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Communication and Mutual Physical Position Estimation System for CubeSat

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In recent years, constellations of CubeSats organized as a swarm are redefining the classical concept of space missions. The biggest challenge for the realization of an efficient swarm is to provide to the CubeSats the ability to interact and communicate each other.

In this paper we present a system able to provide to the CubeSats belonging to a swarm the ability to establish an inter-satellite communication crosslink and to determine the mutual physical positioning.

The basic idea is to provide every CubeSat with a system involving a smart-antenna array.
By exploiting the array, CubeSats can transmit or receive signals to / from every element of the swarm so as to perform the inter-satellite communication. The smart-antenna is managed by a beamforming control strategy: during the transmission, the beamforming algorithm controls the smart-antenna in order to shape the beam and establish a reliable and directive communication link with other spacecraft and/or with the ground station.
Hence, the beam shaping avoid to perform attitude maneuvers to optimize the transmission.

Every CubeSat acquires signals transmitted from other elements of the swarm and estimate the Direction-of-Arrival (DOA) and the distance (Range) in order to calculate the mutual physical positioning. By an appropriate distribution of the antennas on the structure of the CubeSat it is possible to obtain a working range of 4π steradians.

Every element of the smart-antenna is connected to a signal conditioning chain able to modify the phase and the amplitude of the signal transmitted / received. The beamforming algorithm manages this signal conditioning chain dynamically to maximize the performance of the system. Thanks to his small footprint, the system can be mounted on every CubeSat geometry and it is completely integrated with the bus so as not to occupy space dedicated for the payload as shown in figure [1].

Through the use of a deployable structure fully developed at Politecnico di Torino, we increase the external surface of CubeSats: this surface allows to gain the interspace between elements of the smart-antenna (figure [2]). As a consequence, the directivity and detection performance of the DOA system in terms of directivity and accuracy are improved. Moreover, the deployable structure offers a greater usable surface, so a larger number of solar panels can be used, e.g.: up to 40x30 cm^2 for a 1U CubeSat. Hence, the communication distance increase because a power up to 6W is available for the transmit mode.
This paper describes the physical implementation of the antenna array system on a 1U CubeSat using the deployable structure developed.

In section I we describe how the subsystem has been designed, we analyze how the hardware works and we focus on the main blocks that realize the positioning measurement / network communication.
In the section II we describe how the swarm subsystem can be hosted on every CubeSat structure (even 1U) by exploiting a deployable structure able to increase the useful surface of the CubeSat and the antenna baseline. This structure allows to gain the available power supply for the transmission (also for the other on board systems) and improves the precision of the mutual positioning estimator.
In section III we describe how the subsystem establishes the communication between the CubeSats and how it measures the direction of arrival (DOA) and the distance (Range) of the received signals in order to establish the mutual physical position of every CubeSat composing the swarm.

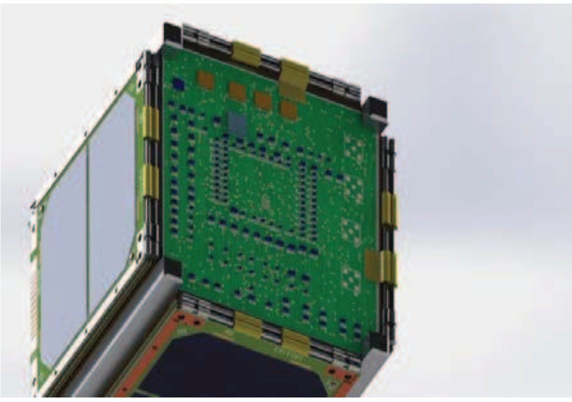

Figure 1 : Hardware occupation on 1U CubeSat of the communication/physical position estimation system.

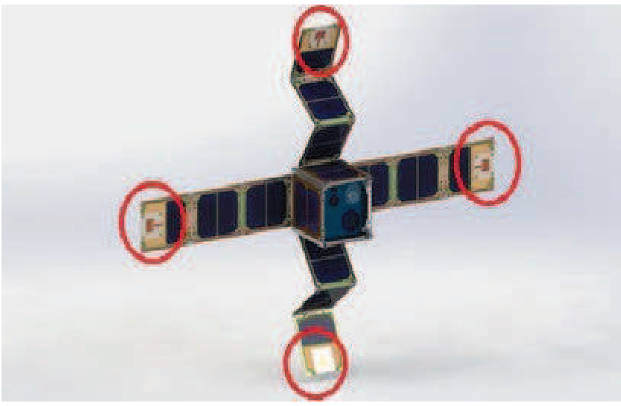

Figure 2: Antenna Positioning on the deployed structure

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