Real Time and Multiple Location Radon (222Rn) Monitoring System

Petre Lucian OGRUȚAN, Mihai ROMANCA, Carmen GERIGAN,
Gheorghe MORARIU, Lia Elena ACIU
Transilvania University of Brașov, 500036, Romania
gerigan@etc.unitbv.ro

***Abstract*—The paper presents a Radon monitoring system. The system is designed for real time multiple location monitoring. The paper presents in the first part a method and an instrument for measuring radon concentration in air. Simulink simulations and implementation of the measurement principle are presented. Instrument position is determined by GPS and transmitted over GPRS along with the measurements results. Data management is accomplished by a software component of the system. The paper presents as an application, an investigation on nanomaterials to be used for Radon mitigation.**

Index Terms—Mobile communication, Nanomaterials, Radiation monitoring, Radioactive pollution, Remote monitoring.

I. INTRODUCTION

Radon 222 (half-life 3.8 days), is a radioactive gas produced by decay of the uranium found in the earth's crust. Indoor exposure to radon is associated with high health risks: at around 3000 cancer affections/year this is the second cause for lung cancer after smoking.

In the outside air, concentration depends on soil, air currents etc. and varies between 7-26Bq/m3. Health risks are very low. High concentrations are found near uranium mines. Inside buildings higher concentrations were measured in the basement and the ground floor depending mainly on soil, construction materials and insulation from soil [1].

A national Radon monitoring system is proposed based on a remote data communication system involving City Halls support.

For areas covered by GSM signal, the GPRS (General Packet Radio Services) transmission provides an elegant solution. The proposed system enables the continuous acquisition of Radon concentration and subsequently transfers the measured data via GPRS to a server which is visible on the Internet. The measured values include both the concentration at a fixed hour, as well as the previously determined average. If the measured Radon concentration is in excess of a pre-established limiting value, an alert message is generated. The developed system was proposed to be employed in the verification of the presumed increase of Radon concentration near seismic fault lines occurring before earthquakes and for environment quality monitoring in accord with standards, as well. The proposed system was used along with other two methods to determine whether nanomaterials can be used for Radon mitigation.

The block diagram of a measurement system for Radon concentration in air with remote data transmission using a GPRS modem is presented in Fig. 1.

Several measurement systems are placed on certain sites of the monitored area. These systems are periodically sending data over GPRS. The transmitted data contain the measured Radon concentration and the module's location. In order to prevent simultaneous transmission from several modules, each module is allotted a transmission time interval. Each module of the received GPS information determines the time. Several wireless transmissions are presented in [2] and [3].

