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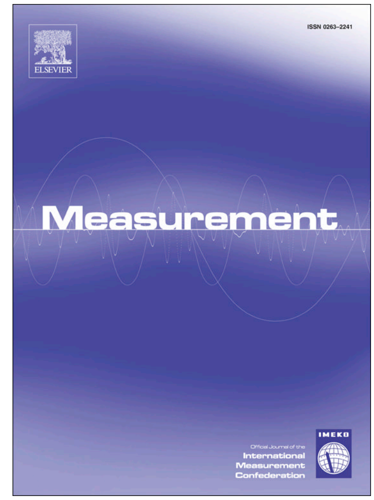

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A Ground-Based Test Facility For Airborne Magnetic Gradient Tensor Instruments Simulating Calibration Flights

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Abstract

Progress is slow in terms of the research and evaluation of calibration algorithms for full tensor magnetic gradient instruments using airborne tests. The main reason is that, based on knowledge gained by actual calibration flights, problems exist regarding high risk, high costs, and long development cycles. In this paper, we describe a ground-based simulation facility for calibration flights which combines the nonlinear aerodynamic model with a magnetic interference model. Environmental magnetic fields can be calculated and produced by tri-axial coils, which are measured by the magnetic tensor gradiometer in calibration flights. Influence from systematic errors and magnetic interference can be extracted from the simulated calibration flight provided by the facility. Compared to system evaluation in airborne operation, this method has the benefit of zero risk, low costs, and short duration of evaluation cycles. In view of ground-based multi-degree of freedom motion platforms, it has the advantages of simple manufacture, good dynamic characteristics, and adaptability to different aircraft types.

Keywords: Aeromagnetic compensation; Calibration flight; Gradiometer; Magnetic gradient tensor; Simulation facility.

1. Introduction

An aeromagnetic survey is an important part of geophysical exploration which is a combination of aviation and magnetic prospecting technology. It has been developed to the stage of measuring the magnetic field and/or magnetic gradient tensor [1]. The magnetic gradient tensor is the spatial variation of the three components of the magnetic field. It has the advantages of resisting the temporal and spatially homogeneous changes in the Earth's magnetic field, high spatial resolution [2], rich information [3] and is widely used in the fields of detection of underground unexploded explosives (UXO) [4], underwater UXO [5][6], mineral and oil exploration [7][8], and magnetic dipole localization [9]-[12]. In addition, since the Earth's magnetic field gradient tensor has often small amplitudes of the order of tenth of pT/m, the magnetic gradient tensor measurement does not have the same disadvantage of extreme sensitivity to the direction of the measurement as is the case for the magnetic field vector, and is especially suitable for being loaded on a moving platform for mapping magnetic anomalies [13]. At present, there are three kinds of magnetic tensor gradiometers suitable for an aeromagnetic survey, which are based on Superconducting Quantum Interference Devices (SQUIDs) [7][8], fluxgate sensors [14] and current-carrying direct string gradiometers [15], respectively.

In an aeromagnetic survey, the magnetic tensor gradiometer is usually carried by an aircraft, and the measurements are affected by two aspects: One comes from the interior systematic error of the tensor gradiometer, such as the scale factor error, offset, non-orthogonal error, misalignment, etc. The other comes from magnetic interference by aircraft, including hard and soft magnetic interference, and eddy-current response, etc. It is necessary to make a full calibration for systematic errors and magnetic interference before actual flight surveys, otherwise valid data will be submerged in the noise.

In order to study how to calibrate errors from the tensor gradiometer and compensate for magnetic interference from the maneuvering of the aircraft or how to evaluate the performance of different calibration methods, there are in general two approaches: First is via actual calibration flights, namely the aircraft carrying a magnetic tensor gradiometer climbs to a region at high altitude where the magnetic gradients are low in amplitude, and the pilot maneuvers according to the planned flight path. This method is suitable for the stage when the calibration method and the aircraft are relatively fixed, instead of the research and development stage, because there is high risk, high cost, and long development cycles, etc. The second approach is to manufacture a magnetic or non-magnetic mechanical ground-based motion platform [16]-[18], that is, to utilize the platform to partly simulate magnetic interference caused by the maneuvers of the aircraft during the high-altitude flight. The mechanical simulation platform has three types of shortcomings: First, the multi-degrees of freedom motion platform adopts a mechanical structure, which commonly has the problems of slow response and difficulty simulating the eddy-current magnetic interference due to the aircraft's dynamic interaction with the