

FACTA UNIVERSITATIS

Series: **Working and Living Environmental Protection** Vol. 11, N° 3, 2014, pp. 177 - 184

WIRELESS SYSTEM FOR MEASUREMENT OF NATURAL BACKGROUND GAMMA RADIATION

UDC 551.509.1:535.1

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Abstract. *In this paper a solution of wireless system for measurement of natural background gamma radiation using a commercial portable instrument GAMMA-SCOUT is presented. Since the GAMMA-SCOUT does not have factory built-in wireless communication it is necessary to upgrade its functionality by implementing an additional hardware module. Prototype of the module is based on a microcontroller Microchip PIC16F887 and RF transceiver Telit LE70-868. Structure and functionality of this hardware module are also presented in this paper in detail, as well as the experimental results obtained by the realized system.*

Key words: *Wireless measurement system, Natural background gamma radiation, GAMMA-SCOUT, Microcontroller, RF transceiver*

1. INTRODUCTION

In the recent years, the world has become very concerned regarding radioactive pollution. One of the main domains on this issue is the danger due to possible nuclear plant accidents. Since radiation is also very harmful its intensity must be continuously monitored using monitoring systems.

In normal conditions people are exposed to radiation from three types of sources: cosmic, terrestrial, and internal.

Major radiation sources along with their share (represented in percentages) according to NCRP Report No. 160 are displayed in Fig. 1 [1].

Background radiation of low energy photons is thought to be the remnant of the so-called big bang that created the universe.

Natural background radiation is the main source of radiation for most people. According to UNSCEAR the worldwide average background dose for a human being is about

Received November 11, 2014 / Accepted January 15, 2015

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2.42 mSv/year [2] which may vary depending on the geology and altitude of a region in which people live - in the range between 1 and 10 mSv/year, but in some locations it may be more than 50 mSv/year.

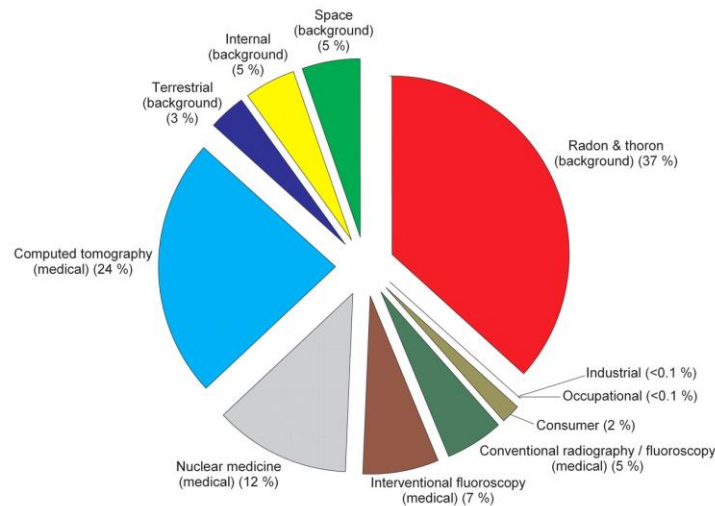


Fig. 1 Major radiation sources

In most countries, the current maximum permitted dose is 20 mSv/year. This value is recommended by the International Commission on Radiological Protection (ICRP).

Measurement of natural background gamma radiation requires very sensitive instruments which are due to their characteristics most often stationary instruments. However due to limitations in costs sometimes is necessary to use portable instrument on several locations.

Following the accident in Chernobyl in 1986, most European countries have installed networks for the monitoring radioactivity in the environment. Monitoring of gamma radiation in the Republic of Serbia is being performed through a real-time early warning network constituted of nine detectors. Six of them are MFM 203, one is MFM 202 and two are ionization chambers RSS-112.

Sophisticated instruments like MFM 203 are often quite expensive. Sometimes it is necessary to employ less expensive solutions such as one presented in the paper [3]. By employing several low-cost instruments presented in the paper [3], it would be possible to perform measurements from more locations at the price of one sophisticated instrument.

In the paper [4] under the same criteria a comparison between 20 different detectors while monitoring environmental background radiation was performed. Depending on the type of detector compared to the reference device (ionization chamber high-pressure RSS-131) analysis noted either positive or negative difference in measurement results. Variations of result in systems with the same type of detector were also noted and they are defined as detector's self-effect.

The active detectors are most commonly used as sensors in monitoring instruments. They are designed to measure the environmental radiation dose equivalence. One of the

active detectors most frequently employed in commercial instruments are Geiger-Müller (GM) tubes due to many advantages they provide, reasonable prices and robustness.

