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Data Transmission Analysis and Communication Scheme Design for TianQin Mission

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ABSTRACT Compared with ground-based gravitational wave detection, space-based gravitational wave detection has become a research hotspot because of its abundant wave sources. However, how to reliably transmit the detection data, obtained by the space gravitational wave detector, back to the ground station from a distance of 10^7 kilometers is a huge challenge. In this paper, the visibility analysis and link budget are carried out for the data transmission of gravitational wave detection in geocentric orbit space, and a high real-time data transmission scheme is provided to support the mHz band gravitational wave detection. In more detail, we firstly establish a theoretical model for visibility analysis and link budget based on spacecraft dynamics model and communication link model. Secondly, through visibility simulation and calculation, we obtained the average communication time per day, and found that the Zhuhai station has a more uniform distribution of communication time compared with other ground stations. Subsequently, the link budget model indicates that link performance is largely determined by various gains and attenuations during the link process, which are related to the link working frequency band and resource allocation. Comparing the differences on gain and attenuation between X-band and Ka-band, we design an X-band communication scheme with the transmission rate of 1Mbps and bit error rate of 10^{-5} . The calculation results also show that the communication scheme has a C/N_0 margin of 4.10 dB, which meets the data transmission requirements of TianQin. Finally, the research shows that compared with the heliocentric orbit of LISA, the geocentric orbit of TianQin has obvious advantages in transmission delay, communication time and real-time performance of data transmission, avoiding the antenna pointing issues and is more conducive to the multi-messenger detection of large astronomical events.

INDEX TERMS gravitational waves, link budget, satellite communication, visibility analysis

1. INTRODUCTION

Albert Einstein proposed the general relativity in 1916. One of the ideas is that the asymmetric motion of mass will cause ripples in the gravitational field, whose space-time distortions propagate at the speed of light, called gravitational wave (GW). In 2016, Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that it had successfully detected GW from two stations on the ground for the first time on September 14, 2015 [1]. This is the first time that humans have directly observed gravitational wave. In 2017, LIGO and VIRGO announced that three distant gravitational wave detectors detected GW almost simultaneously on August 14, 2017

[2]. However, due to the limited arm length, gravity gradient noise, and seismic noise from the ground, the detection frequency band of ground-based gravitational wave detectors cannot be extended to a lower frequency range. Compared with ground detection of GW, space gravitational wave detection has obvious advantages in terms of wave source type, quantity, signal strength, detectable space distance, etc., and it is an irreplaceable observation method for gravitational wave astronomy research. Therefore, the detection of space GW has become a hot spot in the field of space science detection. Laser Interferometer Space Antenna (LISA) is an all-sky monitor to unveil the Gravitational Universe by detecting

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