Ka-Band Radar Terminal Descent Sensor

Radar altimeter/velocimeter improves velocity sensing by an order of magnitude and eliminates angle-of-descent errors.

NASA's Jet Propulsion Laboratory, Pasadena, California

The terminal descent sensor (TDS) is a radar altimeter/velocimeter that improves the accuracy of velocity sensing by more than an order of magnitude when compared to existing sensors. The TDS is designed for the safe planetary landing of payloads, and may be used in helicopters and fixed-wing aircraft requiring high-accuracy velocity sensing.

The TDS uses 35.75-GHz frequency to optimize accuracy without requiring new technology, and incorporates a millimeter-wave center frequency to eliminate angle-of-arrival errors that can result in large velocity errors over non-homogeneous terrain. A memoryless approach to altimetry reacquires the target on each beam for each unique measurement, overcoming problems of ambiguous measurements or high dynamics that have plagued previous altimeter designs. The independent beam-to-beam and repeat-beam performance avoids "loss of lock" problems, as well as any issue where the heat shield, or an anomaly of some sort, might put the radar in a false state.

The "sky-crane" concept developed for the 2009 Mars Science Laboratory (MSL) mission allows the delivery of much larger payloads than the previ-

The **TDS RF Design** consists of a receiver rack drawer, a frequency synthesizer rack drawer, and an upconverter/downconverter.

ously developed airbag landing methods, and it overcomes the problems of egress that pallet landers traditionally have faced. The system requires high-accuracy velocity on a minimum of three independent beams, high-accuracy slant range measurements on all velocimeter beams, and performance over an aggressive range of vehicle dynamics, including high attitude excursions, high attitude rates, and high attitude vehicle velocities. Also necessary are knowledge and control of the touchdown vehicle velocity: the MSL rover requires less than 1.5-m/s vertical and 0.75-m/s horizontal velocities at touchdown. This altimeter/velocimeter innovation can meet these needs, enabling the sky-crane concept.

At the time of this reporting, the TDS was in breadboard form, and was a single-channel, Ka-band model created with a commercial-off-the shelf (COTS) antenna, connectorized RF components, miniature Ka-band RF hybrids in small, connectorized packages for the T/R module, and a LabVIEW/laptop interface. The RF design is shown in the figure. The equipment has been verified with bench testing that included short-pulse generation, Doppler/velocity product generation, FPGA (field-programmable-gate-array) timing, RF power levels, and RF passband response.

This work was done by Brian Pollard, Andrew Berkun, Michael Tope, Constantine Andricos, Joseph Okonek, and Yunling Lou of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-44462

Metal/Metal Oxide Differential Electrode pH Sensors

These sensors are rugged, and reference solutions are not needed.

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Solid-state electrochemical sensors for measuring the degrees of acidity or alkalinity (in terms of pH values) of liquid solutions are being developed. These sensors are intended to supplant older electrochemical pH sensors that include glass electrode structures and reference solutions. The older sensors are fragile and subject to drift. The present developmental solid-state sensors are more rugged and are expected to be usable in harsh environments.

Like the older electrochemical pH sensors, the present sensors are based on a differential-electrode measurement principle. Each sensor includes two electrodes, made of different materials, in equilibrium with the solution of interest. The electrode materials are chosen so that the electric potential of one electrode is sensitive (or more sensitive) to the pH of the solution of interest while the electric potential of the other electrode is insensitive (or less sensitive) to the pH of the solution. One measures the difference between the potentials on the two electrodes and deduces the pH from the known relationship between that difference and the pH.

One of the electrodes of a pH sensor of the present type is an iridium wire that has been partially oxidized to have a surface layer of iridium oxide about 15 µm thick. The other electrode is a rhodium foil that has been similarly treated to impart a surface layer of rhodium oxide about 5 µm thick.

In calibration tests, the dependence of the electric potential of the iridium/iridium oxide electrode upon pH was found to closely approximate that predicted by the Nernst equation, at a slope between –57 and –59 mV/pH. The dependence of the electric potential of the rhodium/rhodium oxide electrode upon pH was found to be sub-Nernstian, at a slope of about –26 mV/pH. Hence, in constructing a pH sensor, iridium/iridium oxide was used for the sensing (more-sensitive) electrode and rhodium/rhodium oxide for the reference (less-sensitive) electrode. When the difference between