ISSN No:-2456-2165

# Resolving Radiation Interference Problems Due to Neighboring Installed Radiation Detection and Scanning Instruments

W. EL-Gammal, M. Darweesh and Z. Ahmed
Safeguards & Physical Protection Department, Egyptian Nuclear and Radiological Regulatory Authority,
P. O. Box 7551, Nasr City, 11762, Cairo, Egypt

**Abstract:- Effective border security is critical to detect any illicit transport of nuclear and other radioactive Material out of Regulatory Control (MORC). At a State border different competent authority such as customs, police and other stakeholders have different mission areas and instruments operated under their own procedures. At such locations, different types of radiation detection equipment like Radiation Portal Monitors (RPM) and X-ray scanning machines are used to detect nuclear and radioactive material and scan vehicles and containers. Sometimes, due to some environmental constraints, theses equipment may work closely, which may affect their performance. In this work, the Monte Carlo simulation method has been used to investigate the effectiveness of some suggested solutions to eliminate the effect of operation of an X-ray machine on the performance of an RPM device.**

***Keywords:-*** *Radiation Interference, Radiation Detection, Border Security, RPM, MCNP5.*

## I. INTRODUCTION

Large number of radioactive source and large amounts of Nuclear Material (NM) are used worldwide in many areas including scientific research, health, agriculture, education, industry, and power generation. Malicious acts, such as illicit trafficking, theft and unauthorized transfer of NM and other radioactive sources, can lead to nuclear proliferation and/or construction of radiological dispersal and exposure devices. Measures to detect these acts are essential components of a comprehensive nuclear security program. Radiation Portal Monitors (RPMs) provide high sensitivity monitoring of a continuous flow of persons, vehicles, luggage, packages, mail and cargo, while minimizing interference with the flow of traffic [1, 2]. For that reason, RPMs are designed to detect the presence of nuclear or radioactive material at checkpoints on road and rail border crossings, at airports and at maritime ports. RPM are usually based on large volume plastic scintillators, with the capability of measuring the intensity of gamma-ray or neutron radiations, and set on an alarm when the intensity of radiation is above a user-defined threshold [2]. Recently, the demand for RPM systems has been increased, and their capabilities have been improved. The capabilities of PVT and NaI(Tl) gamma-ray detector materials, which representing the main sensitive component in RPMs, have been re-examined and compared with respect to meeting these increased demands [3]. Detection of nuclear and other radioactive materials using passive detectors is complicated by several factors including: (a) drifting background and/or sensor response; (b) variable-length vehicle inspection (“profile length”) due to varying vehicle speed through the RPM inspection zone; and (c) widely varying signal strength and shape depending on ambient background, nuclear and radioactive materials source strength and shielding. The effects of some of these complicating factors have been described in many articles [4-6]. As the RPMs become more efficient, their sensitivity to detect radiation has been increased. Even the operation of other devices employing radioactivity located at relatively large distance from RPMs may affect their performance. In this work, solutions to eliminate the effect of external x-rays emitted from an X-ray machine on the performance of a neighboring RPM are presented. The MCNP code has been used to investigate the effectiveness of the proposed solutions.

## II. DESCRIPTION OF THE PROBLEM

At a certain portal location, which represents a control point to detect illicit trafficking of NM and radioactive sources, two control devices separated by about 83 meters distance were installed. An RPM was installed without any shielding to detect the presence of any radiation sources. Neighboring to it, an X-ray machine - based on a linear accelerator (LINAC) system - was also installed for non-intrusive inspections of vehicles and containers. As illustrated in figure (1), the X-ray machine is installed on the side of the road and is surrounded by heavy concrete radiation shielding walls. On the other side of the road, another concrete wall was constructed to reduce dose rates in front of an X-ray fan generated by the X-ray machine.

During routine operation the operators recognized that the counting rate of the RPM detectors increase above the adjusted threshold without presence of any radiation sources in the vicinity or passing of any vehicles through its inspection area. Investigations indicated that the increase in counting rate is due to operation of the X-ray scanning machine. The responsible authorities were advised, by a certain organization, to build a concrete fence lined with a sheet of lead between the two devices to prevent this effect (see figure 1). However, this solution was resulted only in a slight reduction in the RPM detected count rate, which is still above its adjusted threshold. At this stage, the problem was presented to the Regulatory Authority (RA) to provide the necessary Technical Support.

