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A remote controlled system for continuous radon measurements to realise a monitoring network

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RaMonA (Radon Monitoring and Acquisition) is a compact system for radon and climatic parameters monitoring. The instrument can perform alpha particles spectrometry with a resolution better than 0,5 %, so it is possible the discrimination of radon and thoron daughters. The development of battery operated electronics with integrated amplifier and microcontroller makes the device applicable for in-lab and in-field measurements. Moreover, an Ethernet interface allows to remotely drive the system and the download of acquired data. After a wide use of the prototype in laboratory, a lot of systems has been built and installed in some sites to carry out radon monitoring in soil.

Introduction

The latest years showed the utility in many fields of radon monitoring based on electrostatic collection of radon daughters on a silicon detector. In fact this technique resulted very useful in different radon studies (e.g. emanation power and exhalation rate determination) (Hopke, 1989, De Martino et al.,1998). When used in controlled air-conditions such devices shows a background-free high-efficiency response with good reliability and accuracy. The detection efficiency firstly depends on the cell geometry and electrostatic field intensity or, in other words, on the collection of radon daughters on detector surface. This phenomenon is influenced strongly by gas density and by recombination probability of polonium ions, both depending on humidity, temperature and pressure. Because in many cases, such as in indoor air monitoring, it is not possible to work in controlled air-conditions, it is important to characterize the monitor response as function of such parameters, optimising the measurements in normal environmental conditions.
The characteristic which makes this system particularly effective is the possibility to perform alpha particles spectrometry, allowing consequently the separation of 222 and 220 radon isotopes: this peculiarity is useful study of radon emanation from porous materials.
We built such a device, named RaMonA (Pugliese et al., 2000), in our laboratory and we performed its characterization with the collaboration of the Metrology Institute for Ionising Radiation (ENEA-INMRI, Italy) (Roca et al., 2004). The instrument was

largely used allowing to achieve very good results in study of soils and building materials (Roca et al., 2000, 2004). On the basis of the gained experience we decided to realise a new version with higher performances. In the next sections, after a brief description of the system general characteristics, we will show these new features.

The characteristic of RaMonA

This implementation has not changed the basic characteristic of the monitor. Its detection probe consists of an electrostatic cell with silicon detector with its associated preamplifier and a set of pressure, humidity and temperature sensors, locally coupled to special electronics used for their output adapting. The control unit contains the pulse shaping electronics for the detector, consisting of a linear amplifier and a linear stretcher. An eight channel 12 bit ADC serves the environmental sensors, the detector and the system dead time monitoring circuit.

Detection Unit

The radon probe, extensively described in Pugliese et al., 2000, consists of a 10 cm x 10 cm cylindrical metallic chamber, with a silicon surface barrier detector mounted at the centre of the upper base. Radon can flow through the chamber with a carrier gas (usually air) coming from the external space, or can be originated from a sample of material put on the bottom of the chamber.

The cell can be set to a high voltage up to 3500 V respect to the detector, that is grounded. In this way, the ionised fraction of the ^{218}Po atoms, direct radon decay product, is transported by the electric field in the direction of detector's surface where, after its decay, the emitted alpha particles are detected with ~50% probability. Due to the high mobility of the ions in air (1 ÷ 6 $cm^2\ s^{-1}\ V^{-1}$ (Nazaroff and Nero, 1988), almost all the ^{218}Po ions are collected by the field. As no air layer reduces alpha energy, energy resolution is about 0,5% in the energy range 6 MeV - 9 MeV.

Some secondary effects produce a 200 keV wide tail at the low energy side of each alpha peak (Figure 1) that makes spectral deconvolution more difficult; nevertheless radon isotopes discrimination can be performed. Calibration factor of the chamber for ^{222}Rn is 0.07 $s^{-1}Bq^{-1}l$. In the Figure 1 the 6 MeV line of ^{218}Po is showed, fitted with a gaussian added to an exponential function. In the figure both the total and partial functions are drawn.

