low elevation angles.

CHAPTER-7

RESULTS AND DISCUSSION

7.1 POWER SYSTEM SIMULATION RESULTS:

7.1.1 Boost Converter Results:

A Boost Converter is a DC-DC conversion circuit where in the voltage is Stepped-up from one level to the other. Anyways, the output voltage is always greater than that of Input voltage. Variation in the output voltage depends upon the load applied at the output terminals. If the load is varied the current at the inductor also varies. Here, the simulation results are shown for boost converter which steps up the voltage from 5V to (9-12) V in order to provide the supply for antenna deployment system and other subsystems.

GRAPH:

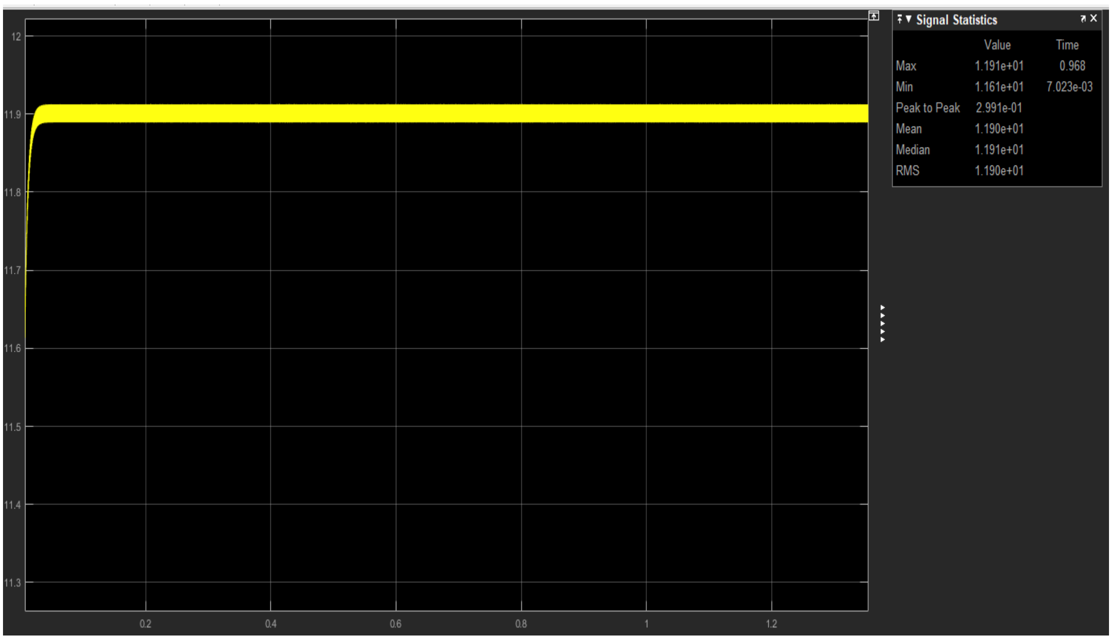


Fig 7.1 boost converter (V vs T) graph

Above graph indications the variation of voltage with time i.e., (V versus T). Some fluctuations are seen due to the ripple current (ΔI). Use of filters can reduce these ripples. The Circuit for this particular graph is already explained in the power system design of the project i.e., in Chapter-3. Output is obtained by using the values obtained in theoretical calculations of the Boost Converter. In this simulation efficiency is considered to be 100%, frequency is considered as 25kHZ, power is considered as 100W. Thus, values of inductor, capacitor, resistor can be determined.

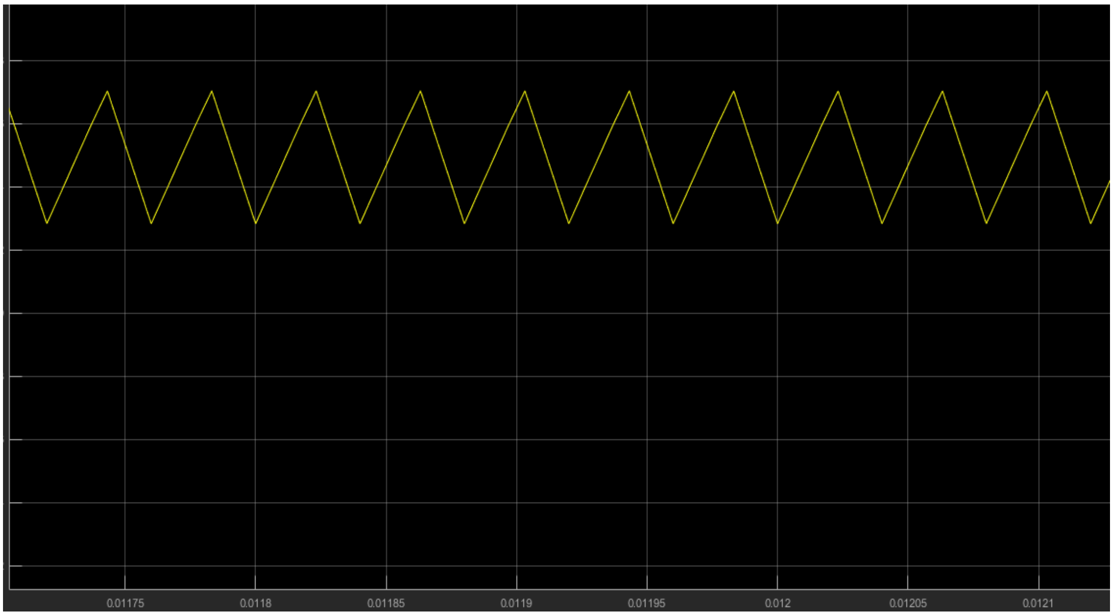


Fig 7.2 Current Vs Time graph

This indicates the change of current with time. Above graph shows the ripple current at the inductor. Ripple current is indicated by ΔI. This ripple current varies between 20 to 40% of the current across the load i.e., I_L.

