ORBIT DETERMINATION FOR A SPACECRAFT BY USING THE MODIFIED ESTIMATOR

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ABSTRACT

Out line

Development of improved navigation techniques which utilize radiometric (Ranging and Doppler) data acquired from some ground stations have received considerable study in several years, as these data types are routinely collected in tracking, telemetry, and command operations. A sequential data 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 estimated parameters, along with the spacecraft trajectory parameters. This strategy differs from current practice, in which the ground system calibration error sources are represented as unestimated bias parameters, accounted for only when computing the error covariance of the filter (estimator) parameters.

This article reviews the fundamental concepts of reduced-order filtering theory, which are essential for sensitivity analysis and error budget development. The theory is then applied to the development of an error budget for a Venus mission cruise scenario in which enhanced orbit estimation is used to reduce X-band Doppler and ranging data. The filter model is described and error budgets are given for two different strategies: X-band Doppler only, X-band Doppler plus ranging.

For this study, the filter model is assumed to be correct representation of the physical world.

In this paper, we introduce the orbit determination and navigation for two focuses as following.

1. Reduced-order filter

In some navigation applications, it is not practical to implement a full-order or the optimal filter when system model, with all major error and noise sources, is of high order.

Use of reduced-order filter 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 results of design trade-offs in which sources of error are most critical to over all system performance. Nevertheless, there are reasons for not always using a full-order optimal filter for spacecraft orbit estimation.

1) Estimator evaluation

There are a number of error analysis methods which can be used to evaluate estimator (filter) models and predict filter performance. Reduced-order error analysis techniques enable an analyst to study the effects of using incorrect a priori statistics, data-noise/data-weight assumptions, or process noise model on the filter design.

2) Optimal and suboptimal estimator

Restricting the detail discussion to the filter measurement up-date equations, the mathematical model presented in this paper is the estimator form of the measurement up-date.

2. Observation strategy and the estimator

1) Observation strategy

Observation data acquisition plan is assumed, containing several passes of two-way Doppler and ranging data per week. And also, the data schedule consisted of about 6 hours tracking pass of two-way

Doppler and of about 2 hours tracking pass of two-way range from USUDA station basis from PE (Planet encounter) – 30 days to PE-10 days. Typical case is Venus encounter.

2) The estimator

The parameters which make up the filter model, along with a priori statistics, steady state uncertainties for the Gauss-Markov parameters, and noise densities for the random-walk parameters. All of the parameters were treated as filter (estimator) parameters and grouped into three categories: spacecraft epoch state, spacecraft nongravitational force model, and ground system error model. Effects of uncertainty in the ephemeris and mass of Venus were believed to be relatively small in this scenario.

The simplified spacecraft nongravitational force model was used. There were filter parameters representing solar radiation pressure (SRP) forces as well as small anomalous forces due to gas leaks and attitude control thruster misalignments, and so on.

3. The error values

The typical case in which both the 2-way Doppler plus ranging data were used, the $\mathbf{B} \cdot \mathbf{T}$ component of the miss vector was determined to about 6 km and the $\mathbf{B} \cdot \mathbf{R}$ component to about 5 km at closest approach to Venus.(See Fig.1)

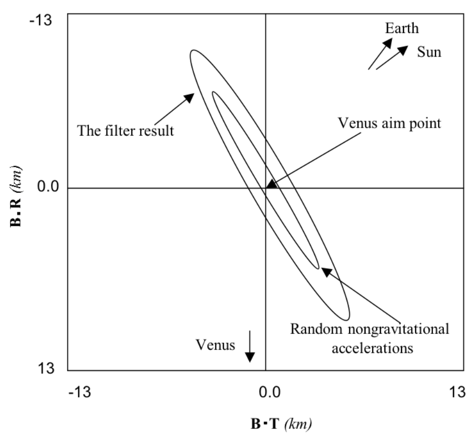

Fig.1 The error ellipse on the B-plane for X-band 2-way Doppler plus ranging at closest approach

4. Conclusions

A sensitivity analysis was conducted for a reduced-order filter referred to as the enhanced orbit estimation filter. In practice, the enhanced filter attempts to represent all or nearly all of the principal ground system error sources affecting radiometric data types as filter parameters. A reduced-order filter technique were reviewed

utilized to perform the sensitivity analysis, and, in particular, to develop navigation error budgets for two different data acquisition strategies.

Error budget performed for the assumed mission strategy revealed that the most significant error source for two data-acquisition strategies studied was spacecraft random nongravitational accelerations, indicating that, for the reference error model, the enhanced filter is most sensitive to mismodeling of small anomalous forces affecting spacecraft. These results suggest that if high-precision navigation performance is to be achieved, the error sources requiring the most accurate modeling are spacecraft nongravitational accelerations error.