Mobile Measurement of Ionizing Radiation

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Abstract. *This document describes an apparatus which can be used for monitoring of ionizing radiation and for building graphical maps representing the radiation dose rates by geographical position. Essential parts of this apparatus are a calibrated dosimeter for estimating the gamma dose rate, GPS receiver and personal computer for storing the measured values and for visualization purposes. This system generates interactive map based on Google Maps API that clearly visualizes ionizing radiation levels for easy examination and localization of radiation anomalies or radioactive contamination zones.*

Keywords: Dosimetry, GM tube, Ionizing Radiation Measurement, GPS

1. Introduction

Nuclear plant accidents and radioactive waste management is still widely discussed topic in spite of high level of security systems and regulations. Such contamination caused by radioactive materials presents a hazard because of the radioactive decay of the contaminants, which emit harmful ionising radiation. The degree of hazard is determined by the concentration of the contaminants, the energy of the radiation being emitted, the type of radiation and proximity to organs of the body. It is always important to measure the dose rates in highly populated areas to reduce the risk of exposition to radioactive substances. When dealing with radiation dosimentry we usually talk about portable radiometry devices used for measuring exposure to ionizing radiation. When it's necessary to perform the measurement on larger area, e.g. around a plant or a city, this measurement is done by personnel walking around with dosimeters and manually localizing the zones with high radiation levels. In case of natural disasters, power plant failures or huge contamination leakages, the measurement needs to be done on larger geographical scale and it's reasonable to investigate the methods for more effective monitoring of radiation leakages.

2. System overview

Calibrated dosimeter as a standalone device is used for measuring the ionizing radiation levels. This device calculates the dose rate by counting the particles registered by Geiger Muller tube (GM tube) during a selected time interval. GM tubes are gas filled at specific pressure anduse Towsend avalanche phenomenon to produce easily detectable electronic pulses from a single ionising event caused by entering a radioactive particle into the tube [1]. We modified the dosimeter to make the filtered output of GM tube available for processing by programmable oscilloscope DS203. The firmware running on this oscilloscope uses the analog input channel for measuring the impulses representing a particle hit, the count of impulses observed during defined time interval is used

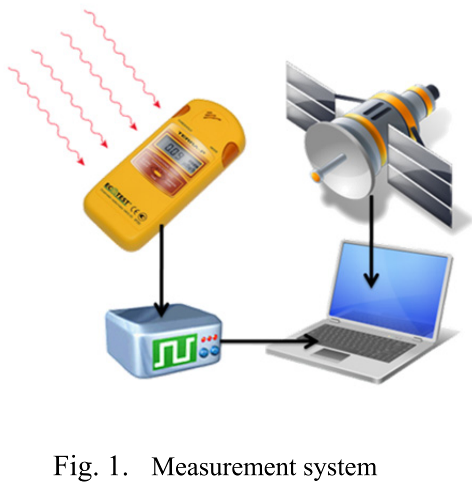

Fig. 1. Measurement system

for calculation of the dose rate. These values are further processed by personal computer by the means of storing the current dose rate value with GPS coordinates in the database. Figure 1 shows this configuration with dosimeter on top left, programmable oscilloscope on left bottom and laptop computer receiving GPS coordinates from satellites.

Software part of this apparatus consists of three components: oscilloscope firmware providing the computer immediate dose rate value through serial link, server application running on PC aggregating the dose rate values and geographic position from GPS receiver and finally a visualization application that analyses these logs, fragments measured values into a grid with fixed sized cells by geographical coordinate and calculates the average dose rate for each cell of this grid. Because there are usually multiple measured values belonging to a single cell, this application also allows the user to apply one of the detector modes on these values to get a single representative value of dose rate for each cell. It can be either calculation of the average, maximum or minimum dose rate.

3. Calculating the dose rate with programmable oscilloscope

For processing the dose rate values by the personal computer we need a device that is able to analyse the output signal of GM tube, count the impulses, calculate the dose rate and provide the result to the computer through serial link. This value is calculated from the number of impulses generated by the ionizing particles, by mutiplication of this number with tube sensitivity and by taking the dead and recovery times of the tube into account [2]. If n’ counts are recorded in a time interval t with a detector of dead time d, it is necessary to compute the true number n that would have been observed with a counter of zero dead time. Since n’d is the total dead time and n/t is the true counting rate, (n/t)n’d is the total number of counts that would have occurred during the total dead time interval. Therefore (n/t)n’d = n – n’. In terms of the counting rate, R=n/t and R’=n’/t. Corrected rate is calculated rate by Eq. 1.