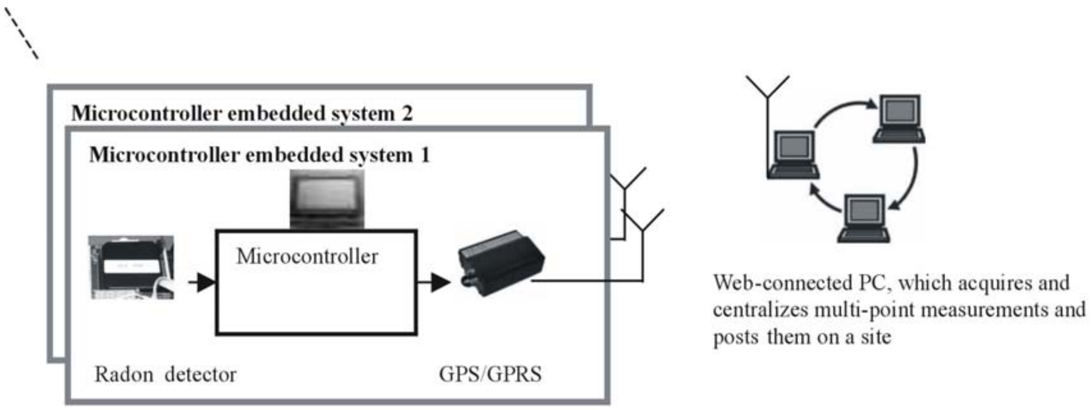


Fig. 1. Block diagram of a GSM/GPRS data link

Digital Object Identifier 10.4316/AECE.2010.04025

II. SIMULINK SIMULATION OF THE MEASUREMENT PRINCIPLE

A. Simulation in SIMULINK of the measurement through integration

The principle of the measurement consists in a transducer – detection chamber that contains a photo-element within an enclosure. The enclosure is to be found within an electric field obtained through the application of a voltage of 250V DC. The alpha particles, incident on the photo-element, generate a small signal in current.

The model of the measurement through integration realized in Simulink is given in Fig. 2.

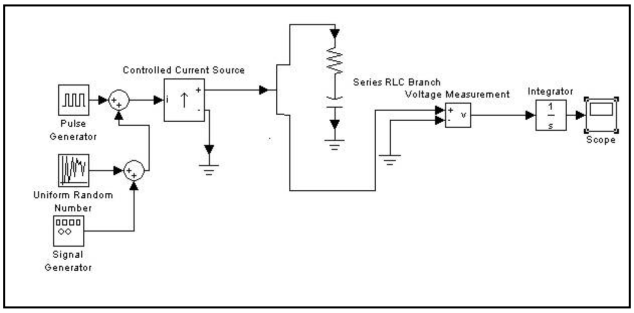


Fig. 2 Model of the measurement through integration

An impulse generator simulates the apparition of a radioactive particle with the frequency of a particle / 10ms, the amplitude of 10-7 A and the duration 0,01% of the period, that is 10μs. The noise is simulated through a generator of random numbers, the amplitude of the noise being of 10-8 A. The photo-cell is simulated through a source of current and the charge resistance is of 10MΩ.

In Fig. 3 there are presented the time diagrams of the outlet in the hypothesis of the data taking over without an integrator. There may be seen the short duration impulses (10μs) mixed with the amplitude noise 1/10 of the useful signal.

In Fig. 4 there are presented the results after the integration (period 10ms, duration of the impulse 10μs). The final value of the voltage is 1,06.10-3, with an error of 6% introduced by the noise.

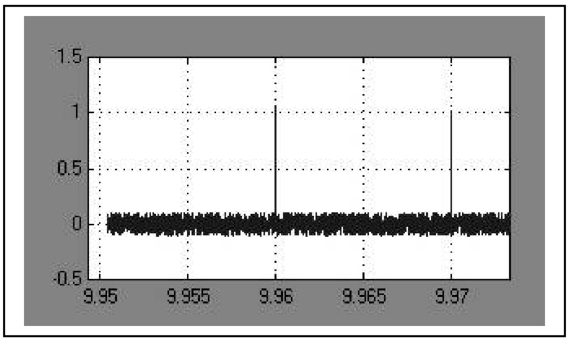


Fig. 3 Impulses and noise without integration

In case of a smaller concentration of gas, that is a particle at 100ms, the error is already of 60%, unacceptably great. The error is greater as the frequency of the impulses is smaller (less particles in time).

Likewise, the error is greater as the duration and the amplitude of the impulses are smaller (obviously, the error depends on the energy of the impulses).

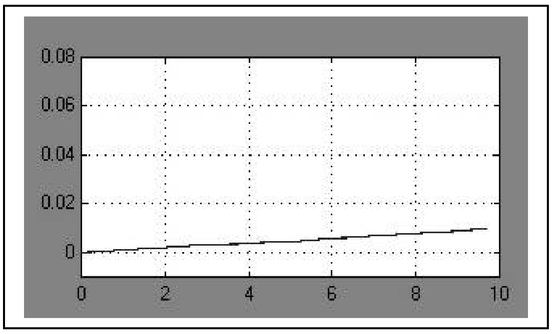


Fig. 4 Voltage after the integrator

From this simulation, there ensues that for a frequency of the impulses of one impulse per hour in the case of the measurements upon a small concentration of Radon, the method through integration cannot be applied.

