A segmented detector for airborne γ-ray spectroscopy

P. Garosi[1 2 3], M. Baldoncini[4 5], A. Iovene[2], F. Mantovani[4 5], L. Mou[3 6], S. Petrucci[2], C. Rossi Alvarez[6], V. Strati[4 6], C. Tintori[2], G. Xhixha[4 6]

1 Introduction

Among the various techniques for radiation monitoring, the airborne γ-ray spectrometry (AGRS) is widely acknowledged as a very efficient technique for large areas monitoring. Indeed the detector system mounted on a helicopter allows for an extensive survey in a single flight time. Furthermore the exposure risk for the operator is quite reduced compared to an on-site measurement.

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 airborne γ-ray spectroscopy measurements, with an innovative detector configuration and data processing algorithms for optimizing the source localization and the on-line response capabilities.

2 Previous result

The first Italian prototype for airborne γ-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.

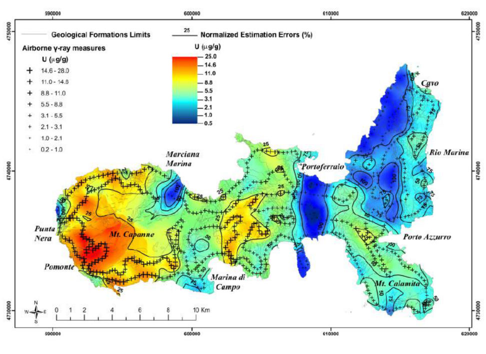

Figure 1: distribution of the Uranium abundance in the territory of the Elba Island (Italy) [2].

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

[1] Corresponding Author, e-mail address: p.garosi@caen.it
[2] CAEN S.p.A., via Vetraia 11, 55049, Viareggio - Italy
[3] University of Siena, via Banchi di Sotto 56, 53100, Siena - Italy
[4] University of Ferrara, Department of Physics and Earth Sciences, via Saragat 1, 44122, Ferrara - Italy
[5] Istituto Nazionale di Fisica Nucleare (INFN), Ferrara, Via Saragat 1, 44122, Ferrara - Italy
[6] Istituto Nazionale di Fisica Nucleare (INFN), Legnaro National Laboratory, viale dell'Università 2, 35020, Legnaro - Italy

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].

3 The new segmented detector system

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

The 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 γ-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.

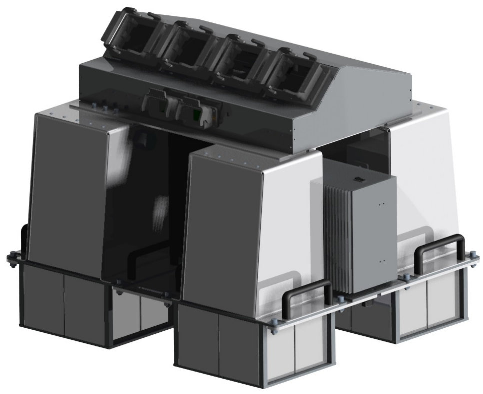

Figure 2: design of the segmented detector system for airborne γ-ray spectroscopy.

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 makes the system easily portable by a single operator, and rapidly mountable on most common helicopters (e.g. Robinson's R44 Raven and Eurocopter Ecureuil).

Dedicated power supply and acquisition systems 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 acquisition system can manage the charge integration and multi-channel histogramming of the signals from each detector. Data registration is flexible: both list-mode and full energy spectra can be selected as recording modes.

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 in [4].

References

[1] IAEA, International Atomic Energy Agency, "Airborne gamma-ray spectrometry surveying". In: *Tecnical Report Series* 323 (1991).

[2] E. Guastaldi et al., "A multivariate spatial interpolation of airborne gamma-ray data using the geological constraints". In: *Remote Sensing of Environment* (2013).

[3] A. Caciolli et al., "A new FSA approach for in situ gamma-ray spectroscopy". In: *Science of Total Environment* 414 (2012), pp. 639–645.

[4] I. Callegari et al., "Total natural radioactivity, Tuscany, Italy". In: *Journal of Maps* (2013).