7.1.2 BUCK CONVERTER SIMULATION RESULTS:

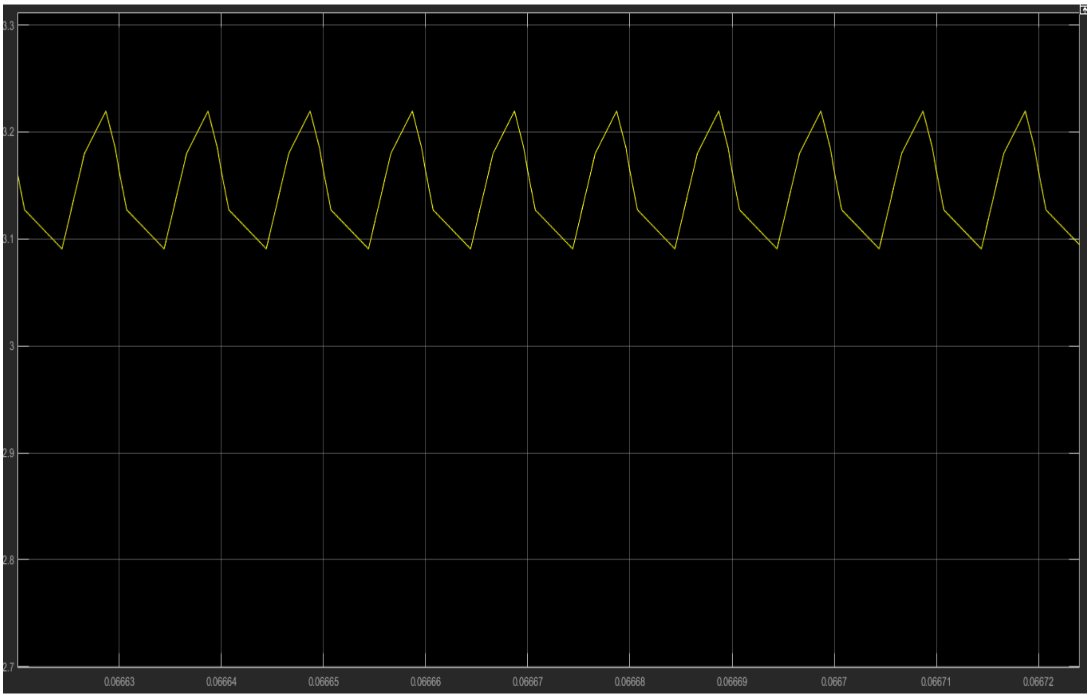


Fig 7.3 Voltage Vs time graph

Above graph indications the variation of voltage with time i.e., (V versus T). Some fluctuations are seen due to the capacitor i.e., ripple voltage (ΔV). Use of filters can reduce these ripples. This Ripple voltage varies between 1% to 5% of output voltage.

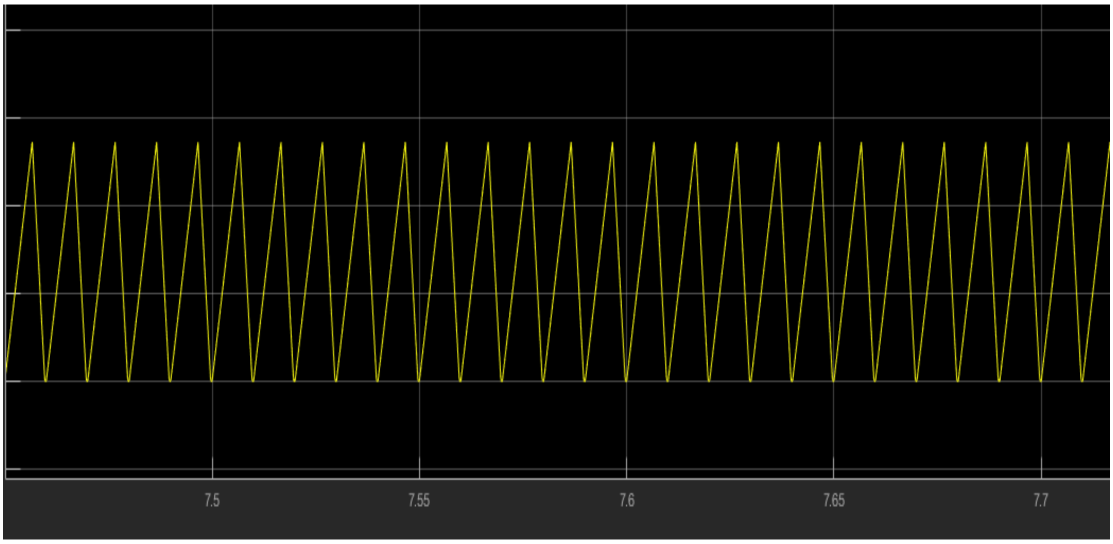


Fig 7.4 current vs time graph

This indicates the change of current with time. Lot of fluctuations are seen due to the energy stored by the inductor. In Buck converter Source current is equal to load current. As considerably the voltages from the hardware of the EPS matches exactly with the theoretical values of the system.