However, with the purpose of verification, there was implemented a circuit of measurement through integration. The practical realization confirmed the simulation; the accumulated noise did not allow the accurate measurement of the concentration of Radon.

B. Simulation in SIMULINK of the measurement through the impulse counting

The signal from the detection chamber is taken over and amplified, and then it is compared with thresholds, one threshold for eliminating the noise, and the other one for the calibration. The level of the signal at the apparition of a discharge will be greater than the level of the noise and a comparing circuit 1 detects the threshold exceeding. The outlet signal is taken over by the microcontroller on a digital inlet of external interruptions.

The duration and the amplitude of a current impulse depend on the energy of the particles incident on the photo-element. The amplitude is increased by the amplifier, however the duration remains small. In order to realize a portable measurement apparatus with low costs, there has to be carried out the widening of the impulses with RC circuits of differentiation.

The variation of the parameters of the environment in which the measurement is carried out, as well as the variation of the parameters of the electronic components makes the measurement to be affected by errors and the functioning of the apparatus to be disturbed. There was implemented a manner for measuring the calibration that consists in a LED to be found in the measurement enclosure (within the transducer) fed from a PWM channel of the microcontroller. A second comparator compares the outlet impulse with a higher threshold that may be reached only when the LED illuminates with a high intensity. The LED is commanded to stronger illuminate at the beginning of the measurement for verifying the calibration.

The scheme for simulating the measurement is given in Fig. 5.

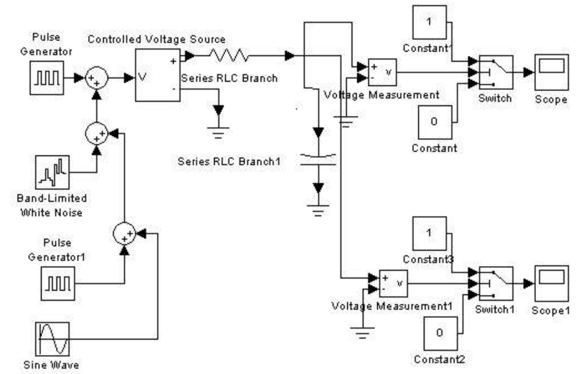


Fig.5 Scheme of simulating the measurement through counting the impulses

The measurement is deemed perturbed and, beside the sources of useful impulses, there may be added a source of random noise that simulates the internal noise of the photo-element and a sinusoidal source that simulates the disturbance of 50Hz that proceeds from the industrial network of alternating current. An impulse generator simulates the impulses of low amplitude that come from a discharge and an impulse generator simulates the high amplitude impulses generated during the calibration through the ignition of the LED. The input signal is similar to the one in Fig. 6 (a).

An RC differentiation circuit increase the duration of the impulse and the thresholds circuits select the impulses according to the amplitude. The output impulses from the comparator 1 and 2 are given in Fig. 6 (b).

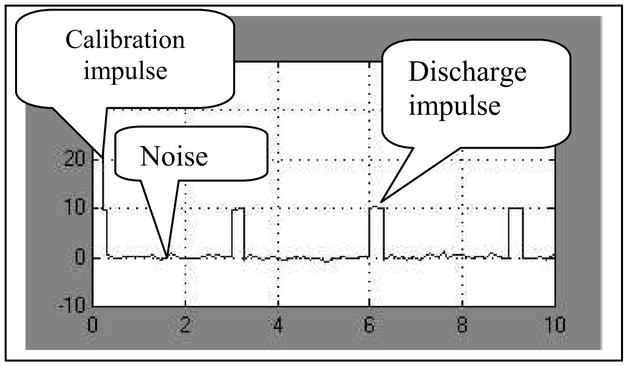
There may be noticed that at the output of the first comparator (Fig. 5 - up) there appear the discharge and the calibration impulses and at the output of the second comparator (Fig. 5 - bottom) there appears only the calibration impulse.