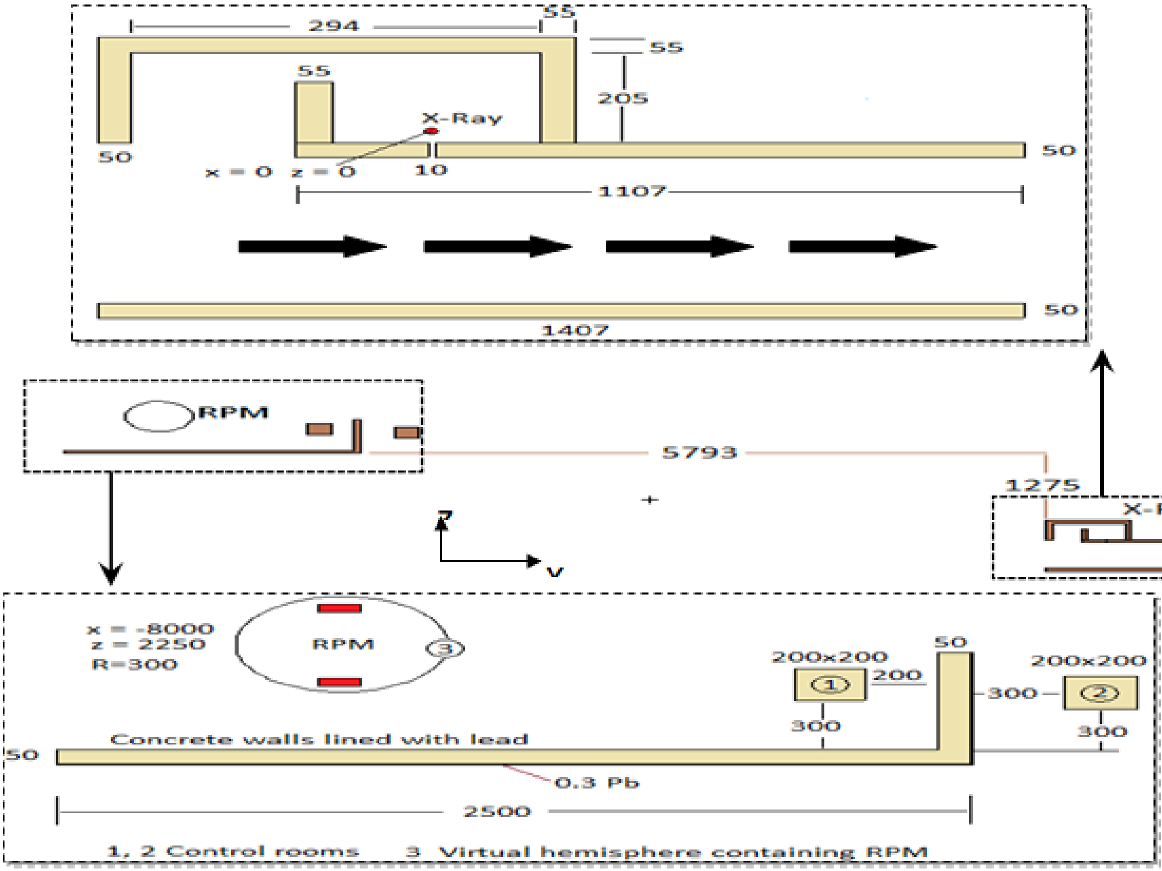

Fig 1:- Locations and modeling parameters of original shielding at the site. (all dimensions are in cm).

## III. TREATMENT AND TOOL

A technical support team was assigned at the RA to study the described problem and provide the responsible authorities at the checkpoint with a variety of possible solutions. The team includes technical members with scientific backgrounds including radiation detection and MC calculations.

It was agreed that the optimum solution could be achieved using MC modeling with conservative approximations and assumptions due to the lack of some detailed information necessary to perform the calculations.

The main target was to reduce the count rate of the RPM detectors due to the operation of the X-ray machine below the adjusted threshold value. Usually, the simplest and direct solution in such cases is to increase the distance separating the two devices. However, this solution was not applicable due to the limited allowable area at the site. Also, the idea to raise the threshold of the RPM was not agreed upon by the operating authority. The remaining proposed solution was to construct a concrete umbrella above the X-ray machine with addition of turned extensions at both entry and exit routs of the scanned vehicles. However due to some safety and technical reasons other shielding designs were also considered. These include the addition of similar shielding on the RPM.

The MCNP5 Code [7] was used to calculate the current of photons at the RPM detectors. The use of MC calculations requires some detailed information regarding the considered problem. Such information includes: the design and specifications of the X-ray machine, such as the flux of the electron beam, the materials and designs of the target, shielding and collimators, and the direction and angle of radiation fan. Unfortunately, little information is available about the machine (6 MeV maximum X-rays with $10^{12}$ photons emission rate). Similarly, only the dimensions of the RPM are the whole available information. Based on the available above-mentioned information, the following data and conservative assumptions were considered for MC calculations:

- The LINAC target design and material were obtained from literature [8]. It was assumed to be a circular tungsten disc with 1cm radius and 0.1 cm thickness.
- The primary narrow beam of 6MeV electron falls perpendicularly on the target with a rate of $10^{12}$ electrons per second (given by the manufacturer);
- No shielding or collimators in the LINAC system were considered;
- Shielding concrete walls were simulated as presented in figure (1), with an opening slit of 10 cm width to produce radiation fan;
- The current of the photons at a hemispherical surface including RPM was calculated to reflect the response of the RPM.

