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A Model of Relation between Fluctuation of Double Differential Total Ionospheric Electron Content and Angular Distance of the Two Satellites Observed by Same-beam VLBI† ⋆

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Abstract Time delay and phase fluctuation are produced when the signals of a spacecraft are transmitted through the ionosphere of the earth, which give rise to a great influence on the measurement precision of VLBI (Very Long Baseline Interferometry). Using the 1-year same-beam VLBI data of 2 satellites (Rstar and Vstar) in the Japanese lunar exploration project SELENE, we obtained a model of the relation between the fluctuation of double differential total electron content in the ionosphere and the angular distance of the two satellites. For the 6 baselines, the root mean square r of fluctuation (in units of TECU) and the angular distance of the two satellites θ (in units of °) has a relation of $r = 0.773\theta + 0.562$, and for the 4 VLBI stations, the relation is $r = 0.554\theta + 0.399$ from the baselines inversion. The results can serve as a reference for the derivation of differential phase delay and for the occultation observation and study of planetary ionospheres.

Key words astrometry: Very Long Baseline Interferometry (VLBI), ionosphere, methods: data analysis, methods: statistical, instrumentation: SELENE

1. INTRODUCTION

Under the actions of the solar UV emission, X-rays, energetic particles, as well as the cosmic rays, the partial high-layer atmosphere of the earth is ionized to form an ionized region,

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namely the terrestrial ionosphere. The ionosphere makes the electromagnetic wave propagating in which change its propagation velocity and curve its propagation path, so that the propagation time of the electromagnetic wave has an extra delay, and the phase has a fluctuation, making a very large influence on the accuracy of VLBI (Very Long Baseline Interferometry) measurement. The VLBI measurement is sensitive to the variation of satellite orbit in the direction perpendicular to the line of sight[1], which can help to improve the accuracy of satellite orbit determination. The same-beam VLBI indicates that the main beam of the radio telescope is used to receive simultaneously the signals from two spacecrafts to obtain the correlation phases and make differences, so that most of the influence caused by the atmosphere, ionosphere, and device can be eliminated, more accurate differential phase delay data can be obtained to upgrade the orbit determination accuracy of two spacecrafts[2−4]. Although the random error of the same-beam VLBI differential phase delay is extremely small, but the condition of its solution is very rigorous. For example, for the unambiguous solution of differential phase delay, it is required that the rms of differential phase fluctuation should be less than 4.3°[5], and the differential ionospheric effect be less than 0.42 TECU (1 TECU=10^{16} electrons), in particular the ionospheric effect is inversely proportional to the squared frequency, when the differential phase delay is solved by using the differential phases of multiple frequency points, the problem of whole-cycle ambiguities is more easy to happen. On the other side, the same-beam observation is also an important method to study the planetary atmosphere and ionosphere. When the phase fluctuation of the electromagnetic wave from one spacecraft is caused jointly by the atmospheres and ionospheres of a planet and the earth, while the phase fluctuation of the electromagnetic wave from another spacecraft is caused only by the neutral atmosphere and ionosphere of the earth, to make the same-beam observation and to make difference, the effects of the terrestrial atmosphere and ionosphere can be eliminated even better, and therefore can study the properties of the planetary atmosphere and ionosphere with a higher accuracy. However, even for the same-beam observation, it is necessary to carefully study the relation between the differential phase fluctuation caused by the earth atmosphere and ionosphere and the angular distance, in order to evaluate better the accuracy of the satellite occultation observation of planetary atmosphere and ionosphere.

Based on above reasons, with the one-year same-beam VLBI observation data of 4 stations at the 2212 MHz single frequency point on the Rstar and Vstar satellites, we have studied and obtained the model for the relation between the atmospheric differential phase fluctuation and the corresponding angular distance[6]. In this paper, using the three frequency-point signals of 2212, 2218, and 2287 MHz, and according to the inversely proportional relation between the ionospheric effect and the squared frequency, we have derived firstly the relation model between the rms of double differential ionospheric total electron content (TEC) fluctuation and the angular distance, including the relation model between the rms of double differential ionospheric TEC fluctuation and the angular distance