The measurement through integration is superior to the measurement through counting the impulses from several points of view, but unfortunately it may be applied only for a high number of discharge impulses in the unit of time, and the measurement of the small concentrations of Radon means a small number of discharges during one day. Through integration, the measurement noise rises in time and produces the saturation of the integration analogical circuit. The method through counting the impulses is also fit for measuring small concentrations and it was practically implemented with success, resorting however more to the resources of the microcontroller.

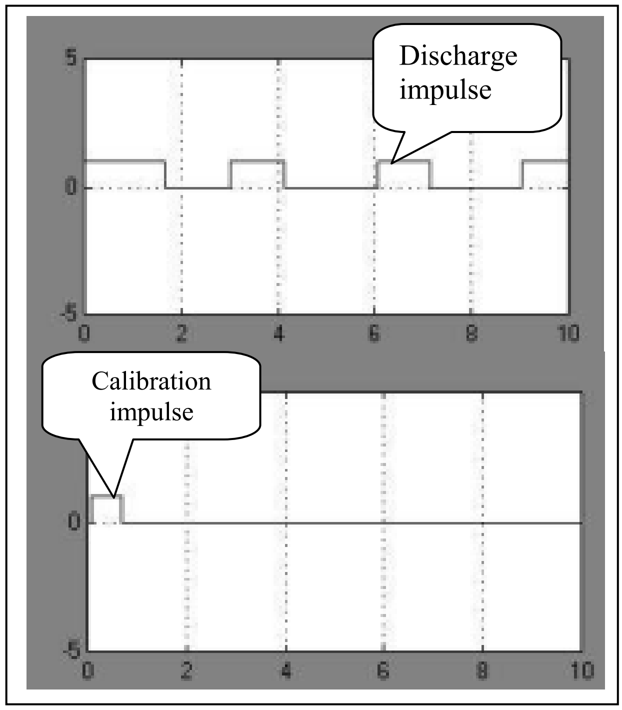
III. THE MEASUREMENT PRINCIPLE

The block diagram of the microcontroller measurement system is given in Fig. 7.

The detection (electrostatic capture) chamber contains a photo element in a capsule that is filled up with the air sample [4]. The capsule is placed inside a strong electric field. Collision-ionized particles are detected by the photo element and converted into a small electrical current, which is amplified by an instrumentation amplifier.



(a - input)



(b – output)

Fig.6 Input and output impulses

The comparator circuit 1 detects the crossing of the threshold when a discharge occurs. The output signal is applied to a microcontroller via external interrupts.

Environment parameter variation and electronic component variations are the main error sources that are perturbing the operation of the instrument. A calibrating system was developed consisting of a LED placed inside the detector, supplied from a PWM channel of the microcontroller. The output pulse is compared (comparator 2) with a higher threshold that can be reached only when the LED's intensity is increased. The LED's intensity is increased prior actual measurement to check detector calibration. If a pulse generated by comparator 2 is detected during the measurement, it is assumed that it's produced by electromagnetic perturbation. The measurement is abandoned after displaying an error message. After calibration, the LED's intensity is maintained very low, which provides maximum sensitivity to the detector. Both the LED's operating modes are controlled by varying the duty factor of a rectangular signal (PWM).

.

