A STUDY OF ORBIT ESTIMATION FOR A SPACECRAFT BY USING DIFFERENCED RADIOMETRIC DATA

Tsutomu Ichikawa
JAXA, 3-1-1 Yoshinodai Chuo-ku Sagamihara Kanagawa 252-5210 Japan,
Phone+81-50-3362-3468*, Email: ben`isas.jaxa.jp*

Keywords: *Orbit estimation, Sensitivity analysis, Delta-DOD, Estimator*

ABSTRACT

An approximate orbital elements (state vector) analytic model for Earth-based range measurements is presented and is used to derive a representative analytic approximation for differenced Doppler measurements. The analytical models are tasked to investigate the ability of these data types to estimate spacecraft geocentric angular motion, the station's clock and frequency offsets, and signal-path calibration errors over a period of a few days, in the presence of systematic station location and transmission media calibration errors. Sensitivity analysis suggest that a few delay calibration errors are the dominant systematic error source in most of the tracking scenarios investigated; as expected, the differenced Doppler data were found to be much more sensitive to some calibration errors than difference range. In this paper, it is described sensitibity analysis for orbit estimation by the analytical model.

Out line

The mathematical models for approximating the differenced range and Doppler measurements were based on the assumption that spacecraft geocentric angular coordinates remained constant over time – a reasonable assumption given that the performance characteristics of these types were investigated for a single tracking pass alone.

In this analysis, the information content of the tracking passes is investigated, with the spacecraft angular coordinates assumed to vary linearly with time. What follows is a detailed derivation of a six-parameter differenced range and Doppler observable model, which is used to assess the performance data types under a variety of tracking scenarios. Despite the fact that realistic navigation operations scenarios are not investigated here, due to the relatively short data arc lengths assumed, the station combination, and the absence of line of sight data such as two-way Doppler or range, the resulting analysis does provide some useful insight into the merit and potential of the differenced data types for navigation purposes. Namely, "DOR(Differential One-way Range)" techniques have some operational advantages over the Delta-DOR techniques of delta differenced one-way range (Delta-DOR) and delta differenced one-way Doppler (Delta-DOD) in that differenced data can be acquired without interruption of spacecraft command and telemetry activities – a characteristic that may prove invaluable during periods of the approach of the approach phase preceding planetary encounters or spacecraft maneuvers. Despite the operational shortcomings of Delta-DOR and Delta-DOD, it must be acknowledged that they are, for the most part, self-calibratioting data types and are therefore less dependent upon accurate externally supplied calibrations of various potential error sources.

In this paper, it introduce the orbit estimation for some focuses as following.

1. Observation model

The mathematical models presented here account for effects due to observing platform and transmission media errors on the differenced data types. The angular motion of an interplanetary spacecraft is nearly linear, hence, the angular rate coordinates of the spacecraft are assumed to be constants for this analysis. The differenced range do impact the differential Doppler model; consequently, the observation partial derivatives required for information content and sensitivity analysis become more involved computationally.

2. Information Content analysis

The partial derivatives of any data type represent, to first order, the ability of that data type to sense changes in a spacecraft trajectory.

The information content of a particular data type is effectively described by the characteristics and behavior of its partial derivatives, and refers to the ability of a data type to determine the various elements that constitute a spacecraft trajectory model.

In this section, it is described Differenced radiometric partial delivatives and analysis in detail. And the estimator is defined Kalman type batch sequential filter.

No a priori statistics were assumed for the spacecraft angular coordinate parameters to be estimated by the filter. It is described Differenced range and Doppler derivatives and error analysis by using the covariance in this section.

3. Sensitivity analysis

A useful analysis is the sensitivity matrix method, which is frequently used in orbit determination error analyses and provides a means to distinguish among the effects of several different unmodeled systematic error sources on the parameter estimates. Knowledge of the sensitivity matrix enables one to compute the full-consider error covariance matrix, which accounts for the computed uncertainty due purely to random measurement noise plus the uncertainty induced by unmodeled consider parameters.

4. Result

In the typical case is shown as following. It is assumed that a orbit is approximately 1.3 AU distance from the earth. Estimation statistics for the two stations baseline are summarized in Fig.1, in which identical assumptions on data sampling rate and measurement accuracy characteristics are made as for the USUDA-CANBERRA study, as well as on a priori statistics.

Results suggest that the differenced data types can together deliver about 0.2 to 0.5 μrad precision for the geocentric angular coordinates and about 3×10^{-12} to 40×10^{-12} rad/s precision for the angular rates, at the conclusion of five successive tracking passes.

To provide a reference point for comparison with the differenced range and Doppler results, angular precision and angular rate precision estimates were computed for both Delta-DOR and Delta-DOD data acquired from single baseline over a period of a few days.

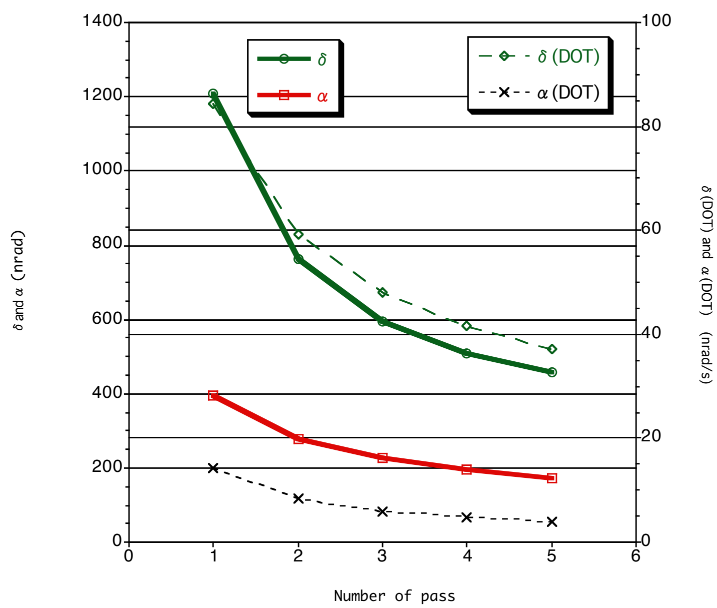

Figure. 1 Differenced Dopp.+Range angular