7.2 SATELLITE SIMULATION RESULTS:

The Satellite object models the properties and behavior of a vehicle in orbit around a central body. Select one or more of the following to model a satellite, impose constraints, and define the satellite's sub objects.

ORBIT: Define a satellite's orbit, including coordinate system, orbital elements and time parameters

ATTITUDE: Define an attitude profile for the satellite.

PASS BREAK: Specify the event that defines the boundary between passes (or revolutions) of an orbiting satellite.

ENVIRONMENTAL ASPECTS: SEET property pages allow values to be entered that affect calculations involving the space environment as modeled by the STK Space Environment and Effects Tool:

- Environment. Set parameters that affect the magnetic field model, and the entrance and exit times and probable fluxes due to a vehicle crossing the South

Atlantic Anomaly (SAA), a region of space with an enhanced concentration of ionizing radiation.

- Thermal. Set material properties and average Earth albedo that affect the determination of vehicle temperature exposed to direct solar and reflected Earth radiation.
- Particle Flux. Set parameters that affect the determination of the level of (damaging) exposure due to meteoroids and debris particles.
- Radiation. Set parameters that affect the expected ionizing dose rate and energetic particle fluxes due to the trapped electron and proton populations, as well as integrated total dose and fluency (flux integrated over time). Radiation computations are also affected by scenario-level settings.

TIME EVENTS: Display text, a marker, or a line to indicate an event that occurs at a particular time on the satellite's ground track.

This simulation includes of modelling a satellite around the earth with the considerable constraints. The sub objects added to the main frame of the simulation are:

SENSORS: The Sensor object models the field of view and other properties of a sensing device attached to another STK object. Select one or more to model a Sensor and impose constraint.

RECEIVER: The Receiver object models the characteristics of a receiver, the antenna it uses and the environment in which it operates.

TRANSMITTER: The Transmitter object models the characteristics of the transmitter, the antenna it uses and the environment in which it operates.

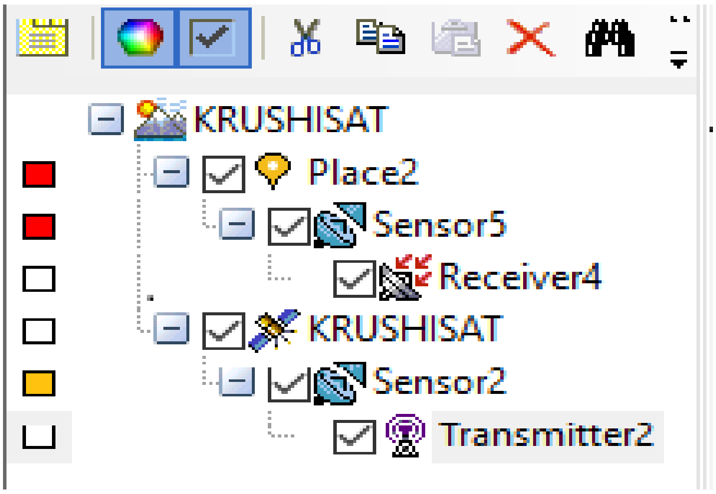


Fig 7.5 Sensors and Respective Components

OVER VIEW OF THE SATELLITE:

After adding the components to the scenario, the satellite objects points towards the earth surface covering over a range of 3kms along the earth orbit. The place from the earth station.

The transmission starts when the satellite enters into the earth coverage area.

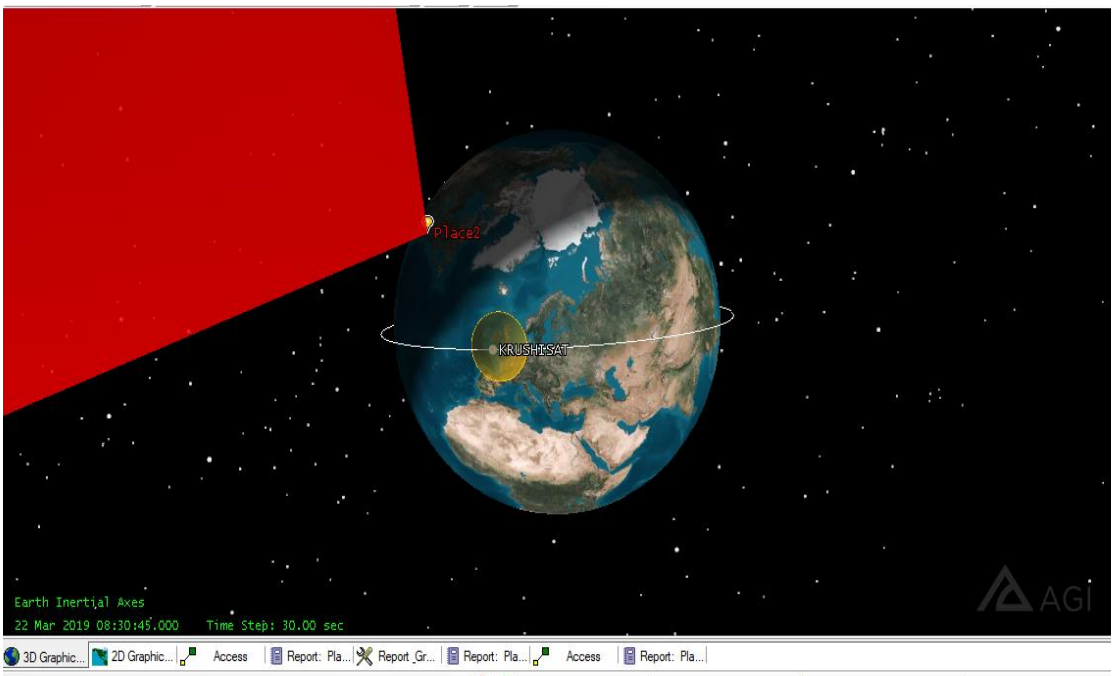


Fig 7.6 Krushisat location in the orbit in STK

The simulation results are from a particular time to time analysis and are recorded accordingly including all the factors of the satellite data.

