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DEVELOPMENT OF A COMPUTER PROGRAM FOR SIGNAL ANALYSIS IN ALANINE-EPR DOSIMETRY

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ABSTRACT

The accurate EPR dosimetry using the amino acid alanine requires adequate equipment, good procedures and specialized staff. The application of this technique for low doses, including the radiotherapy dose range, presents some difficulties. Native signal of detector materials, EPR quartz tube signals and low signal-to-noise ratio for low doses are examples of problems that affect the spectrum and can make difficult the correct signal analysis. This paper describes the work carried out at IPEN towards the establishment of a computer program to increase the detection range of this dosimetry system. The mathematical tools for treatment of EPR signals are evaluated, the best procedures for dosimeters preparation and techniques of measurement are explored, aiming to improve the process. The developed software incorporates the main techniques of data analysis of EPR spectrum and the usual procedures in dosimetry laboratories for high doses evaluation, including the uncertainties calculation of the method. The standardization of the procedures allows obtaining results with better quality and enhanced precision and accuracy.

1. INTRODUCTION

The Electron Paramagnetic Resonance, EPR, dosimetry using the amino acid alanine as sensitive material is a useful dosimetry system applied to transfer and standardization of high dose dosimetry. The technique is based on the quantification of free radicals radiation induced in paramagnetic substances. Traditionally, the peak-to-peak height of the central element of the EPR signal is measured and associated with a calibration curve [1]. Alanine/EPR dosimetry has been used as reference standard method for high dose measurements in the dose range between 10 and 10^5 Gy, extensible to radiotherapy dose levels, 1-10 Gy, with accuracy better than 3% [2]. The EPR technique is applied also for situations involving radiological emergencies by means of the evaluation of the paramagnetic materials found in the accident site, or near the victims, such as sugar, glasses or plastics. In the last years, retrospective dosimetry using tooth enamel and bone was well established, allowing dose reevaluation in the case of Hiroshima and Nagasaki [1, 2, 3]. In all applications, the base of the method is the correct interpretation of the EPR signal and accurate results that requires adequate equipment conditions, good procedures and specialized staff.

The application of this technique for low doses, including the radiotherapy dose range, presents some difficulties. Native signal of detector materials, EPR quartz tube signals and low signal-to-noise ratio for low doses are examples of problems that affect the spectrum and can make difficult the correct signal analysis. Specifically in the alanine/EPR dosimetry, the

evaluation of doses lower than 10 Gy is obtained only after the signal processing of the spectrum [4, 5, 6].
This paper describes the work carried out at IPEN towards the establishment of a computer program aiming to increase the detection range of this dosimetry system [7]. The developed software incorporates the main techniques of data analysis of EPR spectrum and the usual procedures in dosimetry laboratories for high doses evaluation, including the uncertainties calculation of the method. The standardization of the procedures allows to obtain results with better quality and enhanced precision and accuracy [8, 9].

2. STRATEGY TO THE SOFTWARE DEVELOPMENT

The strategy to the software development was based on basic assumptions of new software engineering: modularization, reuse, user-friendliness and web-enhanced. The Prototyping paradigm was used to building the software.

2.1. Requirement Analysis

Problem Characterization:
The software was developed taking account the main activities of the High Doses Dosimetry Laboratory of IPEN [7, 11]. The initial steps were: identification of the main process involving high doses assessment and establishment of procedures to the development of each activity, aiming to define the business-oriented rules and the interfaces of the program.
Laboratory Activities:
The most important characteristic of this system is that it is in total agreement with the Quality System of the laboratory. The main processes identified at the laboratory are presented in Table 1.

Table 1. Main process identified at the High Doses Dosimetry Laboratory of IPEN.

Laboratory Activities:
1) Routine Dosimetry using alanine dosemeters for two dose ranges: A) IP - Irradiation Processing (10 - 10^5) Gy B) RT - Radiotherapy (1 - 10) Gy
2) Dose Reconstruction and Emergency Dosimetry
3) Research & Development - new materials, procedures optimization

2.2. Building the Prototype

Starting from this information was possible to initiate the software modeling. In this study was used software engineering concepts and techniques of construction and analysis of object oriented programming - OOP.
To provide such characteristics the modeling and definition of the interface were performed with Unified Modeling Language (UML) aid [13]. The software implementation was done using object-oriented language Java. An interface based on Java allows the visualization, mathematical handling of the signals and update of the database by Web.

Use Cases:
The laboratory procedures and activities were evaluated and incorporated at the software interfaces by means of the construction of known diagrams named Use Cases. These diagrams give support to requirements definition of the system design taking account the user expectations. The principal Use Cases studied is presented in Table 2. The Use Cases were grouped in scenarios associated with the type of the performed activity. For each Use Case a diagram of events can be elaborated.

Table 2. Scenarios to the use of the software (Use Cases).