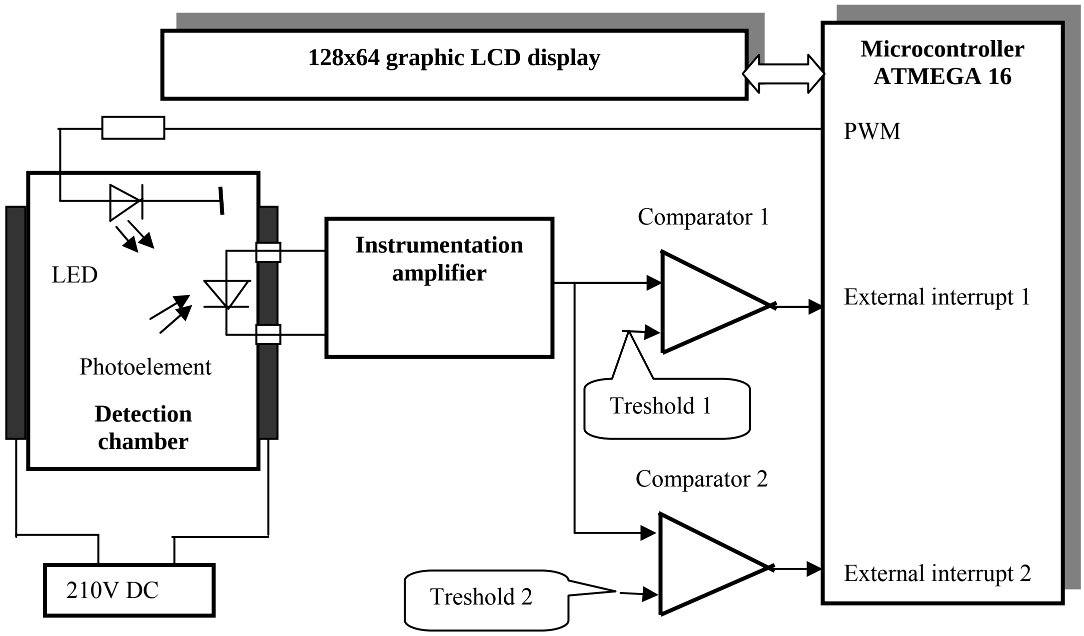


Fig. 7. Block diagram of the pulse counting measurement system

IV. DATA CAPTURE USING DAQ USB ACQUISITION SYSTEM

The developed instrument was tested using an acquisition system from National Instruments connected to a PC via the USB interface. The acquisition chart is presented in Fig. 8.

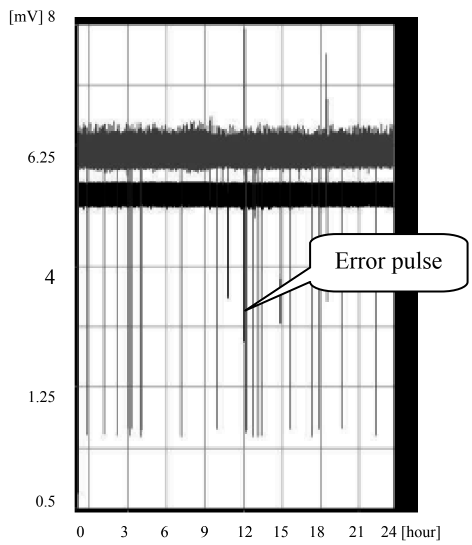


Fig. 8. Acquisition chart over a 24-hour interval using the National Instruments module

Grey pulses mark the detected Radon particles (discharges) whereas black pulses are error pulses. It can be seen that the error pulses occurring during a 24-hours span are not large enough to trigger an error message

V. EXPERIMENTAL RESULTS

We started the research in that field with an integrated measurement system [5]. The proposed system in this paper operates by the principle of pulse counting [6]. Experimental determinations have revealed an excessive noise level, especially for small Radon concentration, a fact that was also confirmed in [7].

Calculation of Radon concentration in air is achieved by averaging over a time unit conventionally set to one hour.

The first result is displayed 48 hours after starting the measurement, since averaging over a few hours would be irrelevant due to the small number of detected values.

The plot in Fig. 9 shows the measurement results over a span of 95 hours. The pulse number and the calculated average are represented. The average is represented after 48 hours. The abscissa shows the time in hours whereas the Radon concentration (level) is marked on the ordinate.