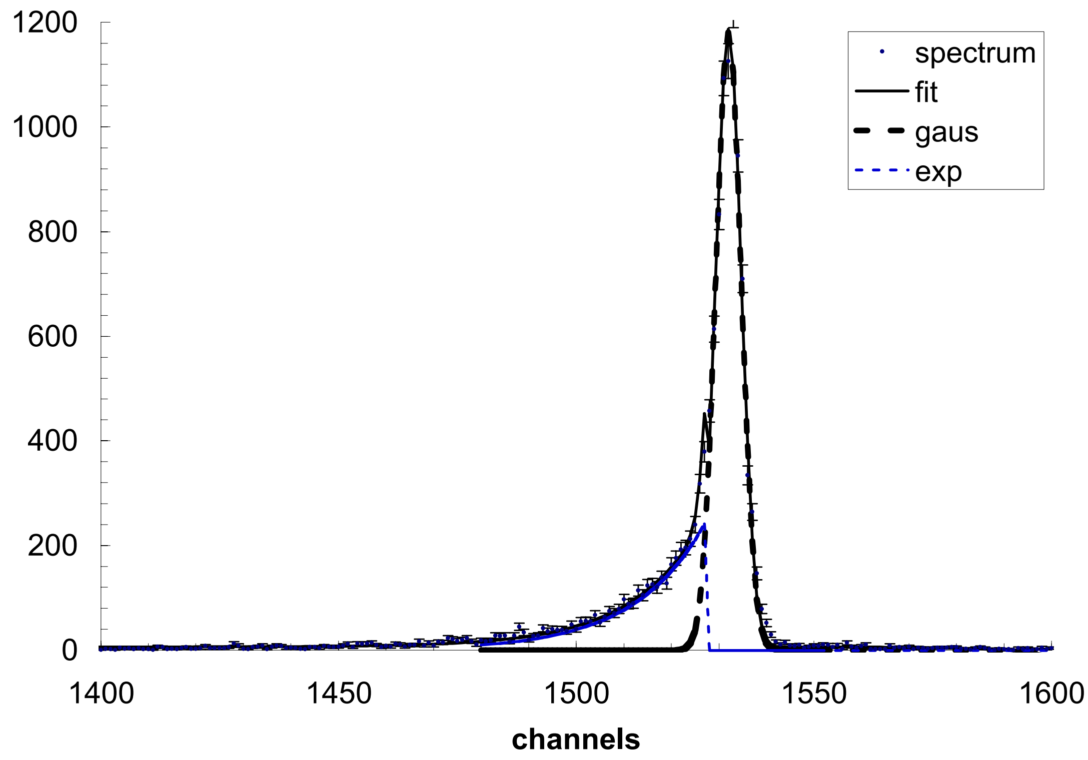

Figure 1: the fit of the ^{218}Po 6 MeV line

Acquisition unit

This section consists of three main sections: a "linear section" providing for the pulse shaping, amplification, stretching and discrimination circuit for silicon detector signal; a "control section", containing a programmable logic device (PLD) for the stretcher and trigger control; a second PLD for the multiplexer and dead time control; a conversion section serving all analogical signals.

It also possible to measure the environmental parameters outside the cell using another set of sensors.

A dedicated software allows to handle data communication and to manage the sensor channels and the energy spectra acquisition and analysis. In addition to general control the software allows typical spectrum treatment, as energy calibration, scale changing, ROI visualization, and peak area determination.

The upgrading

The new version of RaMonA was developed to improve general performances of the system and to make possible its net connection and in field application. First of all the collection chamber was re-designed, mounting inside, on the same card where the detector is hold, a miniaturized pre-amplifier, the sensors of P,T and U and electronics for the signals conditioning. Also a new main card has been projected,

improving the linear and digital signals treatment. A programmable Rabbit microcontroller allows to control the acquisition parameters (i.e. high voltage setting, amplifier gain) and handles communication and data download toward a computer through an Ethernet interface.
The power supply of the system is carried out by a 12 V rechargeable battery. In this way the system can be used everywhere.

The applications of RaMonA
Radon measurements in environmental and geophysical studies demand detection systems and methodologies capable to acquire data continuously (with short integration times, i.e. hour) and with remote control, but also with good reliability and sensitivity. Fluctuations of radon activity in air are also influenced by climatic parameters, such as temperature, pressure and humidity. They have then to be monitored during radon activity measurements. RaMonA fulfills these requirements.
Because in many cases, such as in indoor air monitoring, it is not possible to work in controlled air-conditions, the monitor response has been characterised as function of such parameters, with the aim to normalize it to standard conditions. It is also adequate to make measurements in a local where environmental conditions are changeable and one would study possible correlations.Since the emanation and exhalation rate processes from porous materials depend by temperature, humidity and atmospheric pressure, RaMonA is also used to measure the climatic parameters effects on these processes.
High resolution spectrometry is very useful for the in soil radon monitoring, since it allows to separate the radon isotopes. In figure 2 a typical spectrum from radon soil gas is showed: analysing series of such spectra, evolution of the ^{222}Rn and ^{220}Rn can be observed.
In the framework of the experiment Envirad (www.envirad.it) (Pugliese et al., 2003, Esposito et al., 2004), aiming to study the natural radioactivity in schools with students' direct intervention, a network of stations have been installed for the radon monitoring in soil

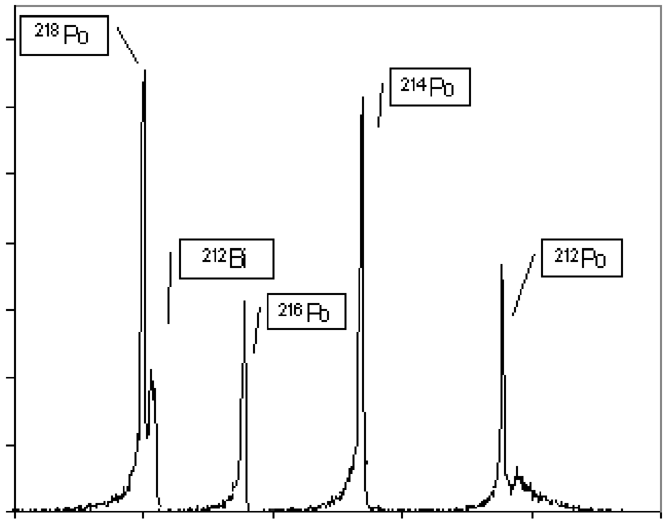

Figure 2: alpha spectrum of radon and thoron daughters present in a sample of soil air.

The aim of this network is to control radon emission from soils in order to relate its variations to possible seismic events and/or variations of activity of Vesuvius volcano. Data collected during a continuous monitoring will be stored on a central data base and they could be used to study correlations between radon emanation and the dynamic of the lithosphere.

Conclusions

The RaMonA system features and its applications have been presented. The characteristics which makes this system particularly effective are: i) alpha particles spectrometry which allows the separation of the ^{222}Rn *and* ^{220}Rn*; ii) the possibility to perform continuous radon monitoring; iii) the continuous control of climatic parameters inside and outside the; iv) an adequate and user friendly software which makes the system particularly simple to use; v) the remote control useful for different applications.*

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