Retro-Directive Transceiver System for Communication Needs of Formation Flying (Swarm) CubeSats

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Introduction

Synthetic Aperture Radar (SAR) is a sensing method in which a moving transceiver can generate large, higher resolution images by creating a "synthetic aperture". Swarms of Cube Satellites are a novel method of implementing SAR as they are groups of rapidly moving sensors. Central to the implementation of SAR on a cubesat platform is managing the swarm and calculating the position and orientation of each of the cubesats in reference to both the earth and one another to enable an SAR algorithm. To achieve this end, 3 phases of testing are proposed. The first phase is designing, manufacturing, and testing the retro directive arrays in a lab setting, and then a mobile platform. Next a satellite to house the system will be prototyped. Finally, the satellite will be fabricated and tested to prove the system can be deployed onto it. Synthetic Aperture Radar is a widely used Radar for civilian as well as military applications. Utilizing the cubeSat form factor to implement an SAR will allow faster, cheaper deployment of LEO-based SAR systems.

Methods

Swarms of small satellites or cubesats offer a new sensor configuration/ architecture for Earth science remote sensing from space as well as for planetary observations, With such swarm, it is possible to realize: 1) synthetic aperture radars for Earth sensing system, 2) large aperture for space telescope, 3) space borne phased array system. To implement such configuration adaptively without external commands, it is essential that each satellite in a swarm to be equipped with a robust communication system that will allow all the time in contact with other members of the swarm. To be able to establish communication link under this scenario, omnidirectional antennas are preferred solution. However, this reduce the power in desired direction, causes low data rate and such system is prone to external interference. Main goal of this work is to design and validate a communication system based on retro-directive array concept that will enable a cubesat to adaptively establish communication link between itself and other members of swarm. Furthermore, the proposed communication protocol will be able to established communication links using time multiplexing.

Procedures

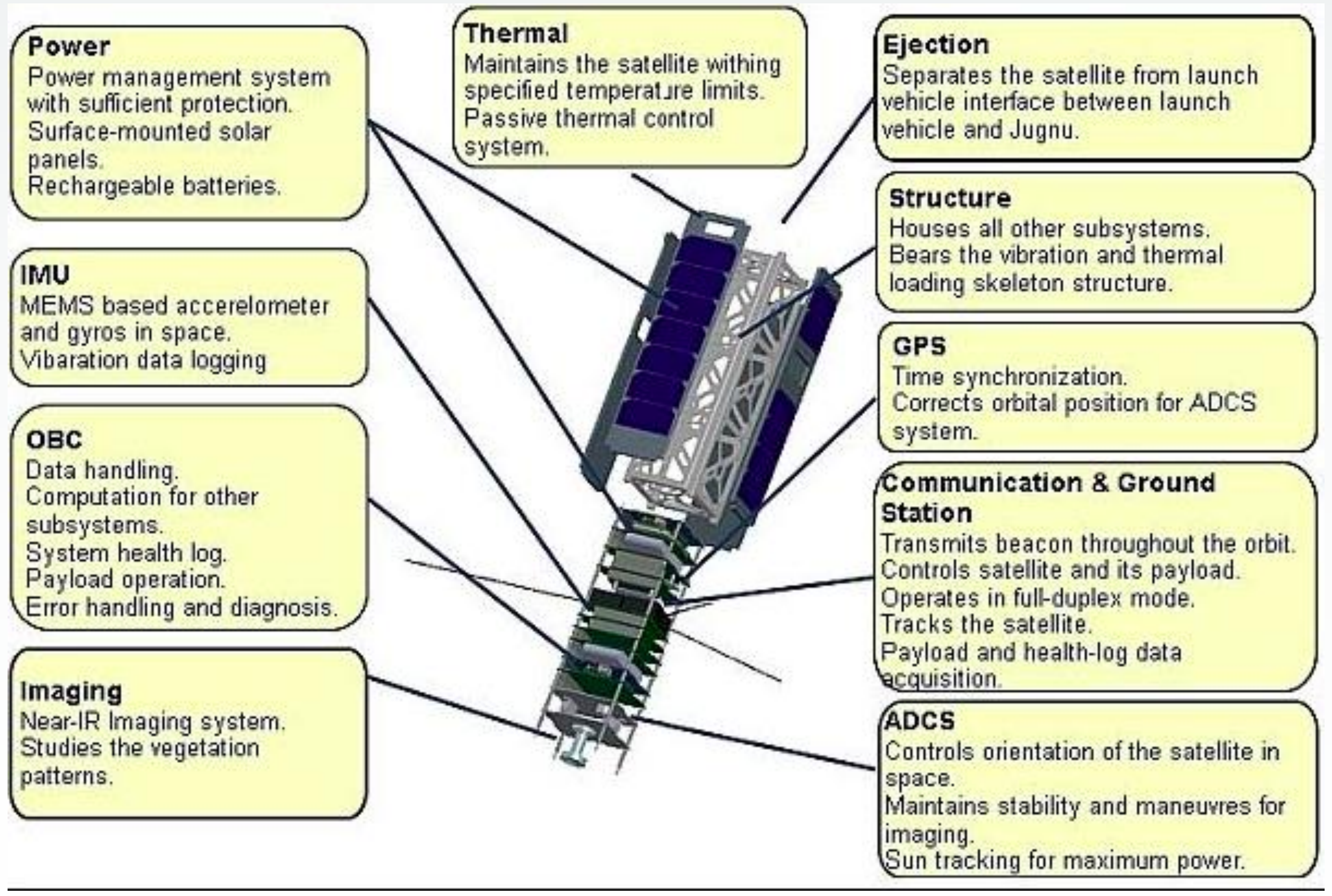
To address this challenge, the retro-directive array concept has been of particular interest due to its cost effectiveness and compactness. A retro-directive array transmits a signal back to the interrogator's position without any a priori knowledge of the incoming angle or relying on sophisticated digital signal processing algorithms. Furthermore, the retro-directive transceiver does not need complex phased array architecture to achieve the above mentioned functionality.

