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Application Research of UAV-based Aerial Gamma Energy Spectrum Survey System in Geological Exploration

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Abstract: A novel application for an unmanned aerial vehicle (UAV) aviation gamma energy spectrum survey system is introduced, representing an innovative concept within the "UAV+" framework. This proposal emerges from a critical analysis of the limitations inherent in traditional geological survey methods, particularly from the perspective of geophysical prospecting. The UAV low-altitude aerial gamma measurement (ULAGM) system integrates a UAV, a nuclear radiation measurement apparatus, and a ground control center. The system boasts a resolution of 7.40%, and it can detect gamma rays within the energy range of 15 keV to 3.0 MeV. Furthermore, the measurement results obtained from this system are comparable to those of conventional ground surveys. Consequently, the ULAGM system is fully capable of satisfying the stringent demands of geological exploration and the quality assurance standards required for environmental gamma radiation monitoring.

Keywords: UAV; gamma measurement; geological exploration; uranium ore.

1. Introduction

Uranium mines and rare earth mines (including associated radioactivity) are important resources in human's modern life. However, it's important for the sustainable development of the economy and society to take a balance between radioactive pollution and treatment during the exploration of uranium mines and rare earth mines. In the past, geological surveys mainly relied on field surveys by investigators. And the radiation monitoring equipment can only be used when there are roads and people, which takes a long time and low observation efficiency. Under some complex conditions or conditions over nuclear facilities, measurement cannot be carried out, and it cannot fully meet the requirements of geological survey [1]. Nowadays, based on the idea of "Geology+", a new idea about "UAV+" is proposed. And it is complementary to the vehicle-mounted gamma spectrometer and the ground gamma spectrometer, forming a three- dimensional radioactivity monitoring and survey of deep ground, ground surface, low altitude, and air without blind areas [2] [3]. The ULAGM system can Complete low-altitude, fast scanning measurement and special fixed-point measurement tasks in specific areas, and can improve related work efficiency and ensure the radiation safety of workers [4].

2. Technology Roadmap

2.1. Overall Structure of the System

The general block diagram of the ULAGM system is shown in Figure 1. The system is composed of UAV flight platform, power supply and system, nuclear radiation measurement system, positioning system and ground control center.

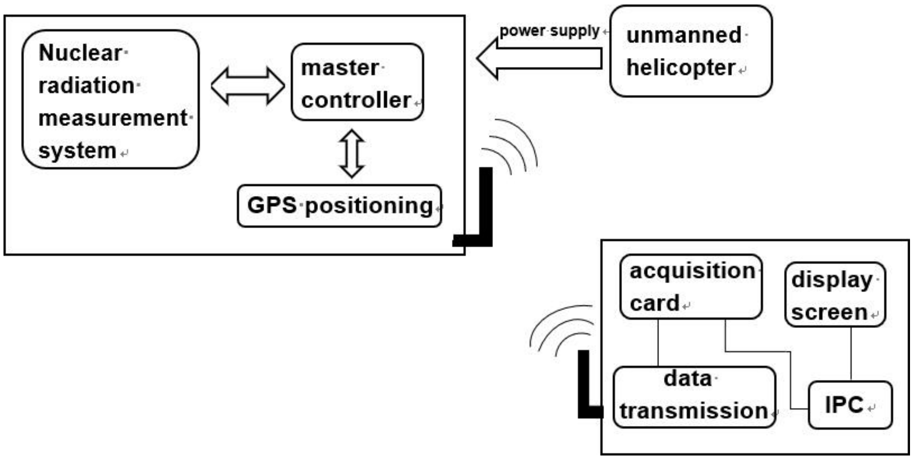

Figure 1. Overall block diagram of ULAGM system

The system uses sodium iodide (NaI) crystal as the nuclear signal acquisition unit, which reduces the weight of the data acquisition system and greatly reduces the cost of the UAV platform. And the system can also realize radioactive data measurement, GPS positioning, video screen information collection and data download of these test results.

The ground control center can solve the functions of instrument self-check, control the system's measurement, acquire data, display real-time data, identify nuclide, display color difference energy spectrum, map environmental dose, and alarm. The system provides reliable supports for searching for radioactive minerals and non-radioactive associated minerals, geological mapping and environmental radiation monitoring.

