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Positioning System for Infinite Source Simulation and Calibration of Radiation Detectors

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1. Introduction

The use of radiation detection instruments to monitor the work environment is provided for in the basic legislation of the CNEN (National Commission of Nuclear Energy) and the Ministry of Health, regarding radiological protection in medical and dental radiodiagnosis [1], [2]. The handling of these equipment under varying conditions of temperature, pressure, and humidity, as well as the characteristics inherent to their electronic system, can lead to changes in the response of the equipment. Therefore, they should be calibrated periodically. [3]

To have a correct reading of a detection system, the system must be properly calibrated. The IAEA (International Atomic Energy Agency) recommends that calibration be done every 12-14 months [4], while the CNEN (National Nuclear Energy Commission) requires calibration every 24 months [1], [2]. Even before the first use of a detector, accurate calibration is required. Often the detector manufacturer himself does not do this initial calibration. Reasons may vary, from the lack of appropriate installations for such calibration to the lack of time to calibrate all instruments. It is common for individuals who acquire a detector to believe that the manufacturer has properly calibrated the instrument and end up having erroneous readings. In addition, small calibration inaccuracies can result in large dose reading errors in the detectors. [4]

The calibration of these ionizing radiation measurement instruments is performed using specific reference radioactive sources provided by primary laboratories, such as ^{137}Cs and ^{60}Co (γ emission), ^{90}Sr+^{90}Y e ^{204}Tl (β emission) and Am-Be (neutron emission) [5]. For a radiation source that has a known dose H, under reference conditions, the calibration factor is obtained by equation $N = H / M$, where N is the calibration factor, H is the true value of the dose to be measured and M is the value measured by the instrument being calibrated [6]. However, calibration of instruments using large diameter and homogeneous sources becomes difficult as the manufacture of these gamma, beta and neutron radioactive sources becomes difficult because calibration factors depend on a range of parameters such as energy, angle of incidence, positioning, dose, type of radiation and a variety of environmental conditions. [6]

One of the factors that can result in an error during calibration is the positioning of the detector relative to the radiation source. A small deviation in positioning can cause a major error in the dosimeter response. [3]

The design and construction of this automated calibration system is being developed in the DEN (Department of Nuclear Engineering of UFMG) and aims to simulate a homogeneous infinite source to be used in detector calibration. The angular and linear displacements will be operated by Arduino plates which will allow a great accuracy of the source-detector positionings. The system will be used to make measurements of dose rates of different radiation sources of different energies, with different diameters for calibration of detectors. In addition, the experimental results obtained may be used for future validations of computational simulation data with MCNP (Monte Carlo N-Particle Transport), code that is used by several researchers of the DEN.

2. Methodology

The system will have 2 step motors, controlled by Arduino, which will make the displacement of a radiation detector in relation to a reference source, punctual. The offset will be linear, approaching or moving the detector away from the source, and angular, rotating the detector on the source axis.

