UAV Magnetic Measurement System for Regional Geomagnetic Survey

Dai Jialong¹*, Huang Kui¹, Xu Chaoqun¹, Zhang Shaohua¹, Yi Zhong¹, Meng Lifei¹, Xiao Qi¹, Liu Chaobo¹, Wang bin¹, Zhang Chao¹

¹ Beijing Institute of Spacecraft Environment Engineering, Beijing, 100094, China

*Corresponding author’s e-mail: npujxfb@163.com

Abstract. Commercial UAV airborne magnetic measurement is suitable for regional geomagnetic measurement in terms of its quickness, convenience, efficiency and easy maintenance. The airborne payload performance, weight and volume are often considered for cost and load design during aviation flight. Due to the small size and limited space of commercial drones, it has a very large impact on magnetic survey. Under the constraints of limited space, the performance of the magnetic field detection payload itself and the magnetic properties of the platform become the main factors that restrict the accuracy of magnetic field detection. This paper introduces the high-precision fluxgate magnetic field detector as the three-direction vector payload of magnetic field detection, and expounds its working principle and its high-precision magnetic field detection method. Based on the analysis of payload working environment and detection modes, the on-board magnetic measurement system of the regional geomagnetic survey is designed.

1. Introduction

Aviation geophysical exploration is an important branch of geophysical exploration. It combines geophysical exploration technology with aviation technology. The essence of aviation geophysical exploration is to load geophysical exploration equipment on an aeronautical aircraft. Before acquisition and study, measurement and data acquisition were completed in the air. Commonly used magnetic measurement methods include aeromagnetic survey and ground high-precision magnetic survey. Domestic aeromagnetic survey generally selects large aircraft. For flight safety considerations, the general flight altitude is 1000 meters from the ground surface. The speed is generally several hundred kilometers per hour. Therefore, the advantage of aeromagnetic survey is that the collection efficiency is high. The disadvantage is that due to the influence of the flying height and speed, the reflected geological effect resolution is low. The ground high-precision magnetic measurement relies on manual operation. The acquisition speed is affected by the walking speed and surface conditions, for this reason the large-scale work cannot be carried out. It is very slow and inefficient. However, the work can reflect the geological effects of the ground with high resolution.

The UAV (Unmanned aerial vehicle) airborne detection system is characterized by miniaturization, intelligence, light weight, small size, low cost and strong endurance. It is easy to transport and use. It has high manoeuvrability and can be measured in complex terrain areas. It can also maintain a low flying height in survey. The UAV aeromagnetic combines the advantages of high-precision magnetic survey and aeromagnetic survey on the ground. It can locate the data quickly, efficiently, and accurately. It can work at a large scale and reflect the geological effects of the ground with high
resolution. The ability to eliminate the effects of disturbances and undulating terrain on the ground surface has received widespread attention from the world's aviation geophysical organizations [1].

With the continuous development of unmanned aerial vehicle (UAV) technology, the use of a small flight platform such as a commercial drone to carry aeronautical electromagnetic measurement payload has become a new trend. The application prospects of commercial drones are widely, and they are favored by private capital and develop rapidly. At present, all countries in the world are actively expanding the application range of commercial drones, which plays a role in the fields of power, communications, meteorology, agriculture, forestry, oceans and exploration.

Vector magnetic field detection is an important method of aeromagnetic measurement. Currently, the aeromagnetic magnetic field vector measurement detectors are arranged on the outer extension mechanism of the aircraft. In order to avoid the magnetic measurement detector from being interfered by the magnetic field of the aircraft itself, the distance between the probes and the body of UAV are increased.

Commercial UAV is applied to aerospace magnetic surveys because of its low cost, portability, and ease of rapid networking. The performance of magnetic field detectors and the magnetic interference of the aircraft itself have become an important factor limiting the accuracy of magnetic field measurement. How to improve sensor performance and eliminate magnetic field interference cost-effectively is a problem that must be solved on the road of efficient and low-cost commercial UAV magnetic field detection. Aiming at the structure and flight characteristics of commercial drones, this paper designs a set of three-axis magnetic field vector detection system on UAV platform to meet the high-precision detection requirements of magnetic fields [2].

2. Airborne magnetic load technology
The magnetic field vector detecting device adopts a three-axis magnetic field probe based on the fluxgate principle as a sensor. The probe combined with a high integrated and high sampling rate magnetic field signal collecting device by 1.2 m long boom. They are all installed under the commercial drone body, the distance between the probe and the drone body reduces magnetic interference.

The fluxgate magnetic field detector uses the Faraday's law of electromagnetic induction combined with the properties of the magnetically permeable material to realize magnetic field detection. Driving circuit is used to apply an alternating current to the excitation coil, which generates a magnetic field due to the change in current. The magnetic fields inside the spiral ring cancel each other out. Under the action of the external magnetic field, when the high magnetic permeability material is saturated, the internal magnetic field makes a corresponding alternating current change, and the alternating magnetic field generates an alternating electric field on the induction coil. Theoretically, an excitation signal with a frequency of f produces a 2f induced signal on the induction coil [3][4].

The three-axis fluxgate detector is widely used in high-precision magnetic field vector measurement because of its high measurement sensitivity, compact size, light weight, and vector measurement. It is a commonly equipment for aeromagnetic [5].