GM tubes provide numerous advantages. Due to high voltage across a tube they generate relatively high voltage pulses which exclude the use of additional amplifiers. The height of output pulses is independent of the initial ionization making GM tubes possible to measure even low energy radiation.

In this paper implementation of a wireless system for measurement of natural background gamma radiation using the commercially available portable instrument GAMMA-SCOUT and the custom-made wireless module is presented.

2. SYSTEM ARCHITECTURE

The proposed system is based on a GAMMA-SCOUT made by GAMMA-SCOUT GmbH & Co. The GAMMA-SCOUT is portable instrument equipped with a GM tube serving as a radiation detector [5]. This device can detect and measure not only gamma radiation, but alpha and beta radiation as well.

The ONLINE model used in proposed system has been designed to transmit data cyclically (synchronized with the measuring). Physical appearance of this device is shown in Fig. 2.

Due to the ISO certification each GAMMA-SCOUT undergoes a rigorous factory inspection and calibration procedure before leaving assembly line. The tested device must be in a confidence interval of 5 % in comparison to a master. This master is adjusted to a gauged reference ^{137}Cs radiation source.

The GAMMA-SCOUT is designed to operate in ONLINE mode of operation that is to transfer measurement results to a PC via USB port. This is highly impractical because the instrument cannot operate without a PC which must be situated very near the GAMMA-SCOUT. This makes the GAMMA-SCOUT practically useless in terms of online monitoring of gamma radiation. Solution for this issue is to “upgrade” the GAMMA-SCOUT by implementing a wireless feature using an additional hardware block and connecting the GAMMA-SCOUT to a remote PC wirelessly.

The GAMMA-SCOUT is designed to transmit the detected pulses to the connected PC in a specific time period via USB port. However, if the PC is to be replaced with a microcontroller (MCU) as a controlling and acquisition device, the GAMMA-SCOUT can still operate in ONLINE mode but it no longer needs an expensive and robust PC.

Block diagram of the proposed portable wireless measurement system based on the GAMMA-SCOUT is shown in Fig. 3.



Fig. 2 GAMMA-SCOUT instrument

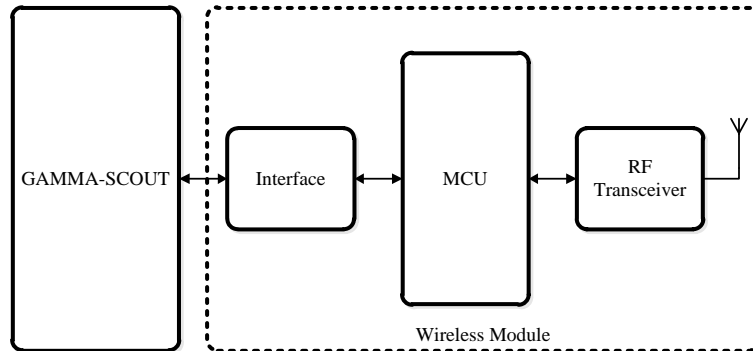


Fig. 3 Block diagram of the realized system

Older GAMMA-SCOUT devices have a RS232 interface via a 9-pin SUB-D connector while the new ones have USB using a FT232RL chip. There are also two different data transfer protocols, v1 and v2. Newer models of the GAMMA-SCOUTs use the v2 protocol which unlike the v1 can initiate the connection instead of activating the PC mode by pressing the proper button. This makes the GAMMA-SCOUT with a v1 protocol virtually useless for continuous data logging.

Communication with the GAMMA-SCOUT is done with 9600 bauds, 7 data bits, even parity, 1 stop bit and no echo. In table 1 the list of the supported commands by the GAMMA-SCOUT is given.

Table 1 List of the supported commands by the GAMMA-SCOUT

ASCII Command	Function
v	Request device status
b	Dump Protocol
z	Clear protocol memory in device
t	Set date and time
X	Quit Data Transfer Mode / Stop Online Mode
O	Switch ONLINE Mode ON
P	Switch Data Transfer Mode ON
s	Request ONLINE - Status (in actual INTERVAL)
0-9	Select ONLINE Interval

The GAMMA-SCOUT is connected to the PIC16F887 MCU using a proper interface. This interface is implemented using two FT232 chips, one in the GAMMA-SCOUT itself and the other connected to the MCU. The MCU is also connected to the RF transceiver Telit LE70-868.

Operation algorithm of the proposed system is illustrated in Fig. 4.