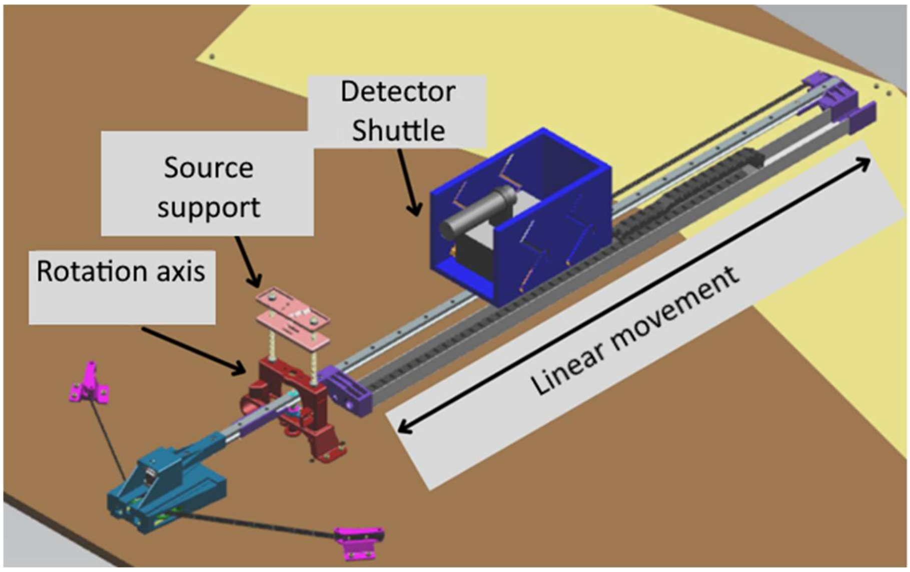

Figure 1: Isometric view of the detector displacement system

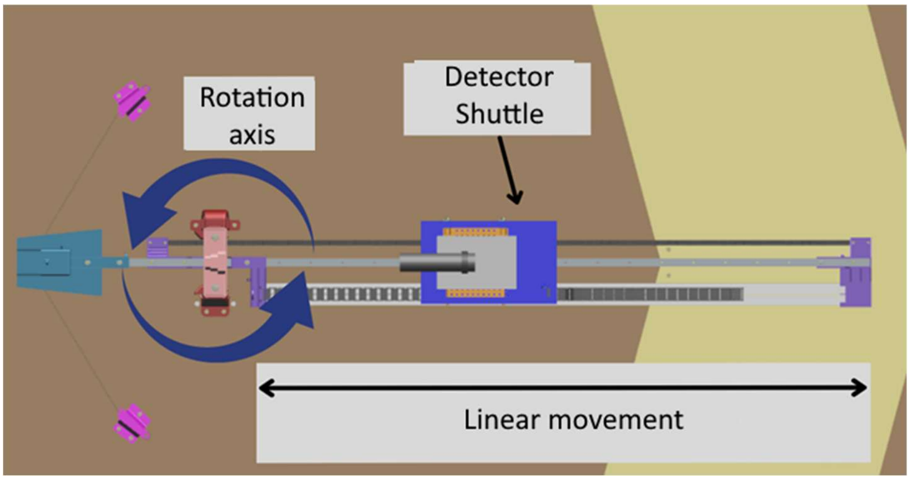

Figure 2: Plan view of detector displacement system

The detector will be coupled to a car that moves on a linear guide, controlled by one of the stepper motors, as shown in detail in Figure 3. Near the end of the linear guide, on a fixed support, the radiation source will be positioned. The holder can adjust the height of the source so that it is aligned to the height of the detector. And in this same support, there will be an axis, in which the linear guide rotates, being able to make an arc of 90º. Rotation is done by the second stepper motor, located at the end of the guide. The subsystem that rotates is displayed in detail in Figure 4.

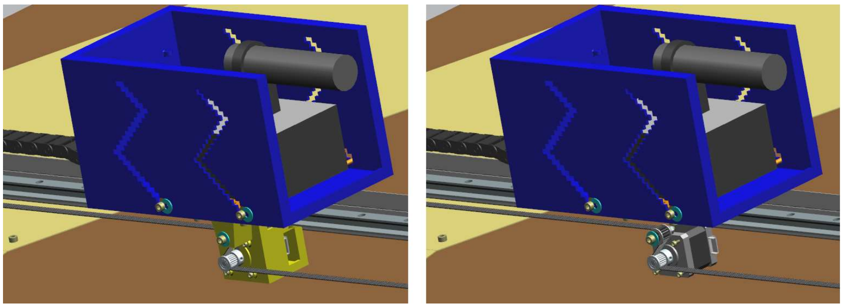

Figure 3: Linear displacement motor detail with motor holder (left) and without motor holder (right)

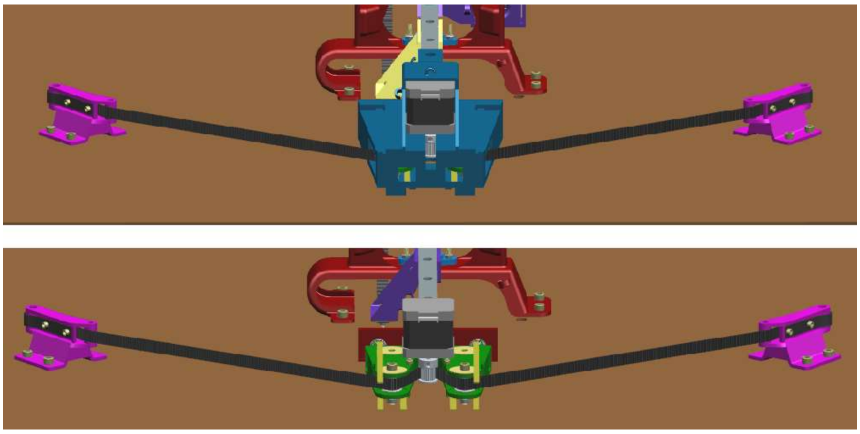

Figure 4: Detail of angular displacement motor (rotation) with motor holder (above) and without motor holder (below)

3. Results and Discussion

3.1 *Using the positioning system as a radiation detector calibrator*

To use the positioning system in order to calibrate a detector, only linear displacement is required. The Arduino, together with the stepmotor, can ensure very precise displacement. Thus, the source-detector distance, will always be quite accurate. Knowing the reference source, simply position the detector at a specific distance and adjust the calibration factor until the measurement coincides with the expected value of the reference source.

3.2 *Using the positioning system for infinite source simulation*

The computational simulations of radiation, which are made by researchers in the DEN, need to be validated, comparing their results with some real experimental data. However, in the laboratory, we have only small reference sources, which from a certain distance from the detector, practically act as point sources. In simulations, as well as in real situations, radiation sources are likely to be much larger. Therefore, to obtain experimental data for a large source (called "infinite" in this work), it is possible to change the positioning of the detector in relation to the point source, thus achieving several different measurements that will simulate an infinite source.

To simulate the infinite source, it will be necessary to make measurements at different distances and angles. First, a measurement is made with an angle of 0º between source and detector. As the angle changes, the linear distance increases and new measurements are made. Each measurement made at a different angle (and consequent linear distance) represents a beam emitted from a different point from the infinite source being simulated. After all measurements are made, the collected data is used together to represent the reading that the detector would make when it was still and facing an infinite source, which would emit beams coming from different directions.

These results can finally be compared with data from computer simulations with infinite source, in order to validate these simulations.

4. Conclusions

Radiation detectors are essential for dosimetry and radioprotection in situations involving the application of radiation. However, it is extremely important that these detectors are only used when properly calibrated. Poorly calibrated instruments can lead to reading errors that can endanger human lives.

Computational simulations with the MCNP code are made by several researchers (and with different objectives) and need to be validated, by comparing the results of these simulations with real experimental data. Obtaining real experimental data for large sources (called infinite here) is difficult due to the difficulty of manufacturing and handling larger reference sources.

The positioning system that is under development in the DEN will therefore have two applications. The first, be used as an automated calibrator of radiation detectors, where the distances between the detector and the source will be precisely controlled by electronic systems. This accuracy is important, since a small variation in the distance between the source and detector can lead to a significant difference in reading. The second application is to use the precision of the positioning provided by the system to simulate an infinite source from a point source. With this, it will then be possible to obtain experimental data that can be contrasted with the results of computational simulations with MCNP code, in order to validate these simulations, even if the computational simulations use fonts of larger sizes.

Acknowledgements

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