ENHANCED GPS ACCURACY USING LUNAR TRANSPONDERS. G. A. Konesky, SGK Nanostructures, Inc., 3 Rolling Hill Rd., Hampton Bays, NY 11946-3716, g.konesky@att.net

Introduction: The position measurement accuracy of the Global Positioning System (GPS), as well as similar satellite-based systems (Glonass, Galileo), depends on how well the ephemerides of these satellites are measured [1]. The process of determining these ephemerides involves ranging to and from stations located on the surface of the Earth, in addition to checks for consistency between satellites. Variations in atmospheric effects from the ionosphere and troposphere, especially in refraction, are often unpredictable and can result in ephemeris errors of several meters [2].

Placing one or more transponders on the Moon [3] and ranging to and from it eliminates any atmospheric-induced errors. The ephemeris of the Moon is well-established and its orbit is not significantly changed by solar wind and radiation, as GPS satellites are. A radio or optical pulse would be sent from each GPS to the lunar transponder periodically, and the transponder would echo back its response. The round trip delay, minus the latency response time of the transponder, would provide the GPS satellite with a distance to the previously known position of the lunar transponder.

We first consider placement strategies of transponders on the lunar surface. A significant advantage of the synchronous rotation of the Moon is that only a small number of transponders are needed since one side of the Moon always faces Earth. If the transponders are solar powered, it would also be desirable to locate them so at least one is always in sunlight. Examples of these locations include the poles [4] of the Moon, and opposite edges of the lunar disc as seen from Earth [5].

Tradeoffs are next considered in terms of radio [6] versus optical [7] ranging pulses between the GPS satellite constellations and the lunar transponders. Issues include aperture, transmitter power and receiver sensitivity, and pointing accuracy, using a link margin approach. High available bandwidth [8] is usually the determining factor in selecting an optical approach. However, in this transponder application, the high gain afforded by a relatively small aperture is more important, and is given by:

$$G_a = 10 \log_{10} (\pi D / \lambda)^2 \qquad (1)$$

Where G_a is the ideal gain, expressed in dBi, D is the aperture diameter and λ is the wavelength. A 25 cm (10 inch) aperture, for example, will produce almost 120 dBi gain at a wavelength of 830 nm. A 10 meter aperture operated in the microwave S-band, for comparison, provides less than 50 dBi gain.

In addition to compact physical size, the high gain with small aperture afforded by an optical approach implies that the transmitter power can be significantly reduced, both on a given GPS satellite, and on the lunar transponder. This has ripple-down effects on other parameters such as required solar array area, and ultimately payload launch weight. Every pound saved on payload delivered to the lunar surface saves on the order of about 1000 pounds in launch vehicle weight [9].

One drawback of an optical approach is target acquisition and tracking due to the relatively narrow beam footprint. Wide beam search and then narrow beam lock-on procedures have been used [10] effectively. Additional considerations include long term operation of the transponders in the lunar environment, and battery reserves to maintain proper internal temperatures during the roughly two week long lunar night. Other optical considerations include the need to add backscattered sunlight from the lunar albedo [11] to link margin calculations (as seen from a GPS satellite), and the need to protect optics from lunar dust and micrometeorite hazing.

References:

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