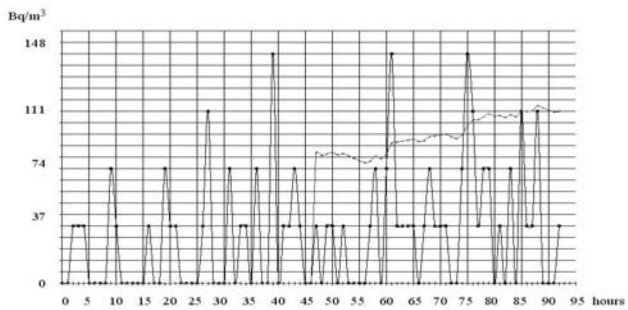


Fig. 9. Results obtained with the proposed measurement system

A server that saves acquired data in a file for each monitored site, to enable subsequent processing, receives the data transmitted over GPS. The measured values are verified for admissible variation limits and if these limits are exceeded, alert signals are generated. The displayed data are inscribed on a Google map indicating the site of the measuring system. The result transmitted to the server by the experimental system located in the N-building of the "TRANSILVANIA" University of Brasov are represented on a map; the presentation will be improved with GIS (Geographic Information System) from the City Hall.

Several parallel measurements have been done with an alternative method for the validation of the proposed measurement system. Both Radon measurement results with Safety Siren 3 (USA EPA Evaluated) system and 2 ENEA alpha-track detectors [7] and also with the proposed measurement system were compared and plotted in Fig. 10.

The obtained values prevailed from 6 to 6 hours (a line for Safety Siren 3 and b line for the proposed system) are similar to those obtained from the alpha-track detectors- 108 Bq/m3 and 125 Bq/m3 .

The implemented solution for the pulse counting principle is unable to detect the type of the captured radioactive particle since the analog circuitry alters the pulse shape.

At present, a discriminator system is being developed using a microcontroller with a higher sampling rate along with a modified version of pulse capturing.

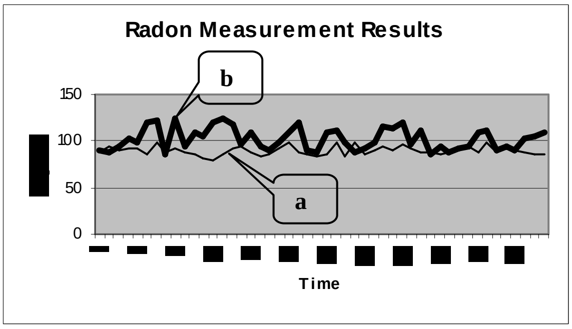


Fig.10. Radon Measurement Results

The system provides a quick response when the imposed limit of Radon concentration in air exceeded while the computer acquires real-time measurement data from several networked instruments.

Fig. 11 presents the setup used in testing.

A new version of the instrument used to detect Radon concentration in the air was designed. For this device, we have applied for a patent [9].

Fig. 11: Setup for measuring Radon concentration and GPRS transmitter

VI. SOFWARE DATA MANAGER

The software data manager reads and processes data from the Radon concentration devices connected in a GPRS system and transmits data/results to a MySQL server to be stored in a data base. The software system has three interfaces:

- user interface (graphic interface);
- Server interface – connect the measurement devices using TCP-IP and various internet techniques;
- MySQL client interface – record and update data in the database.

The PC running the Radon data manager application has a permanent connection to the Internet.

The actions implemented by the application and the way they communicate with the interfaces is depicted in Fig. 12.

VII. APPLICATION: DETERMINING RADON MITIGATION BY USING DIFFERENT MATERIALS

In order to determine Radon mitigation, three measurement methods have been used:

- Track detector
- Geiger Mueller counter
- Proposed instrument

Following operations have been performed:
measurements performed as described in [8],

- using an electronic device (short time measurement – 6 days);
- using a track detector (3 month measurement).

Radon concentration in the air was measured in a stuffy basement. The measurements have been performed using a Safety Siren 3 electronic device.

In the first case, CR-39 type track detectors have been placed in the basement, four of them inside studied materials and the fifth detector free. One of the detectors was placed inside the FE 300 nanomaterial, a plastic material with iron conductive insertion.