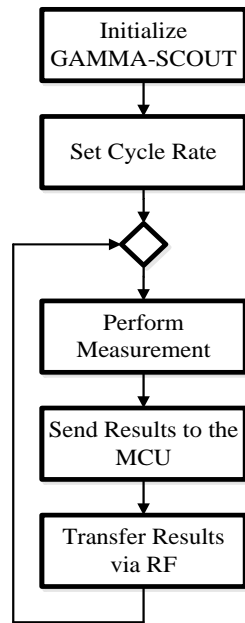


Fig. 4 Operation algorithm

Cycle rate can be set by sending the appropriate command from the MCU instead of a PC [5]. When cycle period is selected, the GAMMA-SCOUT conducts measurement and sends the obtained results to the MCU. These results are later sent via the RF transceiver to a nearby base module connected to a PC. Because the high power LE70-868 RF transceivers are utilized the maximal range between the base module and GAMMA-SCOUT is up to 10 km. Therefore, by adding the wireless module to the GAMMA-SCOUT it gains a greater mobility and functionality. Data acquisition, storage, processing and visualization are performed by the PC to which the base station is connected. Physical appearance of the proposed system is shown in Fig. 5.

Because the proposed system is intended for continuous environmental online radiation monitoring it must be connected to a server (host) so the results can be monitored in the real-time as well as stored using a custom-made virtual instrument developed in LabVIEW.

3. RESULTS AND DISCUSSION

The employed GAMMA-SCOUT instrument was thoroughly tested for measurement of natural background gamma radiation and the obtained test results are presented in paper [3]. However, to properly test newly implemented wireless feature, it is necessary to conduct additional tests. New series of test are performed on the stone blocks built-in along the riverside promenade. Measurements are taken in the city of Niš on the left bank of the river Nišava, on the tracks illustrated in Fig. 6.



Fig. 5 Physical appearance of the proposed system

The measurements were taken 1 m above the ground without any barriers between the instrument and ground, as instructed in papers [6, 7 and 8].

Two successive measurement series were performed each with total 60 measuring points. Distance between the measuring points is 10 m and at one point the distance between the host PC and the portable instrument was roughly 400 m. At each measuring point, the total count for 3 minutes is recorded. In this manner three successive readings were taken for each point.

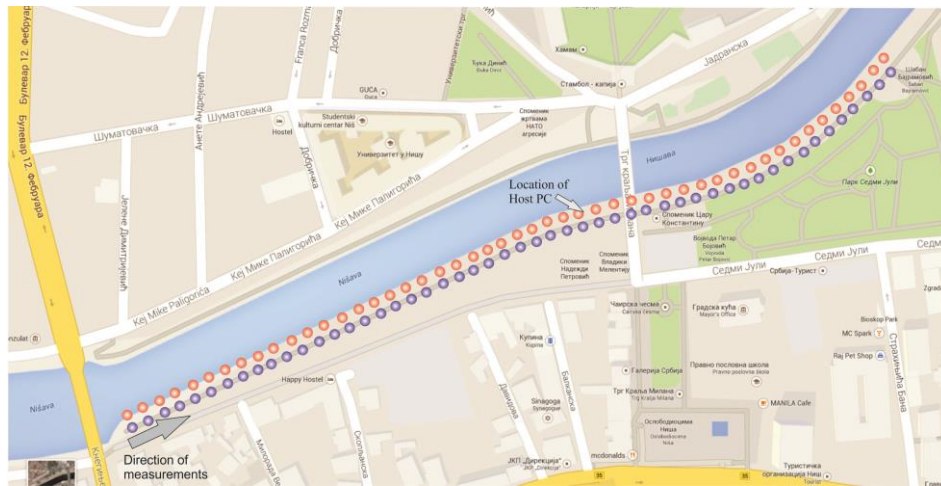


Fig. 6 Location where the measurements were performed

The average total count is converted to count per minute by dividing it by 9 because of 9 minute long (3 readings lasting 3 minutes) measurements. The mean total count and standard deviation is presented in Table 2 and Fig. 7. The average dose rate ($\mu\text{Sv/h}$) for each point was obtained as well and presented in Table 2 and Fig. 7.

