A Study of the Navigation for a Spacecraft by Using the Reduced order Filter

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The error budget analysis is presented which quantifies the effects of different error sources in the Earth-based orbit determination process when the orbit estimation filter is used to reduce radio metric data. The estimator strategy differs from more traditional filtering methods in the nearly all of the principal ground system calibration errors affecting the data are represented as filter parameters.
Error budget computations were performed for a Mars mission interplanetary cruise scenario for cases in which only X-band Doppler data were used to determine the spacecraft’s orbit, X-band ranging data were used exclusively, and combined set in which the ranging data were used in addition to the Doppler data. Random nongravitational accelerations were found to the largest source of error contributing to the individual error budgets.

OVERVIEW

The reduced order sequential filtering strategy currently under study is the orbit estimator, in which most if not all of the major systematic ground system calibration error sources are treated as filter parameters, along with the spacecraft trajectory parameters, along with the spacecraft parameters. The motivation behind the filter is not so much to improve upon the a priori ground system calibrations, but to incorporate a more accurate model of the world in to the filter.

Reduced-order filter

It is implicitly assumed in the development of the filter equations that exact descriptions of the system dynamics, error statistics, and the measurement process are known. Use of reduced order filtering techniques allows the analyst to obtain estimates of key parameters of interest, with reduced computational burden and with moderate complexity in the filter model. Thus, reduced order, or , suboptimal, filters are result of design trade-offs in which the designer performs a sensitivity analysis to determine which sources of error are most critical to overall system performance. Restricting the discussion to the filter measurement update equations, the mathematical model presented this paper is the covariance form of the measurement update for scalar measurements.

RESULT

The orbit estimation statistics were propagated to the nominal time of Mars encounter and expressed as dispersions in a Mars centre aiming plane, or B-plane, coordinate system specifically, the one-sigma magnitude uncertainty of the miss vector, resolved into the respective miss components B・R and B・T, and the one-sigma uncertainty in the linearized time of flight. In some cases, the errors were expressed as dispersion ellipses in the B-plane to graphically illustrate the contributions of the most statistically significant groups of error sources.

In the typical case in which both Doppler and ranging data were used, the B・R component of the miss vector to about 10 km and B・T component to about 4 km, with the linearized time of flight determined to approximately 3 sec. B-plane dispersion ellipses are shown in Fig.1, illustrating the contributions of the major error source groups to the total RSS error and the orientation of the ellipses in the B-plane. In this case, the accuracy with which the range component at encounter was determined was roughly 12 km.

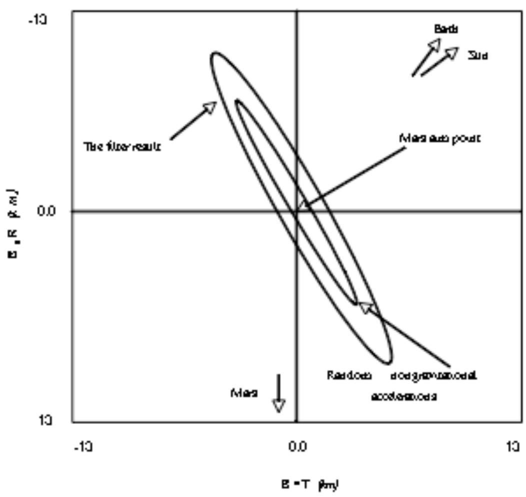

Fig. 1. The error ellipse on the B-plane for X-band 2-way Doppler plus ranging at closest approach