$$R = \frac{R'}{1-R'd} \tag{1}$$

For this purpose we have developed an application for DS203 oscilloscope which setups the sampler to 200 mV/div at 200 ns/div and trigger to reliably capture each impulse from GM tube. Output signal voltage in idle state is 2.1 V and during the ionising event drops to 0 V for 2 μs, total recovery time for the GM tube is 4 μs, the oscilloscope requires extra 23 μs to be ready for capturing next trigger event. Constants of the calculation algorithm were finetuned to get similar reading on the oscilloscope as on the dosimeter. Next task of this application is counting the impulses during chosen time interval. Sensitivity of GM tubes are usually specified as a ratio of count of ionization events per second or minute to micro Sieverts per hour. Thus we need to calculate the count of ionization events per fixed time period. For mobile measurements we use one minute interval and for static measurement the interval of 5 minutes gives very accurate reading, providing one extra digit to the value displayed by dosimeter. Setting the length of time interval is a trade-off between the precision and sensitivity, the longer the interval, the higher accuracy we get at the expense of slow adaptation to environment changes. With short interval we can quickly identify fast changes of the radiation levels, but with lower accuracy.To get immediate reading of the dose rate levels we developed an algorithm that calculates the count of impulses during chosen time interval. Whole time interval (e.g. 1 minute) is divided into 60 time slots

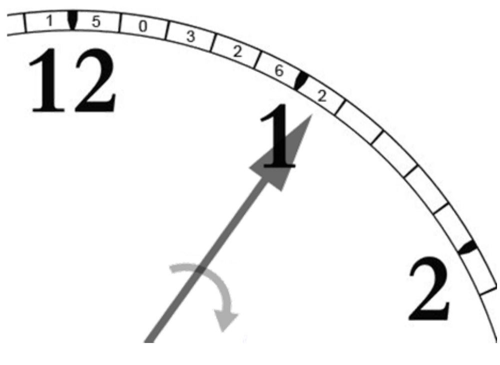

Fig. 2. Continuous filling of the time

(see Fig. 2). Every captured pulse causes an increment of the value of current slot, on the figure this slot is shown as seconds hand on clock. This is periodically moving around these 60 slots same as seconds hand does. When the hand jumps to next slot, it clears this slot to zero. Count of impulses that were captured during last minute is calculated as sum of all time slots, while for the current time slot we use it's value before clearing, because its value is still being changed. By this algorithm the calculation of pulses per minute is quick and trivial task. This algorithm was optimized for running on microcomputer with little available memory and is implemented as ring-buffer in informatics terminology [3].

When not all of the slots are filled yet, the result is calculated as the sum of the N filled slots multiplied by the correction factor that is calculated as ratio of 60 to N. When we want to achieve higher accuracy, we can increase the integration time by slowing the movement seconds hand. For example by slowing the hand 5 times, we get total integration time 5 minutes, thus getting 5 times better accuracy, while keeping the memory footprint of calculating algorithm the same. The application screen running on DS203 is shown on Fig. 3, on top we can see particle counter with calculated dose rate in micro Sieverts per hour and on the bottom there are 60 time slots with the highlighted one in center.

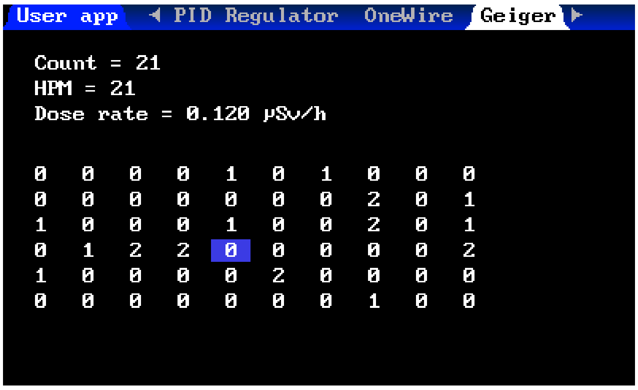

Fig. 3. Portable oscilloscope application

4. Visualization of results

For visualization purposes we have employed the Google Maps API as JavaScript component [4]. Over the road map series of semi-transparent rectangles are drawn representing the dose rate at specific position (see Fig. 4). These rectangles cover whole travelled route. For visual differentiation of the levels we use different colors or grayscale gradient, in this case the rectangles are solid black for values higher than 0.25µSv/h, lower values are drawn with higher transparency and for values below 0.05 µSv/h they are completely transparent.

