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AN ANALYSIS OF CONSTELLATION CONFIGURATIONS FOR A LUNAR NAVIGATION
SATELLITE SYSTEM

Abstract

In the interest of exploring Earth's Moon and expanding sustainable space exploration, a constellation of lunar satellites would provide critical, reliable, and accurate communications and navigation information and services for future lunar missions. Such a constellation would support navigation on the lunar surface, provide localized communication for lunar missions, and reduce the necessity of complex communications and navigation equipment for individual missions (thereby increasing cost-efficiency and making lunar exploration more accessible).

This paper will detail an analysis of different types of constellation configurations for communications and navigation purposes with specific emphasis on the usage of established "lunar frozen orbits". The analysis was originally undertaken as a compulsory component of a graduate level course at Carleton University in Ottawa, Canada. The analysis is completed using Systems Toolkit (STK), and MATLAB, and will compare the coverage of different combinations of constellations and ground stations, considering cost and applicability to communications and navigation objectives.

There exists a variety of methodologies and strategies for designing satellite constellations, with certain types and variations being more desirable for particular applications such as communications and navigation. Certain configurations of Walker delta, Flower and "Below the horizon" constellations were deliberately selected for this study to compare coverage at particular areas of interest or within other established coverage constraints.

Further, in orbit about the Moon, there is the additional challenge of finding stable orbits in the field of gravity which is neither as strong nor as consistent as that of the Earth. There are four known "lunar frozen orbits", which are orbital inclinations where a satellite can stay in a low orbit for a long period of time - theoretically indefinitely.

Analysis of two- and three-satellite Walker delta constellations and three-satellite Flower constellations at the four known frozen inclinations (27, 50, 76, and 86 degrees) has been performed. The three-satellite Walker delta constellation which reaches 100% coverage at the lowest altitude is that at 50 degree inclination (approximately 2250 km), closely followed by that at 86 degree inclination (approximately 2350 km). There is a significant difference in altitude which results in full coverage between the two-satellite Walker delta constellations and the three-satellite Walker delta constellations. For a two-satellite Walker delta constellation at 50 degree inclination, 100% coverage is achieved at an altitude of approximately 7700 km.