Table 2 Dose rates of natural background gamma radiation measured on the tracks illustrated in Fig. 6 (in $\mu\text{Sv/h}$)

Radiation Dose	Both measurement (blue & red)	First measurement (blue)	Second measurement (red)
The maximum value	0.3946	0.3946	0.3195
The minimum value	0.0564	0.0564	0.0752
The average value	0.181	0.1627	0.1993
The median value	0.1879	0.1503	0.1879
The standard deviation	0.0554	0.0558	0.0485

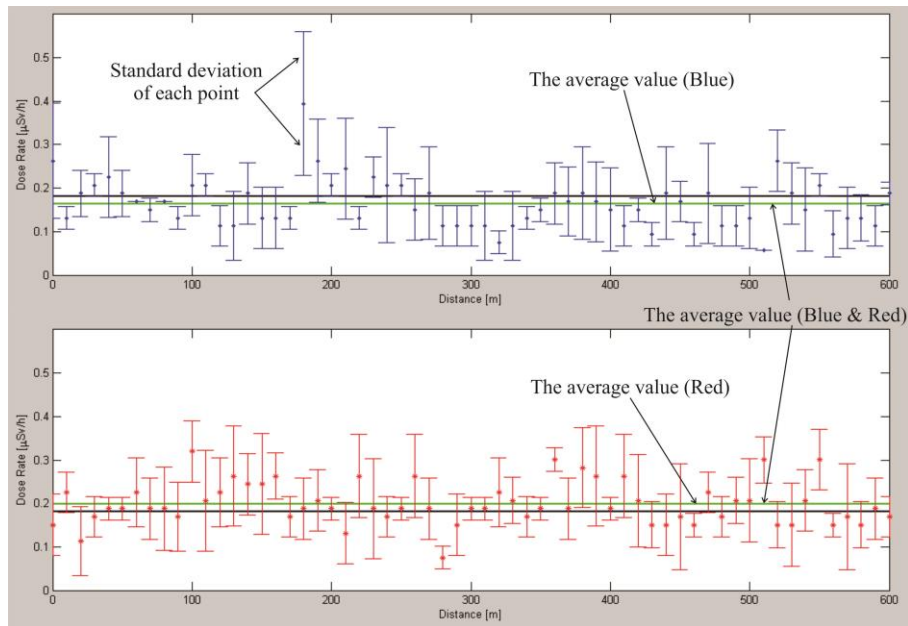


Fig. 7 Measured values of dose rate

Measurements that show the impact of the stone blocks built in the promenade are marked with blue color (first measurement) while the measurements that show the influence of the river are marked with red color (second measurement) as shown in Fig. 6 and Fig. 7, and Table 2. Fig. 7 shows the average value of each measurement series with the corresponding green straight lines and the standard deviation for each sample. The average value of both measurement series is marked with the black straight line on both graphs with the intention to emphasize slightly higher readings of the second (red color) measurement series.

4. CONCLUSION

This paper presents the implementation of the wireless system for measurement of natural background gamma radiation using the commercial portable instrument GAMMA-SCOUT and the realized wireless module. This approach enables similar high-quality and relatively cheap devices to become the part of standard meteorological stations by extending the scope of the measured parameters with additional, such as UV and gamma radiation, solar radiation, etc.

The conducted tests demonstrate that the proposed solution is simple, it works flawlessly and can easily be used. Based on the obtained results it can also be concluded that the natural background radiation observed at the surveyed areas could be attributed only to natural sources (cosmic and terrestrial) since the ambient radiation levels worldwide are about $0.1 \mu\text{Sv/h}$ - $0.25 \mu\text{Sv/h}$. It should be noted that the readings conducted near the river (red color) are slightly higher compared to the readings near the stone blocks (blue color) walled into the promenade.

Acknowledgements. *The research presented in this paper is financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the project III43014.*

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BEŽIČNI SISTEM ZA MERENJE PRIRODNOG POZADINSKOG GAMA ZRAČENJA

U ovom radu predstavljeno je rešenje bežičnog sistema za merenje prirodnog pozadinskog zračenja korišćenjem komercijalnog prenosnog instrumenta GAMMA-SCOUT. Obzirom da GAMMA-SCOUT ne poseduje fabrički implementiranu bežičnu komunikaciju, neophodno je izvršiti njegovu nadogradnju implementacijom odgovarajućeg hardverskog bloka. Prototip hardverskog modula je baziran na mikrokontroleru Microchip PIC16F887 i RF primo-predajniku Telit LE70-868. Struktura i funkcionalnost ovog modula su takođe detaljno prezentovani, kao i eksperimentalni rezultati dobijeni primenom realizovanog sistema.

Ključne reči: *Bežični merni sistem, prirodno pozadinsko gama zračenje, GAMMA-SCOUT, mikrokontroler, RF primo-predajnik.*