The point to point messaging from the satellite to ground station over a coverage area is recorded as follows:

The magnetic line of force passing through the satellite and stabilizing it in the space without any external power being consumed by the thrusters and other stabilizing systems. The Magnetic rod suspended in the satellite aligns its magnetic field as per the earth's magnetic field. It aligns itself in the direction of Earth's magnetic field. So, that antennas always point towards the ground station and thus transmit the data i.e., healthy communication is carried out. Mainly, this attitude determination in satellites is introduced in order to stabilize the satellite. Because, when the satellite is suspended in Low earth orbit or in any orbit in the space satellite rotates in all directions there is no specific direction and stability. The satellite aligns its magnetic axis with respect to the magnetic lines of Earth. So that, continuous data transmission is enabled.

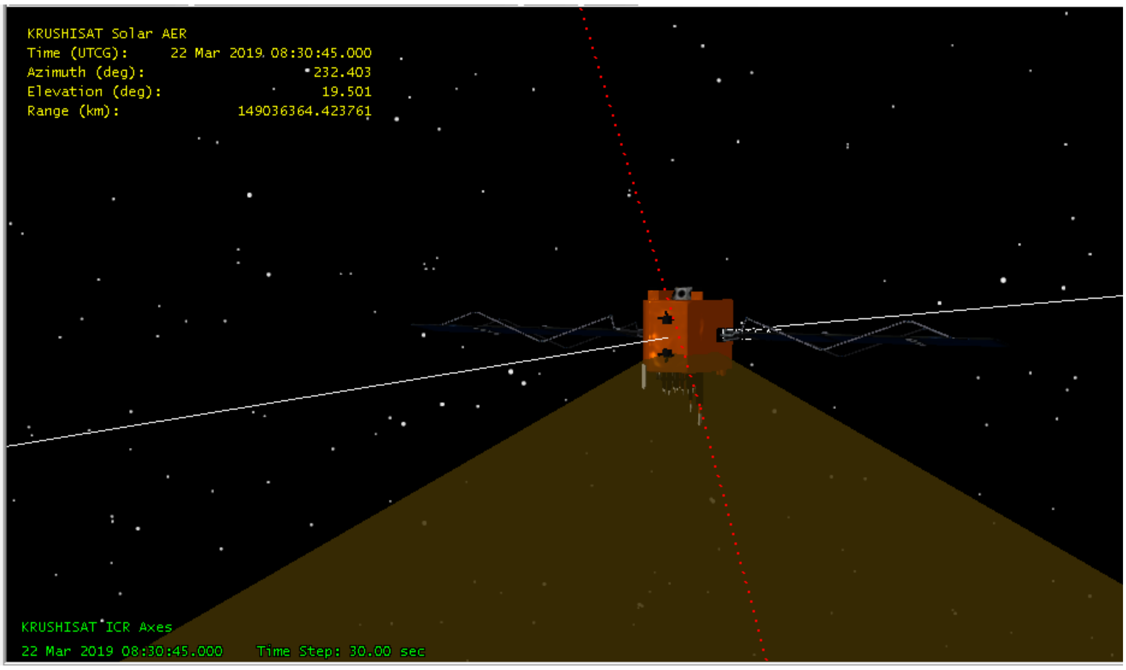
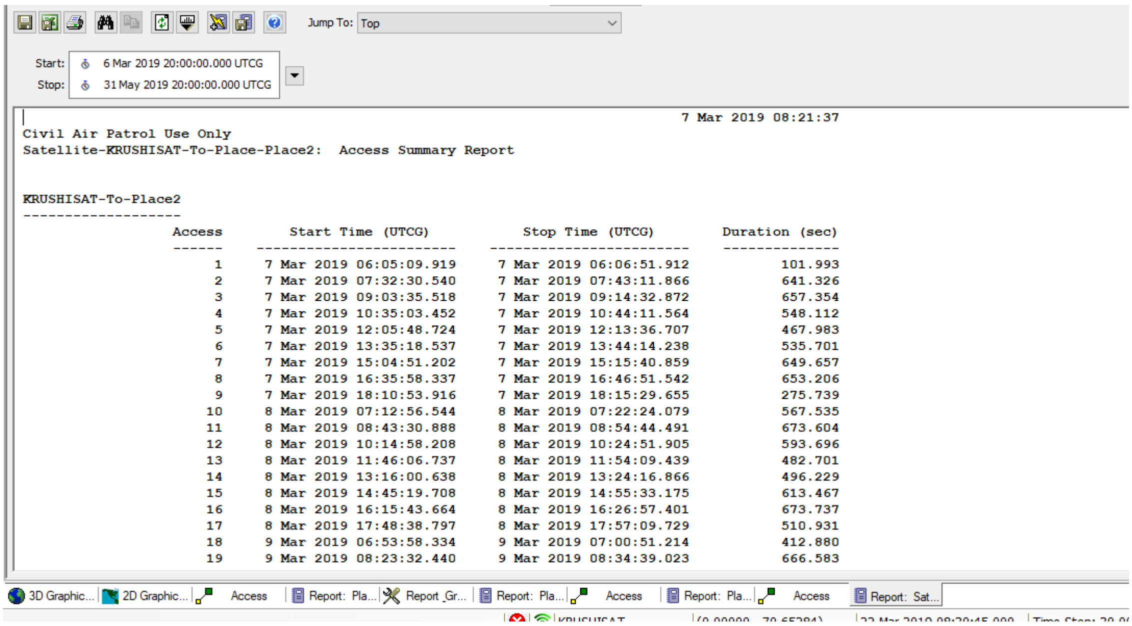


Fig 7.7 displaying the lines of magnetic lines passing through the satellite

It displays the satellite data when the coverage has started and stopped when entering and leaving the zone of coverage. It also displays the time and the duration of the satellite in the region.


