

A SEGMENTED DETECTOR FOR AIRBORNE GAMMA RAY SPECTROSCOPY

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ABSTRACT

The airborne gamma-ray spectrometry (AGRS) is widely acknowledged as a very efficient technique for large areas monitoring. The detector system mounted on a helicopter allows for an extensive survey in a single flight time, thus reducing the exposure risk for the operator. Results from AGRS techniques are exploited in many fields, from the geological research to the homeland security for the search of orphan radioactive sources, from the mining and hydrocarbon exploration to the construction industry.

The new generation of compact digital data acquisition and online processing equipment allows for faster airborne survey campaigns, and enhances the flexibility of operations. In addition, the algorithm for the extrapolation of the nuclide concentrations from the acquired gamma spectra is a challenging step of the entire technique.

We are going to present a new device for advanced AGRS measurements, with an innovative detector configuration and data processing algorithms for optimizing the source localization and the on-line response capabilities. The new compact structure makes the system easily portable by a single operator, and rapidly mountable on most common helicopters. Preliminary feasibility studies have been performed to test the

mechanics and the hardware of the whole system, which is intended to work without any human attendance. The first flights are planned by the end of 2014, with the aim of detecting artificial point sources having intensities on the order of 10^8 Bq and natural enriched fields already monitored.

1. INTRODUCTION

The airborne gamma-ray spectrometry (AGRS) allows to measure the radioactivity level of large areas of interest. Being the survey performed on flight, the risk for the operator is extremely reduced. In the past years many results have been achieved both in geological studies, and for purposes of emergency response.

The first Italian prototype for airborne gamma-ray spectrometry has been recently developed. Following the IAEA guidelines for AGRS surveying, four NaI detectors of approximately four liters each has been used for the data acquisition. The system was mounted on an autogyro, and used to map the radioactivity of the Elba Island (Italy). The energy spectrum information was analyzed offline using the Full Spectrum Analysis (FSA) technique with the Non-Negative Least Square (NNLS) constraint to achieve the relative concentration of potassium, uranium, and thorium. Using interpolation techniques the maps of the relative abundance of radioactive nuclides were generated.

The promising results achieved encouraged the development of a new segmented device for the airborne radiation monitoring. The great innovation is the new design of the NaI detectors layout, with a structure of sixteen detectors of one liter each.

The new detector configuration generates asymmetries in the signal acquisition, that can be used to study the underlying distribution of radioisotopes. The possibility to recognize orphan sources with respect to the natural background has been confirmed by Monte Carlo simulations specifically developed for modeling the expected signals.

The new structure makes the system easily portable by a single operator, and rapidly mountable on most common helicopters.

Preliminary feasibility studies have been performed to test the mechanics and the hardware of the whole system, which is intended to work without any human attendance. The first flights are planned in 2014, with the aim of detecting artificial point sources having intensities on the order of 10^8 Bq and natural enriched fields already monitored.

2. THE FIRST ITALIAN PROTOTYPE

The first Italian prototype for airborne gamma-ray spectrometry measurements has been recently developed following the IAEA guidelines for AGRS surveying [1]. Four NaI detectors of approximately four liters each have been used for the data acquisition. The acquisition system was equipped with a GPS antenna, for the correct positioning of the flight, and with a temperature and pressure sensor.

The system was calibrated in natural sites with known radioactive concentration. The background calibration took care of the intrinsic background of detectors and electronics, and of the cosmic rays as well.

The system was mounted on an autogyro, and used to map the natural radioactivity of the Elba Island (Italy). The location has been chosen because of its high lithological variability (well detailed in large-scale geological map), and excellent exposure of outcropping rocks. The flight has been performed at a mean altitude of 140 ± 50 m, and the energy spectra of the four detectors have been collected for the offline analysis of the radioactive concentrations.

A dedicated algorithm for data analysis has been developed exploiting the Full Spectrum Analysis (FSA) with the Non-Negative Least Square (NNLS) constraint [3].

The events coming from each detector can be individually managed allowing to settle the frequency of sampling of spectra. This specific feature of acquisition allows to study spot area with different surfaces during the data post processing. The results have been corrected offline to get the radioactive concentration at soil level.

A multivariate interpolation algorithm has been implemented with the constraints coming from the geological maps information. The results of this method are the maps of the radionuclides distribution in Elba Island [2]. Figure 1 shows the Uranium abundance, as published in [2]

