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Wang Lihui, Qiao Nan, Yu Le

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Algorithms Used in Restraining Random Noise in Measurements from a Geomagnetic Navigation Magnetometer

Wang Lihui*, Qiao Nan, Yu Le

(Key Laboratory of Micro-Inertial Instrument and Advanced Navigation Technology, Ministry of Education, School of Instrument Science and Engineering, Southeast University, Nanjing 210096, China)

Abstract: Random error compensation is a key to high-precision geomagnetism measurements. A parameterized magnetometer measurement error model was established, where the error parameters are calibrated using different calibration algorithms. The standard least squares (LS) method supposes that random error compensation has a Gaussian distribution; however, random errors in a magnetometer observation equation have a non-Gaussian distribution. The robust total least squares (RTLS) method considers errors in both the coefficient matrix and vector data, with gross errors in the coefficient matrix. The constrained total least squares (CTLS) method calculates the constraint relationships of all error items synthetically, which is suitable for solving the linear optimization problems of associated errors. Owing to the fact that a geomagnetic measurement random error model is seriously sick, the truncated total least squares (TTLS) method was proposed to deal with ill-posed problems, as well as random errors existing on both sides of the observation equation. The simulation results demonstrate that the TTLS can inhibit the pathological effects on the magnetometer measurements well, and that the residual between the real data and the data after TTLS calibration is less than in other calibration results.

Key words: Geomagnetic Navigation Magnetometer, Random error, Ill-posed problem, Least squares (LS) method, Truncated total least squares (TTLS)

1 Introduction

Real-time and highly precise marine magnetic measurements are a key to underwater geomagnetic navigation technologies [1, 2]. Such measurements are mainly conducted using an orthogonal three-axis magnetometer to measure the magnetic intensity in the x, y, and z directions. The measurement accuracy can theoretically meet the demands of navigation; in practical applications, however, the magnetometer measurements are influenced by other factors [3, 4, 5], including magnetic interference, precision errors of the magnetometer, unsufficient geomagnetic observations, and electromagnetic spatial environments. Therefore, the error parameters of a magnetic sensor need to be calibrated and the errors need to be compensated.

The error compensation of geomagnetic measurements is similar to the calibration of a three-axis magnetometer. However, the magnetometer calibration problem is essentially a nonlinear optimization problem [6]. An effective solution to this non-linear problem is obtaining a linearized