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EFFECTS OF FREQUENCY-DIFFERENCE BETWEEN TWO SPACECRAFTS ON SAME BEAM INTERFEROMETRY PRECISION

Abstract

There are many spaceflight applications involving relative positioning of two spacecrafts with the development of deep-space exploration. Sometimes the two spacecrafts are so close angularly as seen from Earth that they may be observed in the same beam-width of an Earth-based radio antenna. Common errors along the four ray paths from the two spacecrafts to two ground stations can easily be reduced by double differencing, so data received at the two stations may be combined to provide extremely precise measurements. This measurement technique is referred to as Same Beam Interferometry (SBI). Furthermore SBI can provide phase delay measurements which can achieve ps magnitude instead of group delay measurements, if the double differencing delay model is precise enough to resolve carrier ambiguity. In a SBI system, each spacecraft is usually required to broadcast tones at more than three frequencies. The frequency-difference between corresponding tones of the two spacecrafts is an important parameter. To guarantee the corresponding tones of the two spacecrafts can be recorded in the same base-band channel as well as distinguished easily in signal processing, the frequency-difference should be chosen carefully. In addition, the frequency-difference also affects the SBI precision as a systematic bias according to our analysis, which may introduce ns magnitude error to the double-differenced delay measurements. However this parameter is usually neglected, and there is still no analysis on how this parameter works and no criterion of how to choose it. This paper is organized as follows: Firstly, SBI signal processing is modeled to derive the double-differenced phase with all errors sources including the frequency-difference; Secondly, the effect of the frequency-difference on the SBI delay precision is analyzed theoretically based

on the double-differenced phase expression; Thirdly, a simulation following the Japanese SELENE signal parameter setting is carried out to show frequency-difference's effect in a real application. In this paper the following conclusions can be drawn: with given delay model precision, frequency-difference may introduce accumulative bias in carrier ambiguity resolution; besides, frequency-difference may also cause error in delay measurements even with no ambiguity resolution bias; algebraic formulas can be derived to describe the relation between the frequency-difference and delay error. The simulation results which tallies with the theoretical analysis shows that the delay error can reach 0.25ns when the frequency-difference is less then 30MHz. So the selection of frequency-difference is crucial and should be done with the consideration of the system demand and delay model precision.