Jump To: Top
Start: 6 Mar 2019 20:00:00.000 UTCG
Stop: 31 May 2019 20:00:00.000 UTCG

7 Mar 2019 08:21:37
Civil Air Patrol Use Only
Satellite-KRUSHISAT-To-Place-Place2: Access Summary Report

KRUSHISAT-To-Place2

Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
1	7 Mar 2019 06:05:09.919	7 Mar 2019 06:06:51.912	101.993
2	7 Mar 2019 07:32:30.540	7 Mar 2019 07:43:11.866	641.326
3	7 Mar 2019 09:03:35.518	7 Mar 2019 09:14:32.872	657.354
4	7 Mar 2019 10:35:03.452	7 Mar 2019 10:44:11.564	548.112
5	7 Mar 2019 12:05:48.724	7 Mar 2019 12:13:36.707	467.983
6	7 Mar 2019 13:35:18.537	7 Mar 2019 13:44:14.238	535.701
7	7 Mar 2019 15:04:51.202	7 Mar 2019 15:15:40.859	649.657
8	7 Mar 2019 16:35:58.337	7 Mar 2019 16:46:51.542	653.206
9	7 Mar 2019 18:10:53.916	7 Mar 2019 18:15:29.655	275.739
10	8 Mar 2019 07:12:56.544	8 Mar 2019 07:22:24.079	567.535
11	8 Mar 2019 08:43:30.888	8 Mar 2019 08:54:44.491	673.604
12	8 Mar 2019 10:14:58.208	8 Mar 2019 10:24:51.905	593.696
13	8 Mar 2019 11:46:06.737	8 Mar 2019 11:54:09.439	482.701
14	8 Mar 2019 13:16:00.638	8 Mar 2019 13:24:16.866	496.229
15	8 Mar 2019 14:45:19.708	8 Mar 2019 14:55:33.175	613.467
16	8 Mar 2019 16:15:43.664	8 Mar 2019 16:26:57.401	673.737
17	8 Mar 2019 17:48:38.797	8 Mar 2019 17:57:09.729	510.931
18	9 Mar 2019 06:53:58.334	9 Mar 2019 07:00:51.214	412.880
19	9 Mar 2019 08:23:32.440	9 Mar 2019 08:34:39.023	666.583

Fig 7.8 result of point to point messaging

Satellite data: This data consists of the parameters of the satellite transmitted from the satellite to the ground station. It contains the health factors of the satellite and also the power consumed, gain, different types of losses, rain loss information, transmission range, receiving range, Doppler shift, and mainly the flux density of the low earth orbit. This flux density of the low earth orbit helps us to find out the concentration of the magnetic field around the earth orbit

Civil Air Patrol Use Only
Satellite-KRUSHISAT-Sensor-Sensor2-Transmitter-Transmitter2-To-Place-Place2-Sensor-Sensor5-Receiver-Receiver4: Link Budget - Short Form

Time (UTCG)	Xmtr Power (dBW)	Xmtr Gain (dB)	EIRP (dBW)	Free Space Loss (dB)	Atmos Loss (dB)	Rain Loss (dB)
11 Mar 2019 16:52:27.997	30.000	45.2399	75.240	154.1818	0.0346	0.0031
11 Mar 2019 16:53:27.000	30.000	13.2077	43.208	156.6782	0.0475	0.0042
11 Mar 2019 16:54:27.000	30.000	24.5800	54.580	160.3676	0.0803	0.0071
11 Mar 2019 16:55:27.000	30.000	8.6373	38.637	163.2791	0.1362	0.0121
11 Mar 2019 16:56:27.000	30.000	20.4204	50.420	165.5369	0.2505	0.0232
11 Mar 2019 16:57:27.000	30.000	20.8051	50.805	167.3509	0.6342	0.0690
11 Mar 2019 16:58:07.127	30.000	20.7699	50.770	168.3857	1.9159	0.3392

Time (UTCG)	Xmtr Power (dBW)	Xmtr Gain (dB)	EIRP (dBW)	Free Space Loss (dB)	Atmos Loss (dB)	Rain Loss (dB)
14 Mar 2019 17:28:04.712	30.000	20.7942	50.794	166.4465	0.3639	0.0352
14 Mar 2019 17:29:04.000	30.000	20.7728	50.773	168.0810	1.3007	0.1814
14 Mar 2019 17:29:16.269	30.000	20.7699	50.770	168.3845	1.9098	0.3404