A graded approach was considered to treat the problem as follows:

- **Case (1)** a concrete umbrella above the X-ray machine only.
- **Case (2)** in addition to case (1), a turned extension umbrella at the entry route of the scanned vehicles is increased.
- **Case (3)** in addition to case (2), a turned extension umbrella at the exit rout of the scanned vehicles is increased.
- **Case (4)** in addition to case (3), an umbrella on the RPM is added.
- **Case (5)** a concrete umbrella above the RPM with addition of turned extensions at both entry and exit routs of the scanned vehicles.

For all cases the height of the umbrella is 700 cm.

## IV. RESULTS AND DISCUSSIONS

Before the five cases were modeled, the original (current) status was modeled in order to be able to obtain the fraction of photons counted after adding any proposed shield. The current status was modeled according to the previously mentioned assumptions and the dimensions shown in figure 1. An MCNP input file was written to calculate the current across the hemispherical surface including the RPM using the current tally "F1". While the presence of the constructed concrete fence (lined with 3mm sheet of lead) was resulted in a reduction of the count rate of about 12% only, it was clear that most of the count rate was due to the backscattered radiation. This may be illustrated in figure (2) which is created using the particle display feature of the MCNP5 Code.

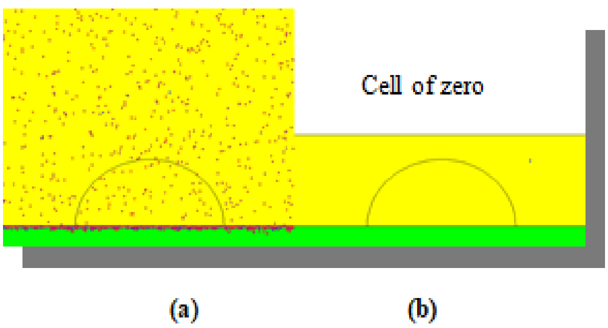


Fig 2:- Current photons at a hemispherical surface including RPM (a) with and (b) without considering the effect of backscattered radiation.

The first assumed case to reduce the count rate of the RPM was to construct a concrete umbrella above the X-ray machine as shown in figure (3) The calculated current was reduced by a factor of 91.5%. The shielding was not complete due to the fact that the umbrella did not prevent all emitted radiations since it is open from both entry and exit sides. Figure (3) shows the directions of emitted radiation indicating the requirement of additional shielding at least at the exit side facing RPM.

Fig 3:- Particle display showing the directions of emitted radiation for case (1).

It was expected that the addition of turned extension at the entry route of scanned vehicles will reduce the counting rate at the RPM, Figure (4). The results of MC calculations show that the effect of this setting reduces the count rate by a factor of 99.35%.

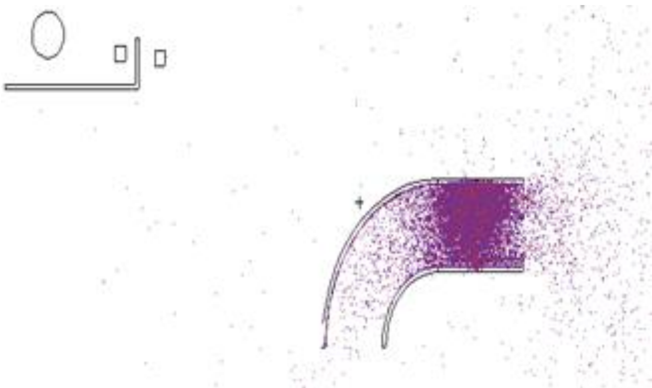

Fig 4:- Model case (2) with addition of turned extension at the entry route of scanned vehicles.

In order to investigate the effect of backscattered radiation at the RPM due to the open exit end of the shielding umbrella, additional round exist is added, Figure (5) The reduction factor in count rate for this case is 99.89%. The case of constructing concrete umbrella on the RPM was also investigated, the reduction factor is 99.98%.

