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Performance of SWaP-C GNSS Modules for Positioning

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Global Navigation Satellite System (GNSS) is now popular for various advantages and is used in myriads of applications with extremely high confidence. Different GNSS positioning techniques and hardware have evolved to fulfill the needs of demanding applications. After the geodetic and OEM receiver boards, compact (<100 gm), low-cost (<1000 USD), single-, and dual-frequency GNSS modules were commercially available from multiple manufacturers, which are also termed as Size, Weight, Power and Cost (SWaP-C) efficient modules. These have clear advantages in cost, size, power requirements, multi-GNSS constellation and signal tracking capability, integration ease with other electronics, and provision for raw GNSS data output. These benefits helped quickly penetrate the location-based application market for the modules in the GNSS. This paper presents the results of systematic and diverse studies on using these modules for research and real-time application development.

Regarding GNSS positioning, SWaP-C efficient GNSS modules concurrently operating with costly geodetic GNSS receivers show similar performances. In the case of Single point positioning (SPP), in GPS-only operation, both the geodetic and compact receiver/ module (uBlox M8T/F9P) showed around 3m 2DRMS values in 2-dimension (2d); in 3-dimension (3d), the dual-frequency module performs similar to a geodetic receiver with SEP values around 1.7 m while the single frequency module offered slightly inferior performance [1].

Exciting results were observed in GNSS Real Time Kinematic (RTK) operation using a uBlox M8T/ F9P, NTL104 modules and a commercial uBLOX ANN-MB patch antenna as the Rover, and a geodetic grade Base station. In GPS+Galileo+QZSS hybrid operation, up to the single baseline distance of nearly 300 km, less than 40 cm 2DRMS 2d solution precision values are obtained. Using only one Base for a long baseline and low-cost, compact module, the Rover offers the scope for overall cost reduction of the RTK infrastructure. The performance of dual-frequency modules as RTK rovers was better than that of the single-frequency modules. In Post-processing Kinematic (PPK) operation, while uBLOX F9P modules are used both at the Base and Rover end, at a baseline length of 2km, below 25cm 2DRMS values were obtained with an overall reduction of RTK infrastructure cost [2]. For Precise Point Positioning (PPP), two CLD modules (uBlox F9P and NTLab 104) showed below 5 × 5 mm horizontal accuracy in GPS+GLONASS operation, which is like their concurrently operating geodetic counterparts [3].

With the clear cost, compactness, and power advantages, this work presents the suitability of SWaP-C GNSS modules for different types of GNSS positioning techniques. The studies point towards the widespread use of GNSS by exploiting its potential for all GNSS stakeholders, especially in cost-constrained situations. The presentation will include the results of these detailed and systematic studies.

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2. A. S. Pillai, S. Mahato, M. Goswami, P. Banerjee, and A. Bose, "Comparison of GNSS Precise Positioning Techniques using Compact GNSS Modules for Test Range Applications", *International Conference on Range Technology 2023 (ICORT 2023)*, February 2023. doi: 10.1109/ICORT56052.2023.10249186

3. A. Bose, S. Mahato, S. Dan, and A. Santra, "Compact, Low-cost GNSS modules for Precise Point Positioning", *MIIGAiK Annual International Scientific Conference*, May 2021. doi:10.1051/e3sconf/202131003001