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Design of a Microsatellite for Academic Research

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Abstract— *Design a radio altimeter having an accuracy of ± 3cm for an mean orbit altitude of 450km from a low earth polar sun-synchronous orbit (LEO). The application in mind for this mission is Tsunami warning to coastal inhabitants giving them sufficient notice time for moving to safe locations.*

Keywords— *Microsatellite, Radio altimeter, Solar panel, Tsunami warning.*

I. Gross Parameters of the Satellite

The satellite will have two payloads, one from M.A.M. School of Engineering and the second from a customer institution. The total launch weight of the satellite will be in the range of 12 to 15 kg. The structure, subsystems and fuel will form 60 to 70% of total weight. Payloads will have a combined weight of 2 to 3 kg. The designed life of the satellite will be 15 months. The total power requirement of all onboard systems will be 100 to 150 Watts.

II. Earth's Gravitational Constant and Gravity Potential

The gravitational force of attraction between two inertial bodies is governed by Newton's universal law of gravitation. Using the relevant geographic constants, the gravitational constant at a geometric height of h_G kilometers is given by the formula

$$g = 9.807 (6371 / (6371 + h_G))^2$$

The numerical values of 'g' obtained from the above relation for altitudes ranging from 10km to 500km are given in figure 1. The value of g is significant in deciding the orbital velocity of a satellite for a specified altitude or radius of the orbit.

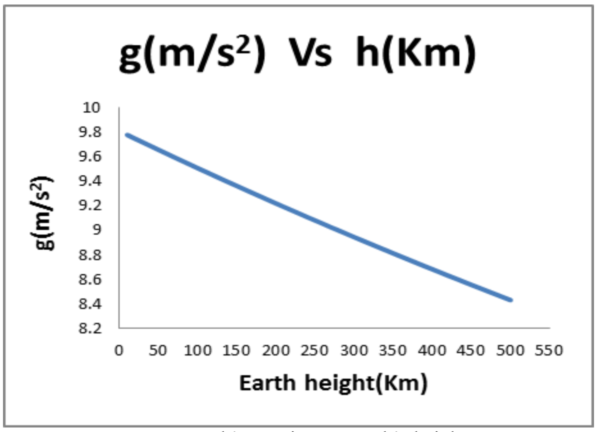

Fig. 1. Earth's gravity Vs Earth's height.

The gravitational constant represents gravity force on unit mass. By convention, the negative gradient of gravity potential gives this gravity force on unit mass. Hence the gravity potential is obtained by integrating –g with respect to altitude, assuming it to be zero on the surface of the Earth. The numerical values of gravity potential obtained from this scheme for altitudes ranging from 300km to 900km are given in figure 2. The values of gravity potential and its variation with altitude are significant in arriving at the energy requirement from the launch vehicle for lifting the satellite from Earth's surface to the parking orbit and also for orbit changing maneuvers.

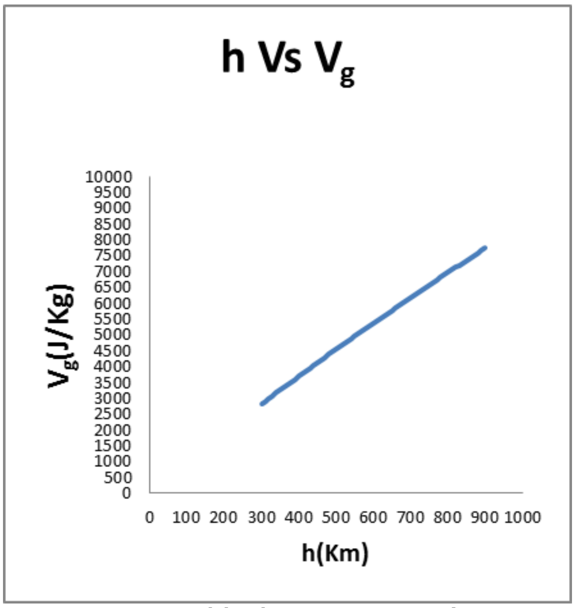

Fig. 2. Earth height Vs Gravity potential.

III. Solar Panel Deployment

With the advancement in satellite technology, solar panel deployment technology is also getting sophisticated. Research organizations from all over the world are focusing on testing their products and technologies on low-cost solar panel deployment. The advantage to test new technologies on solar panel deployment is that they are low-cost and their launches are very frequent. These technologies can provide limited power to the satellite due to limited number of solar cells. Therefore it is required to provide more power to the satellite so that it can deliver power to the subsystems and the research equipment's. Many solutions have been put forward for the deployment of solar panels for e.g. miniaturized motors extendable solar panels and Shape Memory Alloys.

