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Simulation-Based Evaluation of Crosslink Radio Occultation for Lunar Ionosphere Observations

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The lunar ionosphere is a ~100 km thick layer of plasma surrounding the Moon. Despite knowledge of its existence for decades, the structure and dynamics of the lunar plasma remain a mystery due to lack of consistent observational capacity. An enhanced observational picture of the lunar ionosphere and improved understanding of its formation/loss mechanisms is critical for understanding the lunar environment as a whole and assessing potential safety and economic hazards associated with lunar exploration and habitation.

To address the high-priority need for observations of the electrically charged constituents near the lunar surface, the Radio Instrument Package for Lunar Ionospheric Observation (RIPLIO) mission is being developed. RIPLIO would consist of a multi-CubeSat constellation (at least two satellites) in lunar orbit for the purpose of conducting "crosslink"radio occultation (RO) measurements of the lunar ionosphere. This work builds off the concept study for RIPLIO and presents enhanced RO simulations, implementing more realistic models of the lunar ionosphere.

We have constructed models to simulate ionospheric plasma behavior under various heliophysical conditions, including periods when the Moon is exposed to solar wind and when it orbits within Earth's magnetosphere. The lunar ionosphere models include: an exponential decay model ("Luna 19 fit"), a 3-D photochemical model and the "ARTEMIS model"based on statistical averages of ARTEMIS in-situ observations.

The RO simulations compute the differential phase delay of a dual-frequency radio signal propagating in the modelled lunar ionosphere. Initial results show differential phase delay ranges, depending on frequency pairs, from 10^0 to 10^3 cycles within Earth's magnetosphere and from 10^{-2} to 10^1 cycles under solar wind conditions, suggesting that lower HF signal frequencies and larger frequency spacings (a few MHz) are most responsive to lunar plasma.

The results of this work help in narrowing down the system and operational requirements for RIPLIO, including optimal radio frequency ranges, atomic clock stability, antenna specifications, attitude control subsystem and cost estimates for a mission life cycle. A thorough feasibility study including extensive lunar RO simulations and potential selection of orbital configurations will stem from this preliminary work.

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Keyword-2

Radio Occultation

Keyword-3

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