3. Detection system design
The commercial UAV aeromagnetic measurement system consists of an external long boom probe system, an unmanned aerial high integrated digital acquisition system, and a portable magnetic measurement data receiving and processing system. The commercial drone has the characteristics of simple structure, small size and low cost, and is suitable for multi-machine formation networking flight.
Commercial Drone Magnetic Measurement System

Fig. 1 Commercial UAV aeromagnetic measurement system diagram

The entire system adopts a lightweight design to ensure that the UAV load weight is less than 3kg, which fully guarantees the flight stability and the suitability of the multi-machine formation.

3.1 External long boom probe system

The UAV platform is equipped with an externally mounted extension structure to keep the detector probe away from the platform to reduce the magnetic interference of the platform and achieve high-precision detection of the magnetic field, as in Fig. 2. Considering the lifting limit of the drone, the whole detection system adopts the characteristics of lightweight and easy to disassemble. The long boom is made of carbon fiber, and the length of the rod is 1.2 meters, which ensures the stability of the detection and Structural strength. The bracket end of tray extends into the carbon boom through the cross pin to ensure the stability of the combination of the tray frame and the carbon boom. The rear end of the boom is connected with the aluminum tool of the detector probe. Each fixing screw is of non-magnetic materials, which ensures a magnetic environment around the magnetic probe and improves the accuracy of the magnetic survey.

Fig. 2 Magnetic Measurement System

3.2 UAV external high integration data transmission system

For commercial drones, their own flight control systems are often relatively closed. So it is necessary to equip external measurement, control, communication, and power supply functions in the system. The external high-integration data acquisition system of the drone consists of a magnetic field data acquisition and processing module, a magnetic data real-time backhaul module, a power supply module and a multi-machine flight control module. Due to the low load of the commercial drone, the flight weight is limited, light in weight and small in size of the entire system is required. The block
diagram of the external high-integration data acquisition system of the drone is shown in the Fig.3. The entire system is highly compatible with the aircraft platform.

The low-cost characteristics of commercial drones determine its application to multi-unit network joint flight detection. The communication control between drones and the rapid assembly capability between structures need to be considered in the design process.

**Magnetic Field Data Acquisition and Processing Module**

**Power Supply Module**

**Magnetic Data Real-time Backhaul Module**

**Multi-aircraft Control Module**

**UAV High Integration Data Transmission System**

**Fig.3 UAV high integrated data transmission system**

### 3.3 Portable magnetic measurement data receiving and processing system

The light weight, small size and easy assembly of the commercial drone determine that it can be applied not only to the multi-unit network flight, but also to the fast mission response in specific areas detection. The commercial drone adopts the battery-powered mode. In the field environment, the aeromagnetic measurement system is required to have independent power supply capability. In the portable magnetic measurement data receiving and processing system designed in this paper, the data receiving unit is powered by battery, which can guarantee the reception of magnetic measurement data within the time, as shown in Fig.4. The drone is limited by its battery capacity and has a small flying radius. In order to realize real-time display of magnetic measurement data, matching the fast mission requirements of a specific area, ensuring the subsystems do not depend on the characteristics of the drone platform, the data transmission system is independent of the platform operates. It can realize 5km transmission requirements.

**Fig.4 Portable magnetic measurement data receiving and processing system**

### 4. Flight test results and analysis

In March 2018, the project team used the system to complete the first flight test. For a single UAV, the system is easy to assemble for its lightweight and modular design. The drone can complete the assembly of the payload and take off within 10 minutes. It completed real-time acquisition of the magnetic field information of the region. The test was carried out in three times and the detection used with the UAV magnetic measurement system is shown in Fig.5.
The results of the payload detection are shown in Fig. 6. The data of magnetometer on UAV measured the magnetic field $B$ and the three-vector direction ($X$, $Y$, $Z$) magnetic field.

![Fig.5](image1)

**Fig.5** the UAV equipped with the magnetic measurement system (in flight)

Fig. 6 Total field $B$ and $B_X$, $B_Y$, $B_Z$ for a period of time (The 3rd flight)

![Fig.6](image2)

Fig. 7 The three-dimensional flying magnetometer records the magnetic field combined $B$ magnetic field with time. The red curve represents the first flight data filtered, the green curve represents second flight data filtered, and the blue indicates the third flight data filtered.

**Analysis:**

1) The change of flight attitude and flight mode has a great influence on the measurement of magnetic field. Specifically, when the total field $B$ of the magnetic field does not change much, the three vector directions of the magnetic field change drastically. As shown in Fig. 6.

2) Comparison of the measured total field $B$ of the three curves as shown in Fig. 7, the total field $B$ of the detected magnetic field has a variation of about 600nT, which is related to the magnetic field.
characteristics of the detection area itself. Since the single probe aircraft cannot be compared, it needs more machine calibration to eliminate interference.

3) During the flight of UAV equipped with long boom structure, the boom has been deformed in start and stop process, which brings errors to magnetic measurement data. For the three axes vector field measurement, the detection configuration needs to be optimized.

5. Conclusion
This paper mainly introduces the design of airborne magnetic payload for UAV. Firstly, it introduces the characteristics of commercial UAV and aeromagnetic measurement load technology. The airborne magnetic measurement system has been developed. The whole system adopts lightweight and modular design, which is convenient for quick insertion and assembly. It is suitable for field test and multi-machine rapid formation task. From the results of three flight tests, the magnetic field vector data in a small time window is stable and can reflect the change of flight magnetic field. The detection system satisfies the aeromagnetic measurement requirements.

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