THE MULTI-GNSS SIGNAL VISIBILITY ANALYZATION FOR AUTONOMOUS NAVIGATION IN THE CHANG'E 5T1 MISSION

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The three months mission period of Chang'E 3 (CE3) leads to a high cost of manpower and finance in Beijing Aerospace Control Center (BACC) because of the dependence on ground-based measurement and control system. According to China's Lunar exploration program structure, the future lunar probe will return to Earth with soil samples, which means that the mission period will be longer. BACC has to search for an autonomous and low cost approach to be competent for the future missions. The Global Navigation Satellite System(GNSS) is one of those open options which can alleviate the burden. However GNSS signals are designed for users on or near the surface of the Earth, which means the transmitting antennas are earth-oriented and the signal power is limited. only the signals from 'the other side' of the Earth can be received from above the constellations and the visible GNSS signals radiate from a narrow cone centered in the direction of the Earth. It is widely acknowledged from decades of researches that few visible satellites, poor Dilution of Precision (DOP) values and low signal power are primary obstacles for space GNSS users. Nevertheless GNSS has been used extensively in High Earth Orbit (HEO) satellites autonomous navigation and applied by NASA in lunar exploration mission because of the development of GNSS receiver and antenna techniques, as well as the blooms of new GNSS constellations in recent years.

The first re-entry test for the Chang'E 5 (CE-5T1) mission was launched at the end of 2014 which declares China's lunar exploration program has marched into the "Sample and return" phase. As a part of the "test", a 16-channle GPS/GLONASS receiver are mounted on board of the CE-5T1 service module and collected data in the cis-Lunar transfer trajectory, Moon-to-Earth trajectory and the second Moon-to-Earth trajectory for totally about 9 hours. The downlink transmission of these data were delayed several hours, so they are primarily used in afterwards precision check of the orbit determination calculation. However, the GNSS data collected in the CE-5T1 mission are valuable for researchers to have a direct and deep knowledge of GNSS signal characteristics received above the GNSS constellations.

This paper analyzes the multi-GNSS signal visibility for a omni zero-gain GNSS antenna mounted on board operating in CE-5T1 service module's Earth-Lunar transfer orbit and Lunar-Earth transfer orbit using a software simulation model whose parameters are corrected using the CE-5T1 GNSS data. The concept of visibility contains two ideas: the light-of-sight is not obstructed, and the received signal power is sufficiently high for the receiver to do acquisition and tracking. Firstly, the CE-5T1 received GNSS data are analyzed to show the signal characteristics including the satellite visibility, Doppler, Signal-to-Noise Ratio(SNR) and DOPs; Then these results are used to correct the GNSS satellite transmitter parameters of a software model which can simulate multi-GNSS (GPS/GLONASS/Beidou/Galileo) signal characteristics all through the flight of CE-5T1. The real ephemeris are used to model the in-operation GNSS satellites; And the un-launched satellites are modeled according to the planned constellation

parameters. Secondly, the unobstructed satellite number, signal power, Doppler and Dops are analyzed; And accordingly a relatively optimal cut-off angle for receiving antenna as well as the most favorable threshold for the space-borne GNSS receiver can be obtained. The GNSS side-lobe signals are used in particular. The numerical results of this paper can be beneficial to the design of space GNSS receivers and new GNSS satellites/signals for the future applications in China's lunar missions.