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Novel accelerometer concepts for satellite gravimetry and their impact on the performance of gravity field determination

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Satellite-based gravimetry has proven vital to the determination of the earth's global gravity field. The spectral range of these observations, however, is limited mainly due to the height-dependent attenuation of the gravitational signal. This is especially unfavorable for the retrieval of its time-variable components, as their amplitudes lie several orders of magnitude below those of the static part. Since the precise determination of the time-variable gravity field shall be the main focus of next generation gravity missions and signal attenuation cannot be avoided, a set of instruments with the best possible performance has to be implemented. Regarding instrument errors, accelerometers, which are used to retrieve non-gravitational disturbing forces acting on the satellite, are currently the dominant error source of time-variable gravity field solutions.

So far, an electrostatic accelerometer (EA) has been implemented in every dedicated gravity mission. The EA technology, however, seems to have nearly reached its maximum potential. The degraded accuracy in the low frequencies below the measurement bandwidth, which is mainly caused by thermal noise and is thus an intrinsic effect of this measurement technique, limits the potential of further major improvements in its overall performance. Therefore, research is turning towards the development of different types of accelerometers that can be used in space applications.

Recently a hybrid instrument consisting of a regular EA and a novel cold atom interferometer (CAI) has been developed by ONERA. Compared to the EA the CAI features a frequency-invariant measurement accuracy, but due to current restrictions in technology cannot yet reach a similarly low level of noise as the EA in its designated measurement band, thus making a combination that utilizes each instrument's advantages (low frequency measurements shall be retrieved from CAI observations while the EA is responsible for high frequency ones) the best possible solution for the time being.

A different approach is taken by the German Aerospace Center in collaboration with the Chair of Space Technologies of the University of Bremen, who propose the use of an opto-mechanical instrument. Currently, this type of accelerometer cannot reach the EA's peak accuracy either, however, it offers other advantages like exceptionally small size and equal measurement accuracy in all spatial directions as well as a (in parts) more favorable frequency-dependent accuracy behavior in comparison to an EA.

In this paper, at first the advantages and drawbacks of each accelerometer type are presented, primarily with respect to their individual performance. Further, selected numerical simulation results for different satellite flight formations (e.g. GRACE-type, Bender-type, and some high-low inter-satellite ranging configurations) under consideration of these novel instruments are presented and discussed. These results allow for an assessment of each instrument scenario's benefit (or drawback) for the reconstruction of the earth's gravity field and its time-variable components.