THE FLIGHT PERFORMANCE OF THE GALILEO ORBITER USO

DAVID MORABITO, TIMOTHY KRISHER, and SAMI ASMAR
Jet Propulsion Laboratory
Pasadena, Calif.

Radiometric tracking Doppler measurements of the signal transmitted by the Galileo spacecraft using an Ultra-Stable Oscillator (USO) as a frequency reference have been acquired by antennas of the NASA Deep Space Network (DSN) between Dec. 1989 and Nov. 1991. These measurements serve two purposes; 1) the scientific investigation of the gravitational redshift phenomenon as the spacecraft moves in and out of the gravitational fields of massive bodies in the solar system, as predicted by Einstein's theory of general relativity, and 2) engineering evaluation of the USO frequency and frequency stability for calibration purposes, and to evaluate the health and performance of the USO. These calibrations serve as a baseline for Radio Science experiments, such as the Redshift Observation and occultations of Jupiter and its satellites.

The USO is a dual oven-controlled oscillator with an AT-cut quartz crystal (SiO_2) resonator. The output frequency of 19.124980 MHz is multiplied by 120 to produce the transmitted signal frequency (2294.9976 MHz).

There were 82 data acquisition passes conducted between launch (Oct. 1989) and Nov. 1991. Each pass consisted of about two hours of Doppler data sampled at one per sec_t received by the DSN antennas using Hydrogen-masers as frequency and timing references. The Doppler were converted into estimates of spacecraft transmitted frequencies and frequency residuals after removal of the spacecraft trajectory and other effects.

The USO-referenced frequencies showed a significant positive logarithmic increase shortly after initial turn-on, which is probably due to the liberation of contamination on the crystal vibrator surfaces acquired during the long period of inoperation prior to launch. A least-squares fit to an aging model (combination logarithmic curve/linear drift) was applied to the estimated frequencies of the 76 passes acquired during the first in-flight USO on-off cycle (Dec. 1989 to Aug. 1991). The residuals showed a large systematic variation shortly after initial turn-on. Since the aging behavior during this period is complex, the first twelve passes were removed, and the model was fit to the remaining 64 passes. The resulting post-fit residuals showed no significant systematic variation. It is believed that the variations of the 17 mHz rms residual scatter are due to the random walk of the USO or possible unknown mismodeling. It took a little over a year of continuous operation before the USO reached its linear aging realm (-5.6×10^{-12} Hz/day). The USO was powered-off and back on in Aug. 1991 with no adverse effect on its performance.

The average Allan deviations at 1-s and 10-s correlate well with spacecraft range, and fall as τ^{-1}. This is consistent with white PM noise dominating at these time scales due to the low SNR's expected from using the Low Gain Antennas. The Allan deviations at 100-s and 1000-s agree with pre-flight USO stability results at these time scales. The Galileo USO appears to be healthy and functioning normally.