Use Cases (scenarios):
Routine (IP and RT):
Calibration Curve Construction (for each dosemeter material and batch set)
Routine Dose Assessment
Research:
Simulation (amino acid only)
Investigation on new dosimetric substances (characterization)
Accident:
Investigation
Calibration curves (for each dosemeter material)
Dose Assessment

3. MATHEMATICAL APPROACH AND RESULTS

The usual method for alanine/EPR dosimetry is to measure the peak-to-peak height of the central element of the spectrum and make its association with the calibration curve. Doses higher than 10 Gy present a clear signal of easy interpretation. The Fig. 1 presents a typical spectrum of DL-alanine irradiated with 500 Gy of ^{60}Co gamma radiation.

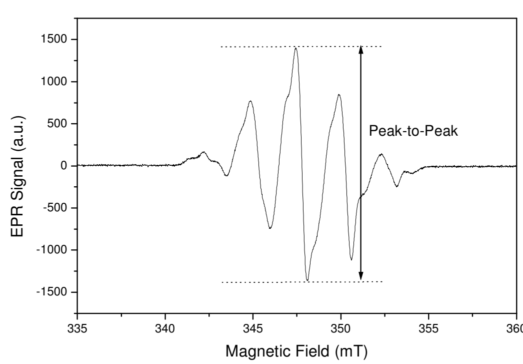

Figure 1. Typical EPR spectrum of alanine for ^{60}Co gamma dose (500Gy).

For doses above 10Gy, the signal-to-noise ratio is low and a mathematical treatment of the data is necessary for the correct determination of the peak-to-peak amplitude. The software developed incorporates the main techniques for EPR signal extraction of the high noise spectra and improve the accuracy of the method. The idea was extract directly the signal, S_D, of the raw spectrum, without carry out through the correction of baseline (Eq. 1). Particularly, Wavelets Transform was used to the signal extraction [12].

$$Spectrum = Signal\ (S_D + S_0) + Noise\ (N_{LF} + N_{HF}) \qquad (1)$$

where:

S_D: absorbed dose signal extracted with filters based in wavelet transform
S_0: background noise (pre-dose) of unirradiated dosimeter
N_{LF}: Low frequency noise - baseline distortion (quartz tube, cavity)
N_{HF}: High frequency noise (electronic associated)

The Fig. 2 presents the application of this method for three EPR/alanine spectra with high noise. The filters based Wavelet Transform presented results 7% better than the extraction of signals using Fast Fourier filters and baseline correction [14].

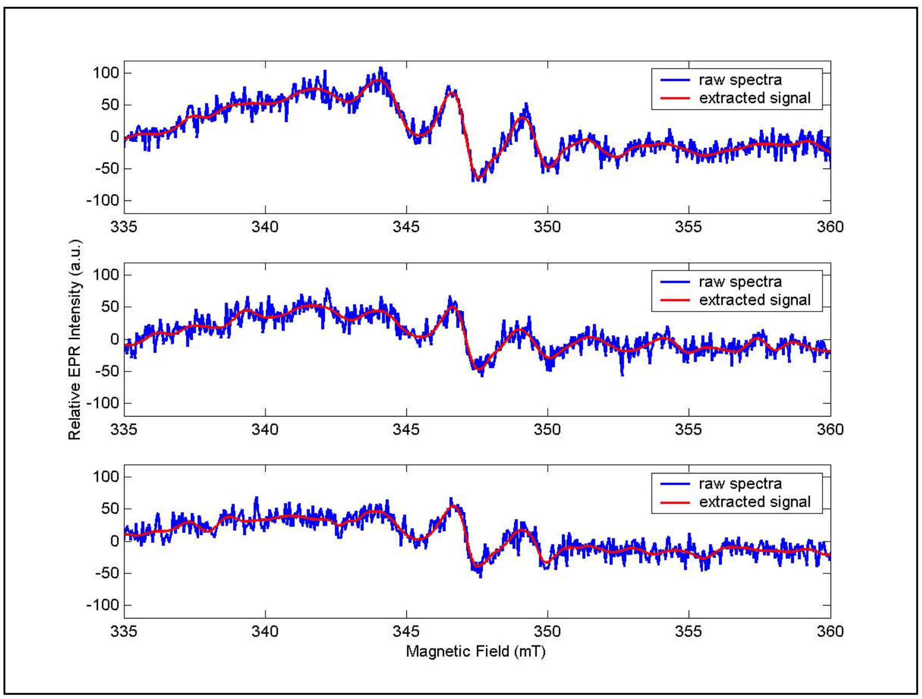

Figure 2. Application of the Wavelet Transform for alanine/EPR dosemeters (1 Gy, ^{60}Co).

4. CONCLUSIONS

The construction of a software to help the dose assessment activities of the High Doses Dosimetry Laboratory of IPEN is part of the process of quality assurance and will improve the accuracy of the evaluated results. The new method for raw spectrum treatment based on Wavelet Transforms has presented better results that the traditionally used Fourier Filters.

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