Time (UTCG)	Xmtr Power (dBW)	Xmtr Gain (dB)	EIRP (dBW)	Free Space Loss (dB)	Atmos Loss (dB)	Rain Loss (dB)
22 Mar 2019 19:17:06.839	30.000	45.0690	75.069	154.1951	0.0347	0.0031
22 Mar 2019 19:18:06.000	30.000	10.8081	40.808	156.6965	0.0476	0.0042
22 Mar 2019 19:19:06.000	30.000	24.5994	54.599	160.3806	0.0805	0.0071
22 Mar 2019 19:20:06.000	30.000	8.8437	38.844	163.2887	0.1364	0.0122
22 Mar 2019 19:21:06.000	30.000	20.4265	50.427	165.5446	0.2512	0.0232
22 Mar 2019 19:22:06.000	30.000	20.8048	50.805	167.3572	0.6372	0.0694
22 Mar 2019 19:22:45.901	30.000	20.7699	50.770	168.3860	1.9159	0.3393

Prop Loss (dB)	Freq. Doppler Shift (kHz)	Rcvd. Frequency (GHz)	Rcvd. Iso. Power (dBW)	Flux Density (dBW/m^2)	Rcvr Gain (dB)	Tatmos (K)
154.2196	-0.013610	2.400000	-78.980	-49.919797		0.000
156.7299	-40.201169	2.399960	-113.522	-84.462351		0.000
160.4549	-52.882392	2.399947	-105.875	-76.815076		0.000
163.4274	-56.655637	2.399943	-124.790	-95.730227		0.000
165.8107	-57.998078	2.399942	-115.390	-86.330357		0.000
168.0541	-58.454095	2.399942	-117.249	-88.189036		0.000
170.6408	-58.512452	2.399941	-119.871	-90.810952		0.000

Prop Loss (dB)	Freq. Doppler Shift (kHz)	Rcvd. Frequency (GHz)	Rcvd. Iso. Power (dBW)	Flux Density (dBW/m^2)	Rcvr Gain (dB)	Tatmos (K)
166.8457	-58.211155	2.399942	-116.051	-86.991570		0.000
169.5631	-58.477169	2.399942	-118.790	-89.730325		0.000
170.6348	-58.486136	2.399942	-119.865	-90.804963		0.000

Prop Loss (dB)	Freq. Doppler Shift (kHz)	Rcvd. Frequency (GHz)	Rcvd. Iso. Power (dBW)	Flux Density (dBW/m^2)	Rcvr Gain (dB)	Tatmos (K)
154.2329	-0.013590	2.400000	-79.164	-50.104003		0.000
156.7484	-40.236385	2.399960	-115.940	-86.880408		0.000
160.4682	-52.889658	2.399947	-105.869	-76.808861		0.000
163.4373	-56.660888	2.399943	-124.594	-95.533704		0.000
165.8190	-58.004129	2.399942	-115.392	-86.332559		0.000
168.0638	-58.461008	2.399942	-117.259	-88.199100		0.000
170.6411	-58.519870	2.399941	-119.871	-90.811322		0.000

Fig 7.9 losses and data of the satellite

This report generated from the satellite to the ground station is analyzed for further research purpose. These results enabled us to check the parameters of the satellite in an efficient way and the frequency received from the satellite to the ground station is also matched i.e., 2.4 GHZ.

7.3 COMMUNICATION SYSTEM RESULTS:

Temperature and Humidity are determined by DHT22 sensor and the results are obtained by serial monitoring data in the Arduino software. The signals are sent and received through NRF24L01.

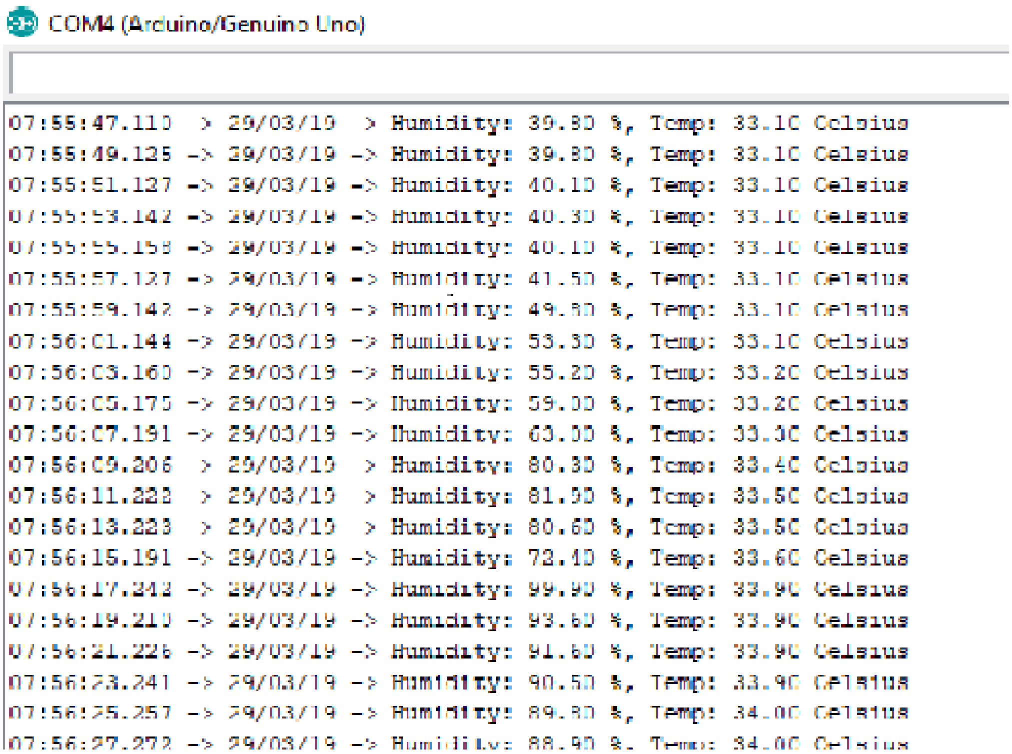


Fig 7.10 data from transmitter

7.4 ANTENNA DEPLOYMENT CIRCUIT RESULTS:

As discussed earlier the antenna deployment plays a major role in the transmission of the data. This deploying mechanism can be done by different methods, in this satellite the nichrome wire heating method used to deploy the antenna. The minimum voltage and current required for the antenna to get deployed are 9v and a current of 7.5mA. The antenna deployed by heating of the wire though a voltage and current passed through it.