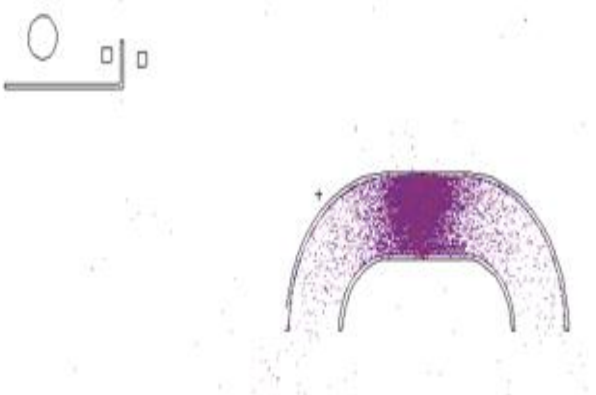

Fig 5:- Model case (3) with addition of turned extension at the exit rout of scanned vehicles,

ISSN No:-2456-2165

In all the above cases the main shielding was assumed to be constructed over the X-ray machine. However, for this shielding it is expected that the radiation dose rate under the umbrella will be relatively higher than that at normal operation due to backscattered radiation from concrete walls. Moreover, a question is raised regarding the quality (resolution) of the generated images which may be also affected. For these reasons another proposal was considered in which a shielding umbrella is constructed over the RPM only, Figure (6) The MC calculations indicate a reduction in RPM counting rate with a factor of 99.99%.

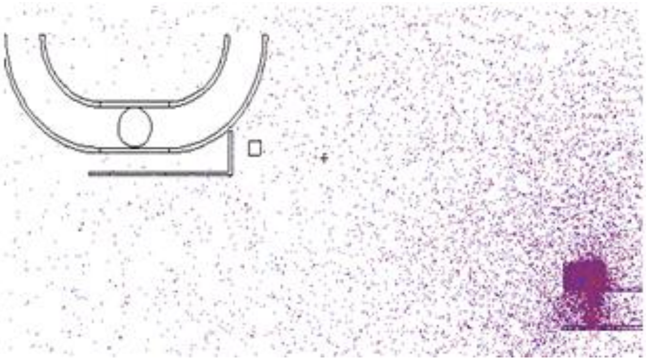

Fig 6:- Model case (5) with an additional umbrella on the RPM.

Table 1 summarizes all assumed and studied cases. It is clear that the last proposal is the most optimum solution for the current conditions. The calculated counting rate is comparable with that for the proposed umbrella on the X-ray machine.

| No. | Percentage of photons in comparison to current situation | Blocking ratio |
|---|---|---|
| Current situation | **100 %** | **----** |
| Case 1 | **8.65 %** | **91.35 %** |
| Case 2 | **0.65 %** | **99.35 %** |
| Case 3 | **0.11 %** | **99.89 %** |
| Case 4 | **0.02 %** | **99.98 %** |
| Case 5 | **0.008 %** | **99.992 %** |

Table 1:- shows the calculated number of photons in the area of RPM in each case

## V. CONCLUSION

The problem of radiation interference among radiation detector and radiation scanning devices has been resolved. Five possible solutions for such problem are presented. The described solutions could be considered whenever distance and operational time separation are non-avoidable. Consequently, shielding solutions have to be considered. The graded shielding approach allow cost saving. The obtained results could be improved if more accurate manufacturer data are available.

.

## REFERENCES


[1]. IAEA Nuclear Security Series No. 6 , Combating Illicit Trafficking in Nuclear and other Radioactive Material, I NTERNAT IONAL ATOMI C ENERGY AGENCY VIENNA, 2007

[2]. Qibiao Wang, Gamma-Ray Source Positioning Using Array NaI(Tl) Detectors in the Radiation Portal Monitors, Journal of the Korean Physical Society, Vol. 75, No. 3, August 2019, pp. 196~201, DOI: 10.3938/jkps.75.196

[3]. R. T. Kouzes,* J. H. Ely, The role of spectroscopy versus detection for border security, Journal of Radioanalytical and Nuclear Chemistry, Vol. 276, No.3 (2008) 719–723, DOI: 10.1007/s10967-008-0623-9

[4]. Burr, T., Gattiker, J., Myers, K., and Tompkins, G. (2007), "Alarm Criteria in Radiation Portal Monitoring," Applied Radiation and Isotopes, 65, 569–580. [296,297,302,305]

[5]. Burr, T., and Myers, K. (2008), "Signatures for Several Types of Naturally Occurring Radioactive Material," Applied Radiation and Isotopes, 66, 1250–1261. [296,306]

[6]. Burr, T., and Myers, K. (2009), "Background Suppression Effects on Signal Estimation," Applied Radiation and Isotopes, 67, 1729–1737. [296]

[7]. X-5 Monte Carlo Team, MCNP — A General Monte Carlo N-Particle Transport Code, Version 5, LANL (2003).

[8]. S. Hanna. "RF Linear Accelerators for Medical and Industrial Applications", Artech House Publishing, 2012.