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Digital Multi-harmonic Signals Acquisition for L-Band EPR Tooth Dosimetry

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1. Introduction

Electron paramagnetic resonance (EPR) spectroscopy is a non-destructive technique that detects free radicals in the sample [1]. Generation of stable radiation-induced radicals in the human tooth enabled dose estimation by measuring the amplitude of EPR signal [2]. Ex-vivo X-Band EPR tooth dosimetry was used for various retrospective dose assessments [3]. However, tooth extraction during the sample preparation limits the applications of ex-vivo EPR tooth dosimetry.

Advanced in-vivo EPR tooth dosimetry using L-band (1-2GHz) was developed to evade dielectric loss in water [4]. Because tooth extraction is not necessary for in-vivo measurement, L-band EPR tooth dosimetry has been considered as a suitable dose estimation method for triage after a mass casualty radiation emergency [5].

Development of technology capacitated EPR spectroscopy improvements using digital signal processing [6]. Direct digital conversion of modulated EPR signal reduced additional noise source and increased the amount of signal using multiharmonics.

We developed an improved homebuilt L-band EPR spectrometer for in-vivo tooth dosimetry by applicating simultaneous digital phase-sensitive detection of multiharmonic EPR signals. For this purpose, spectrometer operation and signal processing software were designed in LabVIEW, and signal conditioning circuit was produced to optimize the signal conversion.

2. Methods and Results

2.1. Instrumentation

The EPR spectrometer was improved based on established homebuilt spectrometer. [7] The spectrometer is controlled by a developed operation software installed in the controller (PXIe-8861, National Instruments, USA).

The measured EPR signal is down-converted at the frequency mixer, and conditioned before converted at the analog-to-digital converter (ADC). After the digital conversion of signal, the operation software simultaneously extracted multiharmonic EPR signals by digital phase-sensitive detection. For the EPR measurement, 1.15GHz carrier frequency, and 21.6kHz modulation frequency was used.

2.2. EPR operation software

Schematic diagram of developed EPR software is shown in Figure 1. The measured signals were saved at the hard disk and processed after the measurement.

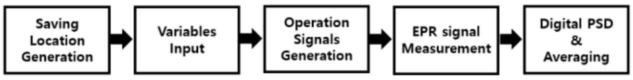

Fig. 1. Schematic diagram of EPR software

To acquire multiharmonic signals digital phase sensitive detection was repeated using multiples of modulation frequency.

2.3. EPR multiharmonic signals acquisition

The first 4 harmonic EPR signals were acquired in one minute measurement using 50 Gy irradiated tooth sample. (Figure 2)

The first harmonic signal is greatly clear. The second and third harmonic signals are clear enough to estimate the signal amplitude even though these are considerably weak compared with first harmonic signal. The fourth harmonic signal was significantly noisy compared with other harmonic signals.

Therefore, first 3 harmonic signal acquisition for L-band EPR tooth dosimetry would be meaningful to increase signal to noise ratio (SNR).

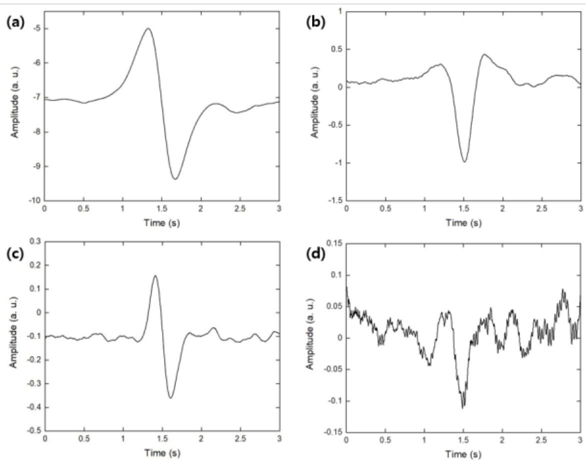

Fig. 2. (a) 1st (b) 2nd (c) 3rd (d) 4th harmonic EPR signal of 50Gy irradiated tooth sample. Total 1-minute measured data was averaged.

4. Discussion and Conclusion

Applying digital signal processing for L-band EPR tooth dosimetry has a number of advantages. By this improvement, clear EPR spectrum and its harmonics were acquired. However, some improvement points are left.

The amplitude of the harmonic signals could be highly increased by overmodulation [8]. In this study, some components limited the modulation field amplitude. However, if the modulation field could be amplified sufficiently, the advantage of multiharmonic signal acquisition would be increased.

In the future study, validation of developed signal processing system would be progress for in-vivo measurements.

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