Step 1:

Circuit closes and the passage of the current from the ground to the drain makes the wire get heated.

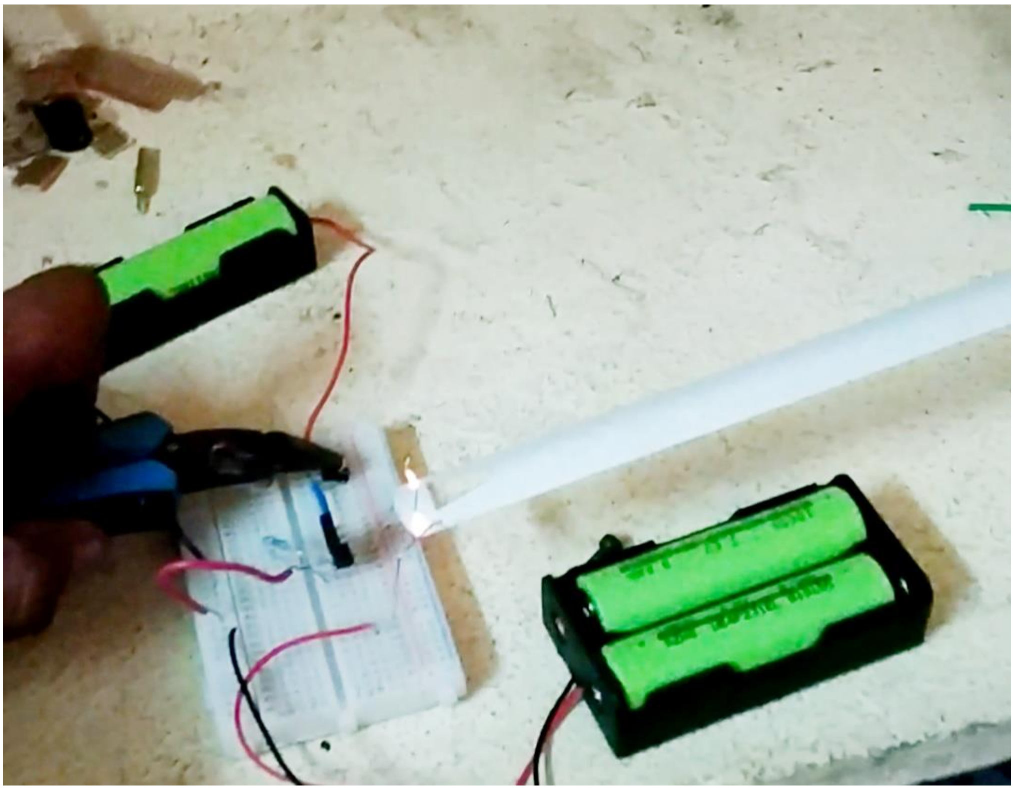


Fig 7.11 Burning of Nichrome wire

Step 2: wire disintegrated from the circuit

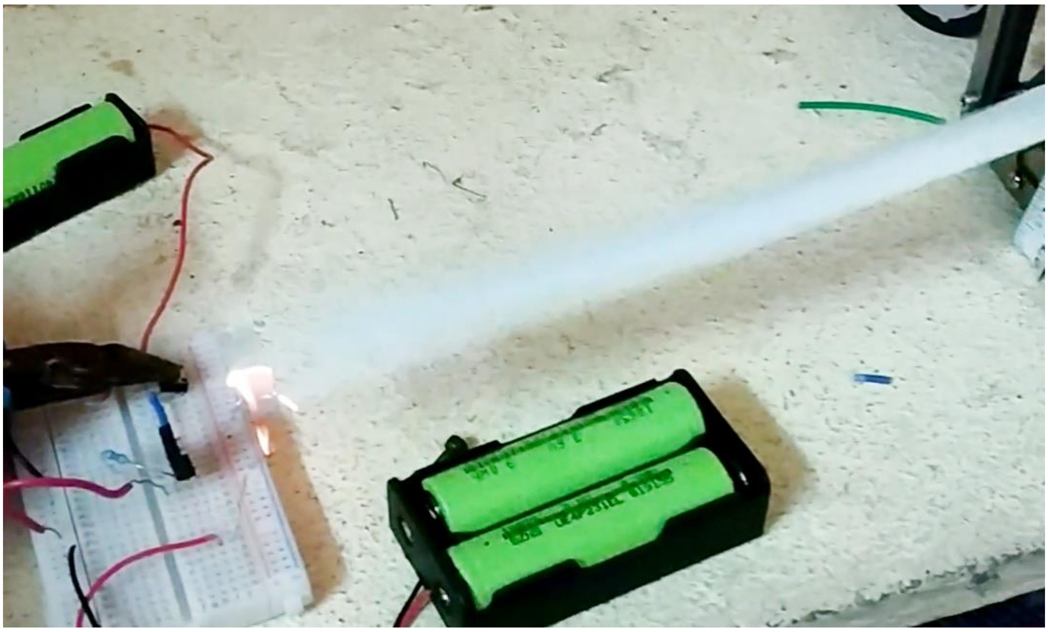


Fig 7.12 Antenna deploying

Step 3: Antenna deployed

Fig 7.13 deployed antenna

CHAPTER 8

CONCLUSION

The project has presented new approaches to design and implementation of all the sub systems for small satellites that increase the level of autonomy. The entire Satellite was divided into Payload, On Board Command and Data Handling, Communication, Electronic Power System and Structure, such that each item could be designed and tested separately. Thus developing a low cost mission with remote sensing application provided an opportunity to have an experience in the field of space craft design. Further scope of improvement can be outlined and this could pave a way for low cost mission fulfilling the same goals as that of larger satellites.

