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ANTENNA PLACEMENT AND ARCHITECTURE FOR A WIND-DRIVEN, SPHEROID TUMBLEWEED ROVER ON MARS

Abstract

Interest in Mars exploration has seen stark growth in recent years. Advances in distributed systems, miniaturization and commoditization of space electronics, and innovations in communications permit the rise of innovative concepts such as the Tumbleweed Mission - a low-cost Mars surface mission using a swarm of wind-driven mobile impactors. The antenna accommodation proves challenging for this mission, primarily due to the semi-controlled tumbling motion of the rovers and the fact that the structure is subject to abrasive contact with the Martian surface.

Insufficient realized antenna gain, potential interference with structural elements and mechanical damage could prevent the rover from successfully transmitting its data to the data relay orbiter in Mars orbit. In prior work on the communications architecture for the Tumbleweed Mission, antenna integration was identified as an issue to be addressed for exploration vehicles with semi-random movement. The data downlink is a crucial aspect of every exploration mission, for without it, the mission has no purpose.

Therefore, the objective of this paper is to find suitable antenna architectures and identify at least one solution meeting the system and performance requirements of the mission. We propose three antenna architectures and conduct a qualitative trade-off taking into account the communication performance and effects on the rover as a hosting platform accommodating the antenna needs.

We examine three antenna architectures. First, we consider a fixed-mounted, single-element omnidirectional antenna, which is low-mass, simple to mount, and requires no electronic or mechanical control. However, it features the worst antenna gain out of all options and could be subject to harmful interference with the rover's structure and suffer from multipath effects. We also study a single-element antenna, which employs passive mechanical steering to achieve zenith-pointing and features improved gain. While this stabilization is already technically realized in Tumbleweed Rovers requiring controllability, questions of antenna placement remain. Furthermore, the remaining pointing uncertainty raises concerns for the link availability given undesirable pointing states. Third, an electronically steered phased array antenna with elements integrated into the rover's outer structure is examined. It features improved gain without moving parts, yet it requires a large number of antennas coming with complex electronics to drive it and could be subject to harmful contact with the Martian surface.

In the paper, we present an antenna architecture fulfilling the requirements of the Tumbleweed Missions and recommend further steps to mature and validate its design.