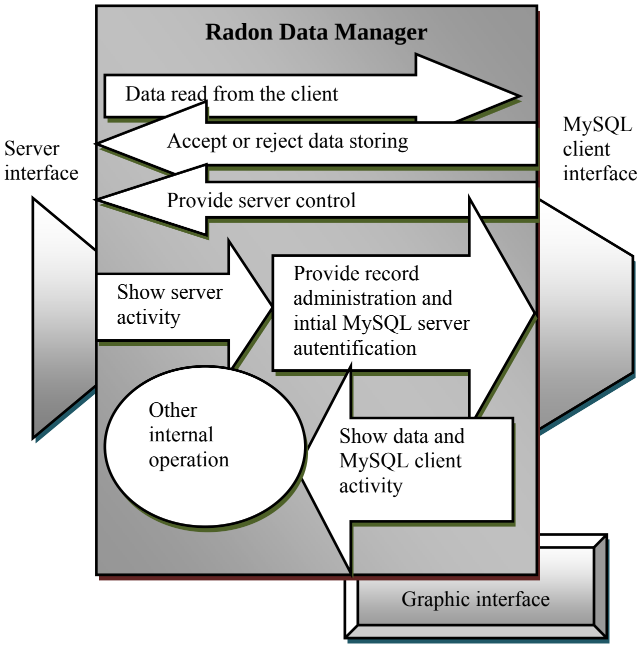


Fig. 12: Software data manager

CR-39 track detector is made of a plastic polymer having allyl diglycol as active substance. The detector is sensitive to α radiation with energies in the range 0,2-8 MeV. The CR-39 exposure interval was August 29, 2008 – November 22, 2008. Afterwards, the detectors have been developed in special laboratories in Cluj-Napoca and read using a RadosYs 2000 optic microscope

The second method used a Geiger Mueller counter. The counter has it's own software providing tools for data acquisition, storing data and statistic data processing. The counter stores instantaneous values measured in CPM (Counts Per Minute). The data stored in a file are mediated in an Excel application – every value that is displayed is the average of the current value and all the preceding values.

Three cases have been considered to collect experimental results. The results are presented in Fig. 13:

1. The Geiger Mueller counter was used in the air: (line a) and the average values (line b). The average calculated value for 700 samples is 44,79 CPM.
2. The Geiger Mueller counter was placed in a box made of a 2 mm sick FE 300 nanomaterial and a 0,07 mm aluminum foil. The average value calculated was in this case 42,20 CPM (line c).
3. The Geiger Mueller counter was placed in a box made of 1mm thick iron plate. The average value was 36,15 CPM (line d).

VIII. CONCLUSIONS

The purpose of the application was to investigate whether electromagnetic field and Radon concentration is attenuated by nanomaterials. For electromagnetic field attenuation, the results are clear [10]. The results are not illustrating for Radon concentration attenuation, although each of the experiments proved Radon concentration is attenuated when using different material boxes. It is important to mention that the Geiger Mueller counter measures the total radiation while the track detector and the proposed device measure Radon concentration. The attenuation measured using the three methods is summarized in Table 1.

We obtained an interesting result using a diaphragm provided by Monarflex which has an aluminium foil as insertion [11]. Using such a diaphragm to isolate a home would provide in the same time a high degree for the electromagnetic field attenuation, thus eliminating all the disturbing influences of the devices in the neighborhood.