Robust channels will be given priority over less robust channels. Generally, each member of the swarm will be able to communicate with at least one other member. In this way satellites can relay position information so that two satellites separated from one another can have knowledge of each other's position with out forming a direct link. A scheduler will have to be developed using the FPGA fabric on the Lime SDR which will further justify its use in the project.

Traditionally, beam scanning phased arrays are used for beam formation. This requires high processing overhead to acquire prior knowledge of the cubesat location. Retro-directive arrays do not need prior positional information.

Results

Swarms of small satellites offer a new sensor configuration/architecture for Earth science remote sensing from space as well as for planetary observations. To implement such configuration, it is essential that each satellite in a swarm is equipped with a robust communication system that is in contact with other members of the swarm at all times. In order to generate a Synthetic Aperture Radar (SAR) Image, accurate position and timing must be known of array element. In an unorganized swarm environment this can be particularly difficult. This research proposes to design and validate a communication system for swarm cubesats based on the use of retro-directive arrays for use in synthetic aperture radar to gather such timing and positional data. SAR is a sensing method in which a moving transceiver can generate large and high resolution images by creating a "synthetic aperture". Swarms of cubesatellites are a novel method of implementing SAR as they are groups of rapidly moving sensors. Central to the implementation of SAR on a cubesat platform is managing the swarm and calculating the position and orientation of each of the cubesats with reference to both the Earth and one another to enable a SAR algorithm.



Conclusion

This proposal will investigate retro directive arrays for the use of Formation Flying CubeSats, particularly for the use with Synthetic Aperture Radar (SAR), and large aperture for space telescopes. Retro directivity will be achieved using a heterodyning approach in which mixers oscillating at twice the frequency of the carrier cause a negative phased signal to be retransmitted back to the source thereby steering the beam of the array. This is particularly useful for the above applications as they all require precise timing and positional information due to the dynamic nature of the CubeSat swarm. Adaptive Time Domain Multiplexing will be used to prevent interference as well as save on power by placing priority over robust cross links. In this way, swarm elements furthest away from one another will not have to directly communicate with one another.

References

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