SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (B2)
Advanced Technologies (6)

Author: Mr. Dipak Srinivasan
The John Hopkins University Applied Physics Laboratory, United States, dipak.srinivasan@jhuapl.edu

Mr. Gene Heyler
The John Hopkins University Applied Physics Laboratory, United States, gene.heyler@jhuapl.edu
Dr. Tim McGee
The John Hopkins University Applied Physics Laboratory, United States, tim.mcgee@jhuapl.edu

SPIN AXIS ESTIMATION OF THE RADIATION BELT STORM PROBES SPACECRAFT USING RF DOPPLER DATA

Abstract

The NASA Radiation Belt Storm Probes (RBSP) mission, planned for launch in May 2012, will yield valuable insights into the physical dynamics and processes of the Earth's radiation belts, particularly those that produce hazardous space weather effects and those that can affect solar system exploration. The mission consists of two spinning spacecraft in a highly-elliptical Earth orbit (600 x 30600 km altitude). Each spacecraft has an on-board Sun sensor that, in conjunction with magnetometer data, provides the required data to perform the attitude determination. However, the quality of the magnetometer measurements is compromised at higher altitudes because of a weaker magnetic field and also during solar storms because of variations in the magnetic field. Each spacecraft's on-board S-band radio frequency (RF) subsystem includes a JHU/APL Frontier radio transceiver, which provides a coherent downlink signal used for Doppler navigation. The RF system also includes two low-gain antennas offset from the spin axis with boresights along the spin and anti-spin axes. Due to the spin of the spacecraft, a Doppler-induced modulation is present on the downlink carrier. Once the orbit determination is performed and the Doppler signal is analyzed, this modulation, or spin signature, is apparent. This spin signature can be used to accurately determine the spin rate, spin phase, and, in conjunction with Sun sensor data, can be used to determine the spin axis orientation. This provides a level of system redundancy with the magnetometer for attitude determination. The Sun sensor provides the angle from the spin axis to the Sun vector; the amplitude of spin signature on the Doppler data can provide the aspect angle from the spin axis to the ground station used for a specific pass. These two measurements establish the spin axis direction. This paper describes the theory and a process of determining and processing the spin signature and spin axis. Further, RF-related errors on the Doppler carrier frequency measurement are characterized under the RBSP implementation and related to the error in the spin axis orientation determination. Finally, this paper introduces the concept of attitude determination by processing only the spin signature data over a period of time that encompasses a sufficient change to the spin axis / ground station aspect angle. This can provided a level of further redundancy in the event of a failed Sun sensor. Results from processing actual data from a current mission are given.