2.2. UAV Selection

Table 1. Comparison of advantages and disadvantages of drone flight platforms

categories	advantages	disadvantages
Electric multi-rotor	1. Lowest in weight, easy to carry and transport; 2.Good stability, high safety, the most excellent flight attitude stability; 3. cheaper than others;	1.the carrying capacity of this is 50kg, but short in endurance; 2. It can endure 35 min when carry 10 Kg load.
Fixed-wing UAV	1. Long endurance and large deadweight, suitable for carrying large-volume sodium iodide crystals; 2. easy to control and moderate price; 3. Large working area and it can work up to 100 kilometers;	1. It's affected by the weather and easy to fall; 2. Unable to hover or measure at a fixed point; 3. Complex conditions for take-off and landing;
Oil-fired unmanned helicopter	1. more flexible attitude adjustment in horizontal direction; 2. The speed is moderate when endurance; 3. This UAV has higher energy utilization ratio than multi-rotor; 4. It can carry large volume sodium iodide crystals;	1. It's difficult to control; 2. It's more expensive 3. The rotor wing span is large, so the security index of flight is not high in complex environment is not high; 4. It's Heavy and difficult to be carry;

As an emerging industry, UAVs have rapidly used in civilian in recent years. The so-called unmanned aerial vehicle is an aircraft that does not carry people. According to technology, unmanned aerial vehicles can be divided into three categories: unmanned fixed-wing, unmanned helicopter and unmanned multi-rotor aircraft, and they are widely used [5]. (The advantages and disadvantages of the UAV flight platform are shown in Table 1).

According to the above-mentioned advantages and disadvantages and the practical situation, this system uses Oil-fired unmanned helicopter which can match the weight of large-volume NaI (Tl) crystal. Oil-fired unmanned helicopter is stability and effective in flight, and can carry out a flight in ultra-low-altitude or hover state, which is more beneficial for the exploration of uranium and rare earth mines.

3. Test

3.1. InstrumenT TESTing

The China Testing Technology Research Institute has completed the test of the ULAGM system's resolution and detection energy range. The resolution of the NaI(Tl) crystal in this system is 7.40 and The energetic ranges of the gamma that can be detected is larger than 15keV~3.0MeV.

Figure 2. The picture of the system (left) and Resolution test chart (right)

3.2. Field Test

The content of U, Th and K measured in the air, which was measured by the ULAGM system in Jiangxi province in China, was compared with the content of U, Th and K measured on the ground (As shown in Figure 3). The test data were recorded and it's shown in Table 2.

Figure 3. Field test diagram of ULAGM system

Table 2. Air and ground U, Th, K content test data

	The content of U (%)			The content of Th (%)			The content of K (%)		
air	29.00	22.39	22.73	253.96	296.56	228.32	4.35	5.08	4.87
ground	39.02	20.58	26.84	165.77	222.81	250.45	3.56	4.85	3.42
Relative deviation	-14.7	4.21	-8.29	21.01	14.20	-4.62	10.01	2.32	17.49

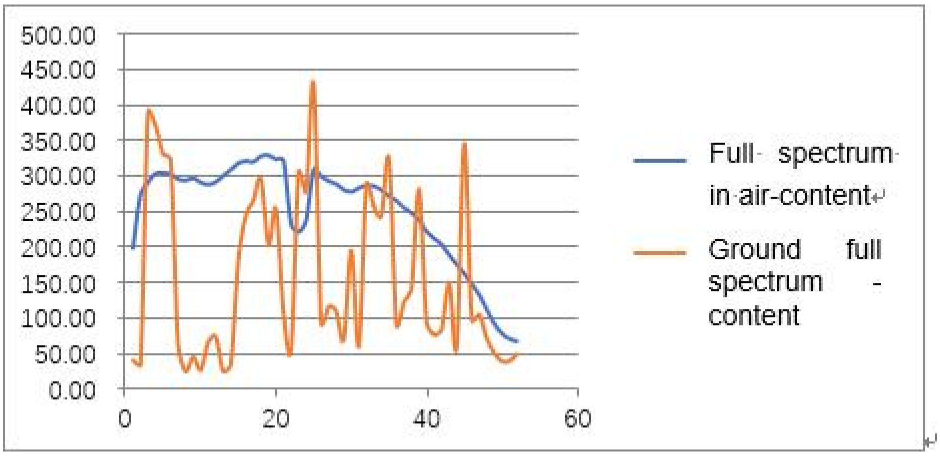

Figure 4. The content trend of full spectrum measured in air and on ground

4. Summary

In this paper, UAV flight platform and power supply system are responsible for flight; nuclear radiation measurement system is responsible for measuring spectrum; positioning system and ground control center are responsible for data transmission and processing. The resolution of this system is 7.40%, and the gamma energy range is larger than 15keV~3.0MeV, which is not much different from the ground measurement. It can fully meet the requirements of geological exploration and radiation environmental quality monitoring in uranium mining field.

Considering at the geological survey work method, the use of ULAGM system is more efficient and convenient. It has changed the manual survey method in the past, which can cover blind areas that cannot be reached by manual surveys, and improved the survey work efficiency. It can provide a rapid survey in a large-scale of the geological and landforms around the mining area, which is of great significance in geological survey field [6].

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