This paper will discuss a new design approach with which one-shot extendable solar panels can be deployed. The design has been made using the classical torsion spring-loaded

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technique which conforms to the rigid mass and volume of the microsatellite design specifications. The design has been successfully developed and will be discussed in detail in later sections.

IV. Design Requirements

The design of a multi-panel deployable solar array panel, it's simple yet reliable and fits within a microsatellite (40cm x 50cm x 30cm).

The innovative design requirements are mentioned below:
1) Pyrotechnic methods should not be used.
2) Provide a light-weight solution for the deployment of solar panels.
3) It should be deployed to get maximum solar angle.
4) Solar array shall have passive deployment and locking mechanisms
5) Should be within the specifications provided by CDS.
6) Able to withstand the mechanical stresses spacecraft is exposed to undergo.
7) Easy to fabricate and easy to assemble.
8) Fulfill the deployer's and launcher's requirements.

The panel was designed and fabricated by using stainless steel material for showing demo of deployment. The below figures 3 and 4 shows the extended and retracted positions of panel frame.


Fig. 3. Extended position of panel.


Fig. 4. Retracted position of panel.

V. Mechanism

The structural design was kept simple but reliable. Since mass of the satellite should also be kept within a range, therefore the mass of the deployment mechanism was of main consideration. And to keep the mass within limits (although there is no limit for the deployment mechanism alone but other scientific instruments are of main concern w.r.t mass considerations) minimum number of parts was designed. The main design calculations were for the torsion spring. First there were some initial assumptions such as the force required to deploy the panels and the dimensions of the spring and the spring constant.

For latching the panels a simple solution by using a fishing line to hold down was used. The latch and release mechanism is still under development. But for testing purpose a temporary solution was developed to test the deployment mechanism. For this purpose a circuit was designed in which, a fuse wire, was used in a loop type shape through which the fishing line was passed. Once the circuit was switched on, the fuse wire melted the fishing line and the panels are deployed. The circuit diagram can be seen in the figure. The circuit is self-descriptive, as can be seen that a supply voltage is connected to the resistive wire and the resistive wire is connected with the MOSFET. One of the legs of MOSFET is connected to a 180 Ω resistor. The switch is connected to the microcontroller is shorted when a 3.3V is applied. The fishing line is passing through a loop of the resistive wire and when the circuit is switched on the current passing through the resistor heats it up and melts the wire.

VI. About Transceiver

The Slink-Phy transceiver system provides a huge payload data downlink for micro, nano or pico satellite applications and the benefit of an additional data uplink for tele-command. It is designed as highly integrated S Band transceiver system with outstanding technical performance and versatile configuration options. The lifetime goal is for at least two years of operation in Low Earth Orbit (LEO) environment. The radio system can be adjusted in a frequency band between 2,200 and 2,290 MHz for downlink (Sat2Ground) and between 2,025 and 2,110 MHz for uplink communication links (Ground2Sat), e.g. for tele-command purposes. An adaptation for various data rate requirements is possible.

Slink-Phy provides the physical layer (RF link) in an Open Systems Interconnection model (OSI). It is fully transparent to higher layer protocols. For this reason, standard satellite ground station transceiver equipment can be used for a bidirectional radio communication with the satellite. It is Fully featured and transparent bidirectional S band transceiver.

Key Specifications:

- Operational mode: FDD / Full duplex
- Data rate Sat2Ground: up to 20.0 Mbps Modulation QPSK
- Data rate Ground2Sat: up to 256 kbps Modulation BPSK
- Linear RF output power: up to +27 dBm (adjustable)
- automatic Doppler shift compensation in Rx: up to 125 kHz

- Low power consumption 12 W max (Rx+Tx) 3 - 4 W Rx only
- DC supply voltage: 7 – 18 V
- Ultra small volume: 50 x 55 x 94 mm3 (without housing)
- Low mass: < 190 gram
- control and housekeeping interface: I2V

	Sat to Ground	Ground to Sat
Frequency Range	2,200-2,290 MHz	2,025-2,110 MHz
RF bandwidth	1.75 MHz (symbol rate 1.5 Msymbols/s)	300 kHz (symbol rate 64 kSymbols/s)
Data Rate	up to 20 Mbps	up to 256 kbps
Operational mode	Frequency Division Duplex (FDD) / full-duplex	
Modulation scheme	QPSK	BPSK
Power supply	7 ... 18 V DC	
Power consumption	8 ... 12 W transmit mode (Rx+Tx) 3 ... 4 W receive mode	
Temperature range	-20 ... +50 °C operating -30 ... +60 °C switch-on -40 ... +65 °C non-operating	

Applications:

- High speed data links from/to LEO
- Micro, nano or pico satellite usage
- bidirectional communication links
- Sat2Gnd / Telemetry 3 Mbps
- Gnd2Sat / Tele-command 64 kbps

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