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APPLIED EARTH-BASED ORBIT DETERMINATION FOR THE SPACECRAFT

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 d range. In this paper, it is described sensitibity analysis for orbit estimation by the analytical model.

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, "VLBI" techniques have some operational advantages over the Delta-VLBI techniques of delta differenced one-way range (DOR) and delta differenced one-way Doppler (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 DOR and 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.