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Geopotential difference determination using optical atomic clocks via coaxial cable time transfer technique

Zi-Yu Shen and WenBin Shen
School of Geodesy and Geomatics, Wuhan University, Wuhan, China (zyshen@whu.edu.cn)

According to general theory of relativity, two clocks located at different positions A and B on ground with different geopotentials run at different rates. If the clock at A runs faster by dt/T than the clock at B, the geopotential difference between A and B is dW=9.0*10E16 dt/T m2/s2. Thus one can determine the geopotential difference between A and B by comparing the running rates of the clocks located at these two positions. Due to the fact that the present time transfer technique provides time comparison accuracy by higher than 10ps via 100m coaxial cable, and the to-date most precise optical atomic clocks achieve a stability of 10E-18 level, the relativistic geodesy method for determining geopotential may be realizable in the near future. In this study, we proposed, designed and described in detail an approach for determining the geopotential difference between two positions based upon a simulation experiment. We selected two stations A and B whose spatial distance is about 100m and height difference is about 30m. It is assumed that each station is equipped with an optical atomic clock with its instability about 3.2*10E-16/sqrt (Tao) (where Tao is time in second), and these two clocks are priori synchronized. It is noted that such a kind of optical atomic clock with so high a stability was generated in 2013 in USA. The two stations A and B are connected with a coaxial cable for time transfer. In the simulation experiment we first set the true value of the geopotential difference between A and B, and consequently the clocks' running rate difference between A and B can be a priori calculated. Then we generated simulated data sets of time comparison, which are contaminated by various possible error sources. Thereafter we estimated the clocks' running rate difference and the corresponding geopotential difference by least squares estimate using the simulated data sets. Finally the accuracy in determining the geopotential difference using the proposed approach was assessed by comparing the true input value and the estimated one. Our simulation experiment results show that the accuracy is around 0.5m2/s2 (equivalent to 5 cm in height) after a period of observation in four hours. This study is supported by National 973 Project China (grant Nos. 2013CB733301 and 2013CB733305), NSFC (grant Nos. 41174011, 41210006, 41128003, 41021061, 40974015).