Title of workshop: Eighth International Workshop on Signal Processing for Space Communications (SPSC 2003)

Topic: Coding, modulation, transmission and access techniques, or DSP techniques for payload and data processing

Title of paper: **Development of an Entry Descent Landing (EDL) Support Capability for NASA Mars Exploration Rovers**

Author(s) name(s) and affiliations:
David Fort, National Research Council, Canada
Christine Chang, Jet Propulsion Laboratory, U.S.
Timothy Pham, Jet Propulsion Laboratory, U.S.

Contact: Timothy Pham
Jet Propulsion Laboratory
Mail stop: 161-260
Pasadena, California 91109, U.S.
Phone: 1-818-354-4288
Fax: 1-818-393-4643
Email: Timothy.Pham@jpl.nasa.gov.us

Abstract

In January 2004, the two NASA Mars Exploration Rovers will be arriving at Mars. The rovers will conduct geological studies of Martian soil to search for water and signs of life at the landing sites. Prior to such an exciting scientific operation, both spacecraft have to pass the critical task of entering and descending through the thin Martian atmosphere, and landing onto the surface. The entry needs to be achieved with a proper flight angle. It needs to be large enough for the spacecraft to be captured within the atmosphere but small enough to avoid burn-up. The descent requires proper deployment of the parachute at the designated altitude to enable a slow touchdown at the selected landing area. The softened landing calls for inflation of the cocooning balloons at a precise moment.

Throughout these choreographed activities, the spacecraft communication with Earth needs to be maintained. Lessons learned from past failures mandate the need for constant communications during mission critical operations, such as the entry, descent and landing (EDL). From a communications perspective, this is a challenging task. During the 6 minutes of entry and descent, the signal will experience a large Doppler uncertainty caused by spacecraft rapid de-acceleration. The signal level will widely fluctuate due to swinging motion of the parachute bridle. A short period after landing but prior to the opening of the petals that house the rovers, the signal may be very low due to unfavorable orientation of the landing platform. To maximize the signal detection probability in the face of these challenges, a special development for EDL support is needed.

This paper describes the development in the ground system of the NASA Deep Space Network (DSN) to support EDL operation of Mars Exploration Rovers. In particular, it focuses on the development of the EDL Data Analysis (EDA) capability. The EDA software runs on a commercial-off-the-shelf computing platform. The hardware is made up of a Unix workstation responsible for high-level monitor and control, and a cluster of PC boards that offers maximum computing power. The server software supports multiple client connections via standard network; thus, enabling detection results to be viewed at different locations. The signal processing is multi-threaded, each focuses on one of three processes: "forward track" to keep up with real-time data, "backward track" to fill in any gaps, and "refined track" to further improve the detection. The signal detection is referenced to multiple frequency-shift key (MFSK) modulation of 256 tones. Due to the constraint of low signal-to-noise ratio and high frequency dynamics, signal integration needs to be done both coherently and non-coherently modes. The detection algorithm also employs the concept of state transitions for optimization. As data are processed, the configuration settings can progressively migrate toward a local optimal state that would provide maximum detection probability with minimum required processing. In this paper, various aspects of requirements for such an implementation, different design considerations and the performance of EDA are highlighted.

Also discussed is the option of arraying multiple antennas to enhance signal detection. The technical challenges in maintaining signal alignment, especially under the unique EDL conditions, and possible solutions are identified.