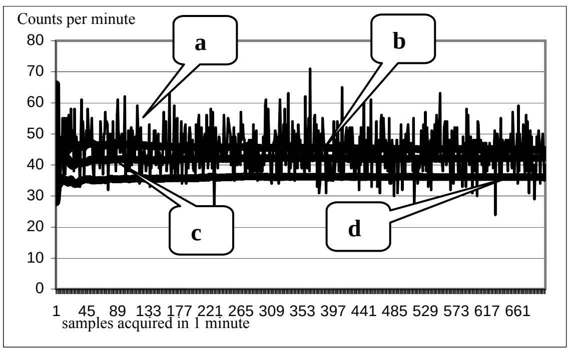


TABLE I. RESULTS FOR THE ATTENUATION MEASURED IN THE EXPERIMENT

Method	**Track detector**	**Geiger Mueller counter**	**Proposed device**
Attenuation	30%	6%	12%

Future developments:

1. The team at Transilvania University in Brasov is working now to simulate and measure the optimal attenuation of the electromagnetic field for buildings made up of stratified conductive structures.
2. Other application we plan to develop is to verify the hypothesis that earthquakes are preceded by an intense radon emission due to seismic earth faults movements [12].
3. We also intend to use CMOS type sensors to detect the presence of Radon [13] in order to simplify the transducer part of the system.

REFERENCES

[1] J.Eickenberg, *Radium Isotope Systematics in Nature, Division for Radiation Protection and Safety*, Paul Scherrer Institute, Switzerland, 2003.

[2] S. Yamamoto, K. Yamasoto, T. Iida, "Development of a real-time radon monitoring system for simultaneous measurements in multiple sites," Nuclear Science Symposium, 1998. Conference Record. 1998 IEEE, Volume 2, 8-14 Nov. 1998, pp.1052 – 1055.

[3] V. Roca, A. Boiano, A Esposito, S. Guardato, M. Pugliese, S M.abbarese, G.Venoso, "A monitor for continuous and remote control of radon level and environmental parameters," Nuclear Science Symposium Conference Record, 2004 IEEE , Volume 3, 16-22 Oct. 2004, pp.1563 – 1566.

[4] N.Noto, H.Ohsumi, S.Kobayashi, "Performance of the electrostatic collection type radon and toron detector," Nuclear Science Symposium Conference Record, 2002 IEEE , Volume 1, 10-16 Nov. 2002, pp.429 – 434.

[5] Gh. Morariu, P. Ogrutan, Cs. Kertesz, M. Alexandru, "A Novel Procedure and Apparatus for Measuring the Radon Concentration in Air," in *Proceedings of the 11-th International Conference on Optimization of Electrical and Electronic Equipments*, Brasov, 2008, IEEE Catalog Number 08EX1996C, ISBN1-4244-1545-4, Library of the Congress 2007905111

[6] A. Nachab, "Radon reduction and Radon Measurements at the Modane Underground Laboratory," 2nd Workshop in Low Radioactivity Techniques, 2006, Aussois.

[7] G. Sciocchetti, G. Cotellessa, E. Soldano, M. Pagliari, "A newtechnique for measuring radon exposure at working places," in *Proceedings of the 21st International Conference on Nuclear Tracks in Solids, Radiation Measurements*, Volume 36, Issues 1-6, 2003.

[8] US Environmental Protection Agency/ Air and Radiation, Protocols for Radon and Radon Decay Product Measurements in Homes, EPA 4021-R-92-003/1993.

[9] L. Purghel, Gh. Morariu, P. Ogrutan, M. Alexandru, Cs. Kertesz, L. Suciu, "Apparatus for Measuring the Radon Concentration in Air," Patent Request nr. OSIM A/00259 9.04.2008.

[10] G. Nicolae, P. Ogrutan, L. Aciu, A. Mailat, „Measurement System and Methods for Determining Electromagnetic Field Attenuation in Nanomaterials", RECENT, Vol. 9, no. 1(22), March, 2008

[11] Monarfle website [online], Available: www.monarflex.com .

[12] J. Planini, V. Radoli and B. Vukovi, "Radon as an earthquake precursor, Nuclear Instruments and Methods in Physics Research," Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 530, Issue 3, 11 September 2004, pp. 568-574.

[13] S. Higueret, D. Husson, T. D. Le, A. Nourreddine and N. Michielsen, "Electronic radon monitoring with the CMOS System-on-Chip AlphaRad," Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 584, Issues 2-3, 11 January 2008, pp. 412-417.