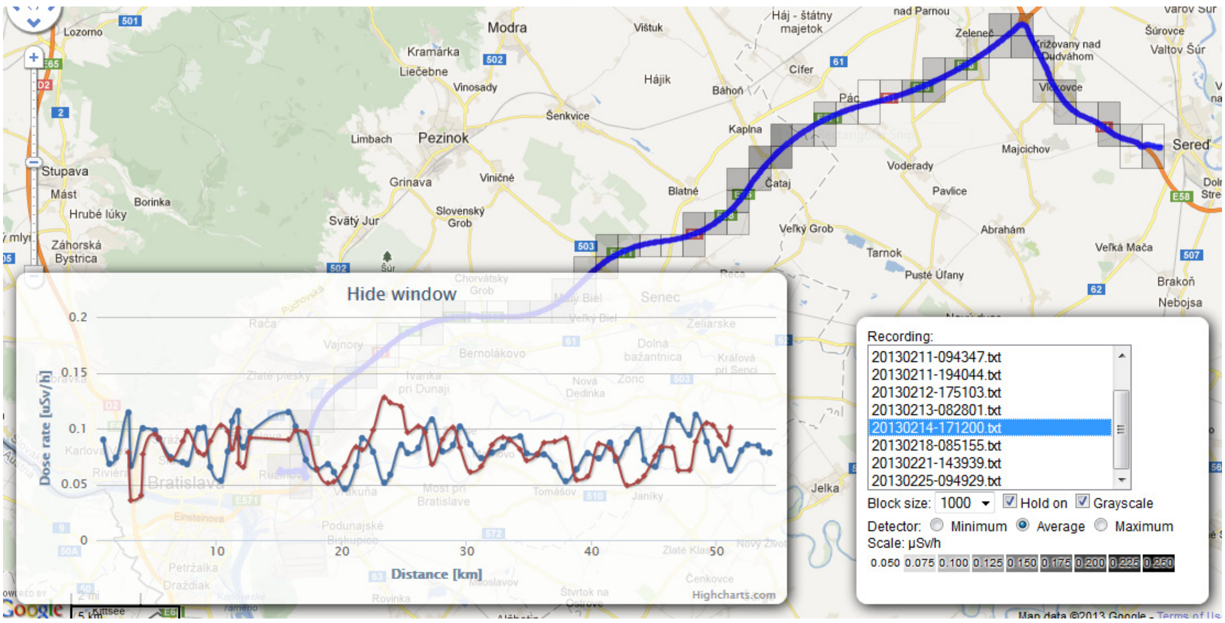

Fig. 4. Measuring while travelling between two cities (50 km).

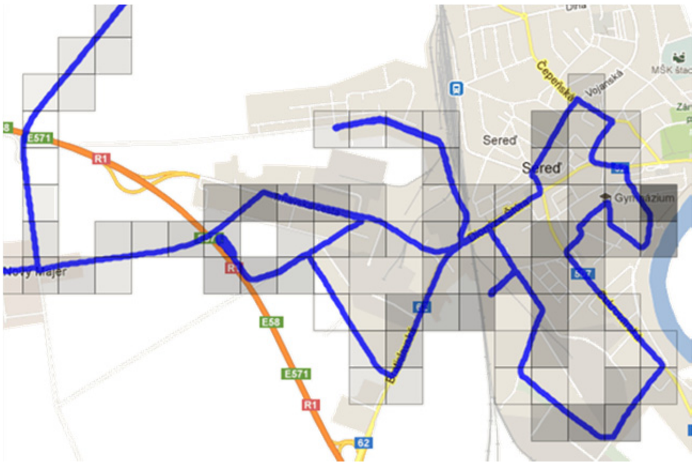

Fig. 5. Measuring inside city

On the bottom left part of the application window there is a graph representing the dose rate levels depending on the position relative to route. For evaulation purposes we travelled the highway between two cities multiple times on different dates and at different times of day to compare the results. Fig. 4 shows the comparison of two recording. The dimension of grid cells can be set in range from 50 meters up to 1.5 km. Smaller dimensions are suitable for measurements performed at low speeds inside city (see Fig. 5) while the higher values are good for visualizing longer routes. Whole travelled route is fragmented into series of these cells, the server application records the dose rate and GPS position in one second intervals, thus we are getting multiple dose rate values belonging to a single cell. Similarily as in other fields of electronics we apply detection mode for getting single numerical value representing the overall dose rate in single cell. It can be either calculation of the minimal value, maximal or average.

5. Conclusions

Presented apparatus offers an innovative mobile method of dosimetry measurement, using Google Maps API we get flexible application allowing the operator to examine and compare measured recordings on any computer platform. We demonstrated this system by measuring the ionizing radiation on highway between two cities mutliple times as such as monitoring the dose rates around a single city helping us to localize areas with higher background radiation levels. In case of radiation emergency by having this system installed on multiple cars, this can be used for investigation of the impact of this accident. By building radiation maps, we can quickly identify the most affected areas and prepare evacuation plans for their inhabitants.

Acknowledgements

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