EARTHQUAKE SIGNATURE DETECTION USING CUBESAT TECHNOLOGY

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Abstract: -

Cubesats play a vital role in development of new micro components being used in various micro/nano satellites. Cubesats have an effective small design and have the ability to get modified easily. Quakesat, a satellite being deployed by Space Systems Development Laboratory (SSDL) is used to study, detect, record, and downlink extremely low frequency (ELF) magnetic signals, which are used to predict earthquake activity. Quakesat is a live example of cubesat technology, uses non space application components and provides a low-cost alternative to launch space missions and support nano satellite infrastructure in future.

Keywords: *Cubesat, Quakesat, ELF, SSDL, Richter Scale*

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1. INTRODUCTION

When earthquakes of Richter scale magnitude of 6 or larger develop, the layers below earth's crust begin to fracture / move as stress builds along. The fracturing of the bedrocks creates the ELF magnetic waves. These signals / signatures radiate from the earthquake epicenter, through the earth (5-80 Km), through the atmosphere to the ionosphere (100-200 Km) and are propagated to the earth's satellite altitude (600-900 Km). The determination of this ground-based ELF signals is of considerable interest at the altitude of a satellite. A Russian satellite, Cosmos 1804 detected 140Hz and 450Hz signals just after a M6+ earthquake in Armenia in 1989 every time the satellite passed within ± 6 degrees. of Lat. And long. of the earthquake.

Therefore, the Quakesat mission objectives are to detect, record and downlink the ELF magnetic data to verify the results from there prior experiments. Investigating the ELF signals can ultimately lead to the prediction of earthquakes of magnitude 6.0 or more. Quakesat will help to determine if the cubesat paradigm is cost effective platform for conducting significant scientific research. Quakesat is designed for a nominal one year long mission life and are deployed in a sun synchronous, low earth orbit (LEO) at an altitude of 65 Km.

ELF waves refract in the Ionosphere and propagate into space along the earth's magnetic field lines. Quakesat will use permanent magnets for passive altitude control to orient the quakesat close to the magnetic field lines. A deployable payload boom contains the ELF magnetometer which collects raw data. This boom is necessary to shield the ELF sensor from any internal magnetic disturbances generated by the quakesat electronics.

Figure 1 Mission Concept

2. PAYLOAD DESCRIPTION

The strategy used to detect these magnetic fields relies on the use of very sensitive AC magnetometer. The ELF sensor is a single axis search coil magnetometer with multiple frequency bands. The magnetometer is 0.3 m long and 0.02 m in diameter. There is no on-board processing of the mission data other than multiple, analog low pass, high pass and band pass filters. Figure 4 shows the architecture of Quakesat. The payload was designed for simplicity but was modified to select specific frequency bands and only power those bands to keep the overall power usage to a minimum. The quakesat frequency bands for the ELF payload are: Band 1: 0.5 to 10 Hz narrow band magnetic; Band 2: 10 Hz to 150 Hz wide band magnetic; Band 3: 10 Hz to 1000 Hz wide band magnetic; Band 4: 130-150 Hz narrow band magnetic; Band 5: 130-150 Hz narrow band electric field. All the bands are sampled at 2-3x their frequency, except the 130-150 Hz band, which is sampled at 1/sec. During data gathering event, one of the other wideband or narrow band filters is also commanded on, and the sample rate is adjusted accordingly.

3. STRUCTURE

The quakesat is a design of cubesat design itself and has a length equal to three cubesats and weighs 3 kg. The magnetometer is fixed inside the structure after being attached to the end of the boom. Quakesat also contains an inner rack that slides inside the outer structure. The flight apparatus and circuits are fastened to the inner rack and arranged so as to fit the components. The spacecraft is symmetric when the solar arrays are fully deployed, the product of inertia is zero and center of mass only shifts along the axis.

4. COMMAND AND DATA HANDLING

Command and data handling of quakesat is designed to operate with timed commands to synchronize data gathering with historically active earthquake prone areas. To sample the data world is mapped into grid of 5 degree or 10-degree squares of latitude and longitude. This resolution was derived to allow sensor to be properly calibrated. The position of quakesat is determined by NORAD Two-line Element Sets and a ground-based propagator. The determination of quakesat orbital position will be calculated on the ground. The ELF data will then be down linked through one or more ground stations on the earth. It will also allow changes in sample rates of the pay load and direct on/off commanding of the payload. A capable CPU is selected to satisfy the requirements. The Prometheus processor is selected based on its wide operational temperature range.

5. COMMUNICATION

The major components used for communication are Tekk T net mini 9600 Baud, half duplex crystal-controlled radio and a modem. The Tekk radio is one of the smallest 9600 baud data packet radios. The communication system uses UHF frequency for both transmission and reception. Quakesat has four antennas that are quarter wavelength long about 70 mm and 6.5 mm wide. Each antenna is mounted on four corners of the satellite at 45 degrees.

6. ELECTRICAL POWER SYSTEM

The electrical power system includes three subsystems: a power source, storage and a regulator. Power source consists twelve solar panels: four are body mounted and four are deployable wings. The panels are programmed keeping in mind the direction of the sun. The deployable wings are canted at an angle of 150 degrees. The power levels expected are 2.8 W to 12.6 W over the clock. Every solar panel has dimensions of 330*86 mm and produces voltage accordingly and store them in high efficiency Li+ batteries. Each charge controller limits the current and maximum charging current to 3 A. Quakesat uses a passive thermal controller and the temperature excursion is expected to be between 27-to--38-degree celcius.

Figure 2 Antenna Directions

7. GROUND STATION OPERATION

Once quakesat is launched and the solar panels are deployed, the satellite is commanded through the quakesat ground station. The satellite will be given a satellite ID number for tracking purpose. Pre-determined areas of interest will be compared against the satellite track and appropriate payload on-off times will be computed using the world map. The ground station will determine which frequency gives the best possible data and then generates a file of channel on- off times. When the clock reaches the proper time, individual payload power switches will be toggled as the satellite crosses a particular area. The files are stored in the ground station server and based on the calculation done by applying various algorithms the earthquake can be detected. Based on a pre-coordinated schedule, Quakesat will download the data files with ID. Subsequently it will be transmitted using FTP to quake finder headquarters.

8. CONCLUSION

We see in this paper that the Quakesat is an effective small satellite that may be modified to accommodate larger academic and even commercial missions. Quakesat is being launched at the lowest of prices and hence should prove that Cubesat class of satellites provide an effective and cost alternative to larger space missions. This paper also describes the use of ELF. Quakesats mission goal is to monitor that ELF signatures can also be detected from LEO and ground stations data. Periodically the report can be generated of earthquakes of magnitude 6 and above around the world. This analysis shows if ELF signals can be detected by a satellite before and after large earthquakes.

9. REFERENCES

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