Geophysical Research Abstracts
Vol. 16, EGU2014-10844, 2014
EGU General Assembly 2014

Using the synergy between ranging, data- and time-transfer: How a future GNSS system can look like

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Ranging, data- and time-transfer are all based on an exchange of electromagnetic signals, with the need of slightly different additional information. In this contribution we discuss how synergy between these different techniques can be exploited to support various space applications. From the point of view of data-transfer there is a demanding need for high data rates. Growing data volumes are in contradiction with short contact times of low orbiting satellites (LEO). This discussion led to ESA's concept of the EDRS (European Data Relay Satellites) constellation, where the data of LEOs is transferred to up to three geostationary satellites (GEO) by a high rate optical two-way link and from there transferred to ground. ESA's ranging concept to support LEO missions is based on the Galileo satellite navigation system which in the future will be equipped with precise intersatellite ranging links. Looking at the error budget for LEO orbits, the intersatellite links will result in better GNSS satellite orbits and GNSS clock synchronization, leaving however the error contribution of LEO clock synchronization and phase center variations and offsets of the sending and receiving antennas unchanged. This gap can nicely be filled considering the synergy to data- and time-transfer. In the ESA study GETRIS (GEodesy and Time Reference In Space) we examined how a GEO constellation equipped with an atomic clock must look like to support LEO precise orbit determination based on GNSS tracking: A minimum constellation of five GEOs is needed, as two GEOs have to track a LEO at the same time, and the ranging of GEOs below the LEO's local horizon is required to allow tracking also above the poles. The biggest challenge is the required accuracy of the GEO orbit, even if considering tracking side lobes of GNSS signals. Our study concludes with the demonstration of the necessity for a joint concept for data-, time-transfer and ranging. This concept can be based on GEO satellites integrated into the Galileo constellation, or a Galileo constellation optimized for data transfer. From the point of view of a time reference in space both system concepts have to be studied with respect to their capability to determine accurate velocity and position in the potential of the clock. For the last aspect it is worth to mention that the two-way tracking has the potential to routinely determine the gravity field on a daily basis.