Abstract

Mars Exploration Rover Telecommunications Subsystem

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The Mars Exploration Rover (MER) mission is designed to investigate Martian geology, investigate the role of water, and seek information on the climate history of the red planet at two sites that may have been conducive to life.

NASA launched twin rovers to explore Mars in June 2003. With unprecedented mobility (up to 100m/day) and a more capable suite of science instruments than Mars Pathfinder, each rover will return as much as 100Mbits of science data every 2 sols (1 sol = 1 Martian day = 24.6 Earth hours). The first rover will land on January 4, 2004, the second rover is expected to land on January 25, 2004.

The MER mission has three distinct phases; Cruise (7 months), Entry/Descent/Landing (EDL, 16min) and Surface Operations (90 sols). Spacecraft command/control and telemetry information return required from each phase determined the architecture of the Telecommunications Subsystem (TEL). TEL (Figure 1) consists of the Radio Frequency Subsystem (RFS) operating at 7.1/8.4GHz (X-band), the Ultra High Frequency (UHF) Subsystem operating at 401/437MHz, the RFS and UHF Antenna Subsystem and the Radar Altimeter Subsystem (RAS) operating at 4.3Ghz (C-band).

Each MER spacecraft consists of a cruise stage, backshell, lander, heatshield and rover. The RFS and UHF subsystems are mounted inside the rover. The RAS is mounted on the lander basepetal. The MER Telecommunications subsystem provides command uplink/downlink/science data direct to Earth, high volume science data and back-up command and telemetry via orbiter relay. The RAS provides altitude data to the MER avionics.

During the Cruise Phase, communications are conducted by the RFS via a low gain horn antenna (LGA) and medium gain horn antenna (MGA,) on the MER cruise stage, to 34m or 70m antennas in the NASA/JPL Deep Space Network. The RFS electronics are comprised of a Small Deep Space Transponder (SDST) and redundant 15-watt Solid State Power Amplifiers (SSPA) and diplexer. Switching between amplifiers and antennas is controlled via coax switches and a waveguide transfer switch. The LGA and MGA are Mars Pathfinder designs and are fed from the rover up through the lander and backshell to the cruise stage via circular waveguide and horn slip assemblies at the rover-backshell and backshell-cruise stage interfaces.

EDL posed significant challenges to telecommunications. The system has been designed to meet a primary requirement to provide direct communications with Earth during EDL through roll-stop and direct communication of data during EDL through

roll stop at a rate and volume to provide support for fault reconstruction. X-band and UHF communications are used during EDL. Prior to the final turn to entry maneuver, X-band telemetry communications are via the cruise stage LGA at a rate of 10bps. Following cruise stage separation, X-band communications are via the backshell low gain antenna (BLGA). The dynamic spacecraft environment and resultant link budget dictated that Manual Frequency Shift Key (MFSK) tones be used to convey the events and spacecraft health from cruise stage separation to landing confirmation. Events are encoded using 256 tones. An X-band patch antenna mounted on the lander basepetal and the rover low gain antenna (RLGA) will be used to transmit a landing confirmation tone. UHF telemetry communications during EDL are transmitted via a deployable dipole antenna on the lander. Telemetry is transmitted to the Mars Global Surveyor (MGS) orbiter at the rate of 8kbps and forwarded to the DSN via the MGS X-band system. UHF electronics consist of a single, solid-state transceiver, diplexer and coax switch used between the descent UHF (DUHF) and rover UHF (RUHF) antennas.

During EDL, the radar altimeter determines the lander vehicle altitude which is used in the rocket assisted deceleration (RAD) firing algorithm. Radar operations begin at 2400m above the surface and conclude at 50m. Altimeter electronics consist of a single, commercial off-the-shelf radar modified to meet MER requirements. The pulsed CW radar utilizes separate transmit and receive antennas

Surface communications operations rely on a two-axis gimbal, high gain, X-band antenna for primary command reception (125bps) and telemetry transmission (1850 bps) direct to Earth. The RLGA is available as a back-up at lower rates. Science data return is enhanced through the UHF subsystem. Communications with the Mars Odyssey orbiter at 8kbps (command) and up to 128kbps (telemetry) are through the RUHF monopole antenna. Mars Odyssey will transmit MER telemetry direct to Earth via its X-band system. The rover UHF system serves as a back-up for commands and telemetry to the RFS. An additional use of the UHF system will be to demonstrate communications with the European Space Agency Mars Express orbiter.

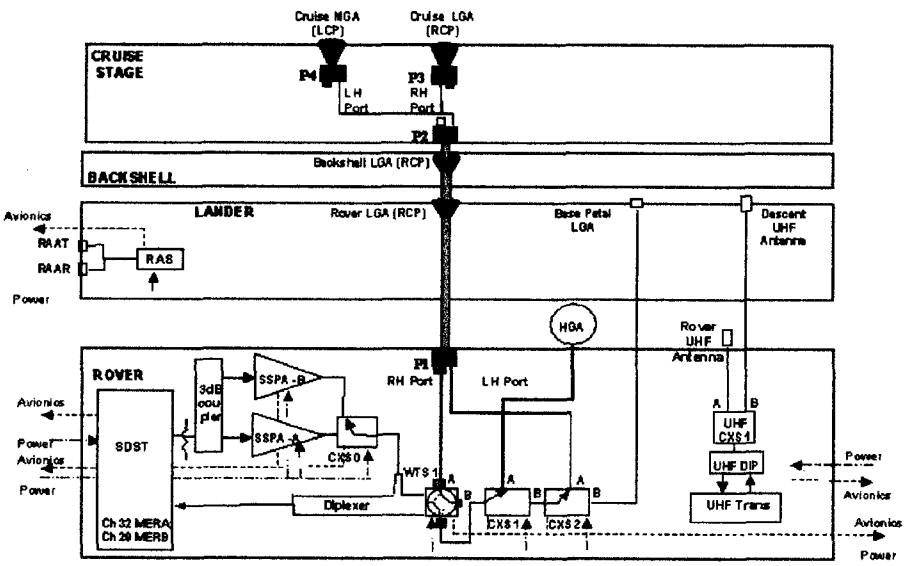

Figure 1. MER Telecommunications Subsystem.