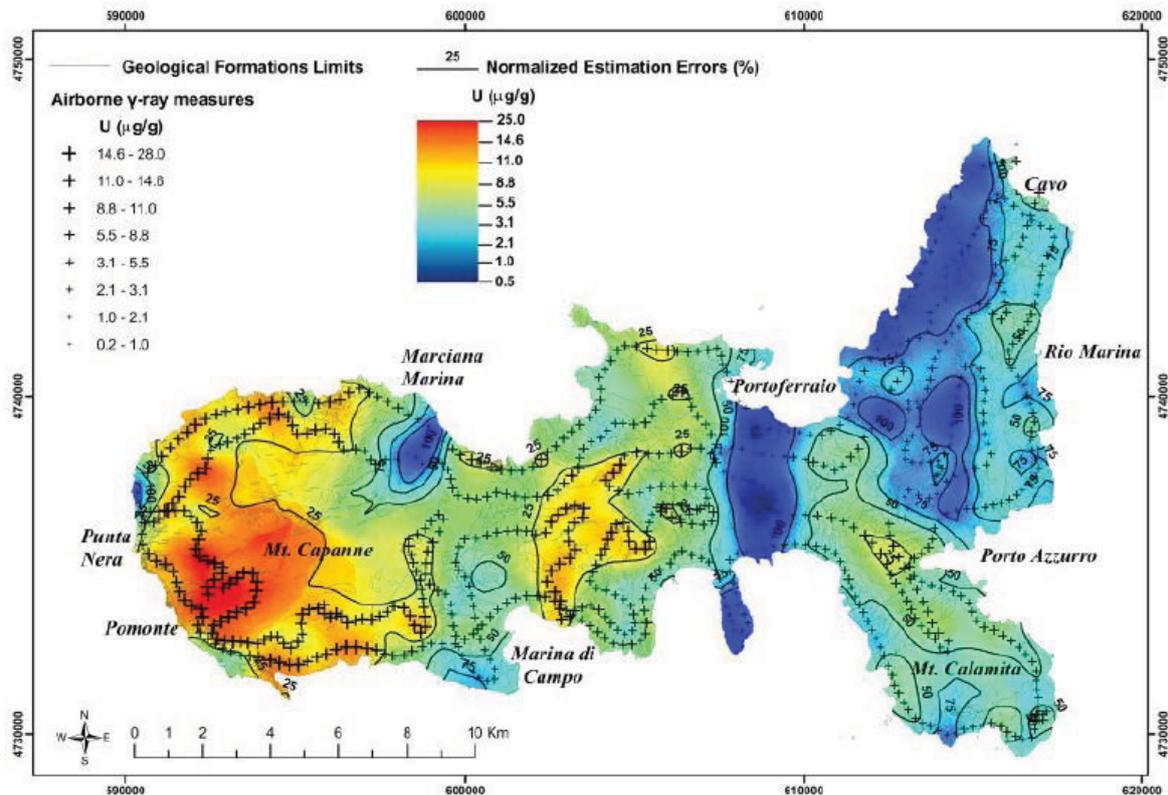


Figure 1. The distribution of the Uranium abundance in the territory of the Elba Island (Italy) [2].

Besides U and Th deposits prospecting, many other interesting applications can be investigated such as soil mapping and geomorphic dynamics monitoring (style of weathering, degree of leaching, and variations of acidity, texture, nutrient status and thickness), ground water discharge and recharge tracking and petroleum prospecting.

3. THE NEW SEGMENTED DETECTOR SYSTEM

The results of [2] encouraged the development of a new instrument for airborne gamma-ray measurements. The new segmented detector system, co-funded by the Regione Toscana under the PORCreo FESR 2007-2013 program, is a ready-to-fly airborne spectrometer designed around ultra-compact data acquisition electronics and NaI(Tl) detectors modules.

Dedicated power supply and acquisition system are developed in the R&D labs of CAEN S.p.A.. An integrated system has been designed to host both the power supply and the data acquisition. The CAEN acquisition system is based on modular multiple channels fast digitizers with online FPGA processing capability. Thus the acquisition system is scalable and can manage the charge integration and multi-channel histogramming of the signals from each NaI detector in real time. Data registration is flexible: both list-mode and full energy spectra can be selected as recording modes.

The major innovation with respect to the prototype is the new design of the detectors layout. The detector arrangement has been designed to provide information about the direction of the gamma-rays, in order to improve the localization of radioactive sources. Sixteen NaI detectors of one liter each are set up in groups of 4x4, as shown in Figure 2.

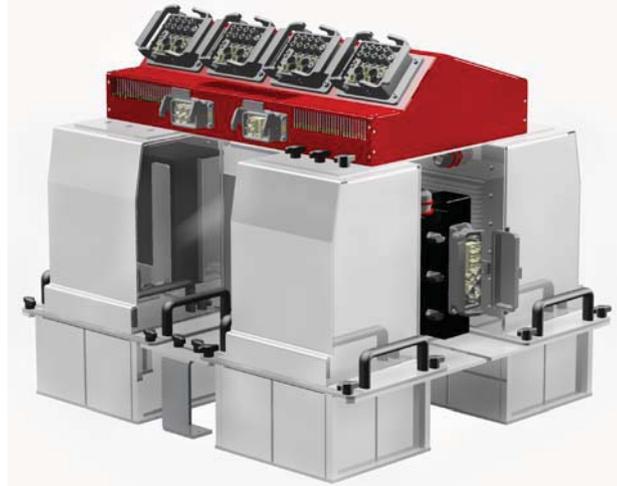


Figure 2. CAD-design of the segmented detector system for airborne gamma-ray spectroscopy.

The new detector configuration generates asymmetries in the signal acquisition, that can be used to study the underlying distribution of radioisotopes. The possibility to recognize orphan sources with respect to the natural background has been confirmed by Monte Carlo simulations specifically developed for modeling the expected signals.

The new structure design makes the system very compact and easily portable by a single operator, and it can be rapidly mountable on most common helicopters (e.g. Robinson's R44 Raven and Eurocopter Ecureuil).

4. CONCLUSIONS

Preliminary feasibility studies have been performed to test the mechanics and the hardware of the whole system, which is intended to work during the flight without any human attendance. The first flights with the new architecture radiometric data acquisition system are planned in 2014, with the aim of detecting artificial point sources having intensities on the order of 10^8 Bq and natural enriched fields already monitored in [4].

A new dedicated nuclear instrumentation laboratory, associated to the research group on heavy ions reactions (GRIPE), at the Nuclear Physics Department of the University of São Paulo (USP), Brazil, is planned to be the basis for applying such systems and methods to the future needs on radiometric airborne surveys over the Brazilian territory for applications ranging from the assessment of the territory radiological emergency status in case of nuclear accidents to the prospection of deposits of natural resources.

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