A low cost prototype based EPS designed and its performance is studied and the values are obtained as per the design specification. The Boost converter, Buck Converter for 5V and 3.3V are designed and simulated. A hardware model is also designed. The performance of the theoretical work is in good agreement with the practical work. The primary application of the developed system is for the deployment of antennas on-board Nano-Satellites, but this model can be employed to deploy any mechanism on the satellite.

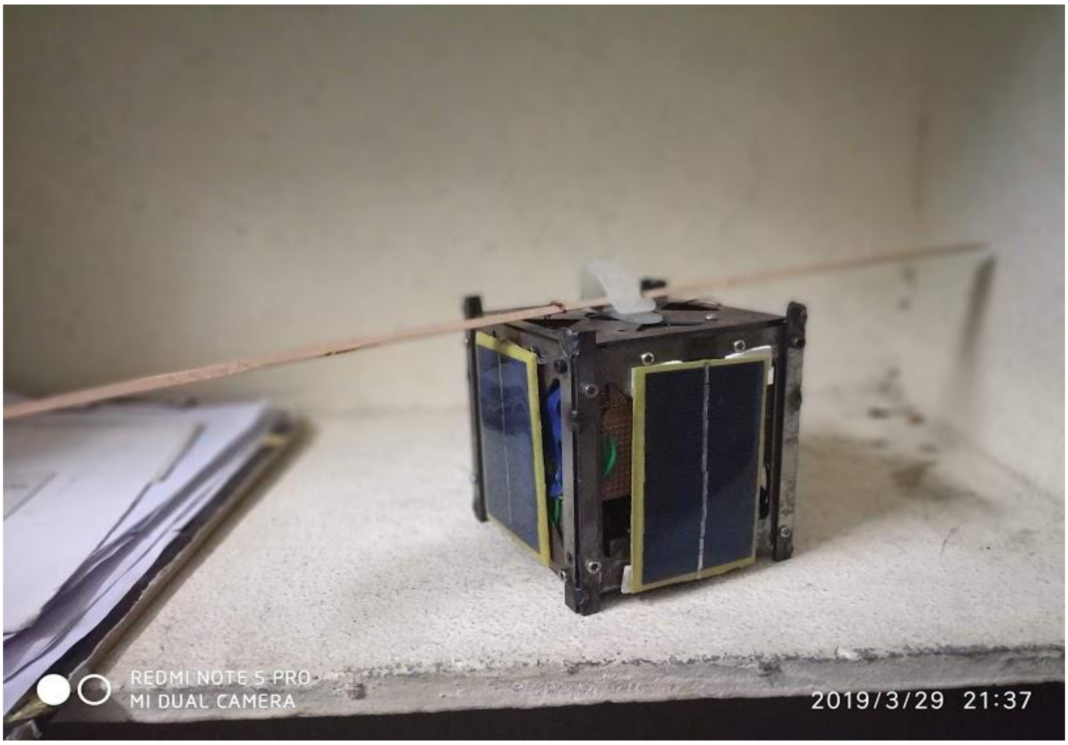


Fig 8.1 KRUSHISAT

FUTURE SCOPE

Larger satellites could not be reduced in size to that of a CubeSat due to their wide range of versatile functions. CubeSat's and larger satellites are meant to work in tandem, with each having their own given area of necessity and operation.

The low cost of these tiny space probes will allow for not only more risky missions to incorporate the technology, but also the ability to pack multiple identical satellites into one launch to allow for redundancy if one is lost. NASA also sees CubeSat's working together to build up one larger functioning cluster of satellites. Each smaller satellite would have a specific function, and all of them working together would have the same functionality as a larger spacecraft.

REFERENCES

(1) STUDSAT: India’s First Student Pico-Satellite Project-978-1-4244-7351-9/11/©2011 IEEE 2 IEEEAC paper#1069, Version 2, Updated 2011:01:14

(2) Antennas for Modern Small Satellites- IEEE AntennasandPropagation Magazine, Vol. 51, No.4, August 2009

(3) Power Supply Design for Satyabhama University Nano Satellite-978-1-4244-9182-7/10/©2010 IEEE

(4) Low cost S band communication system for Nano satellites- 978-1-4244-9616-7/11/©2011 IEEE

(5) On Board Communication Subsystem for Satyabhama University Nano-Satellite-978-1-4244-9182-7/10/©2010 IEEE

(6) Novel Low Cost Standardized Nano-Satellite Structure Bus for LEO Missions-978-1-4673-1813-6/13/©2013 IEEE

(7) Design and Optimization of the On Board DC/DC Converters of Swayam Satellite-2014 IEEE International Conference on Power2014

(8) Development of Antenna Deployment Circuit for Nano-Satellites-Pramath Keny, Arya Menon, Madhura Rao, Urvang Gaitonde, Animesh Gupta, Annamaneni Sriharsha,Manipal Institute of Technology.

(9) https://www.isro.gov.in/