Implementation of Electronically Controlled Tunable Resonator for in vivo EPR tooth dosimetry

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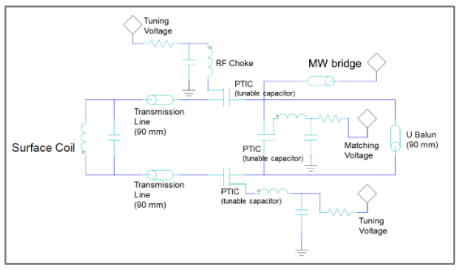
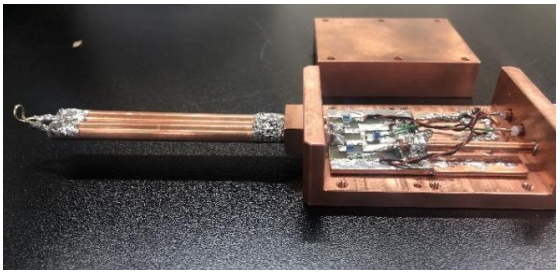
It has been demonstrated that the tooth irradiated by ionizing radiation has free radicals, dominantly CO2-, which is sensitive to electron paramagnetic resonance (EPR). For radiation victims, especially in case of large-scale radiation accidents and radiation treatments, in vivo tooth dosimetry is powerful technique to estimate exposed radiation dose rapidly without any personal dosimeter. [1] We have been developing L-band digital EPR spectrometer for enhancement of our home-built instrument, especially focused on in vivo measurement.

To make in vivo tooth measurement of L-band EPR spectrometer, optimized design of the resonator circuit is necessary for the instrumental advance. Since, the resonator is an essential component for EPR detection as a function of amplifying EPR signal from the detected sample. Especially, when the tooth sample is measured in vivo where motion of the patient is expected, real-time compensation system is necessary to maintain the critical coupling between microwave bridge and the tooth sample. In this study, electronically controlled tunable resonator, which is known to be optimized to conduct in vivo measurement [2], is designed and fabricated.

Schematic diagram of electronically controlled tunable resonator is shown in (Figure 1). Surface coil is main component of the resonator circuit to make B_1 magnetic field and made by 1 mm thickness silver wire with 6 mm outer diameter, which is optimal to EPR tooth dosimetry. [3] In this study, passive tunable integrated capacitor (PTIC, ON Semiconductor Inc.) was used, since it has appropriate specifications: High quality factor and power capability variable capacitance according to input voltage. Through tuning voltage V_T and matching voltage V_M, which are resonance frequency tuning voltage and impedance matching voltage mentioned in (Figure 1), it is possible to control passive tunable integrated capacitor (PTIC),.To verify performance of the tunable resonator, Network Analyzer (E5061B KEYSIGHT Inc.) is used to measure the scattering matrix S_{11}.

Figure 2 shows fabricated electronically controlled tunable resonator. With the fabricated resonator, several specifications, are satisfied for the in vivo tooth measurement of L-band EPR spectrometer. The resonance frequency of the resonator is performed at 1.14 ~ 1.16 GHz, which is within available magnetic field range. The tunable frequency band (MHz) that means tunable resonance frequency range of resonator according to V_T of 2~4 voltage can cover acquired value, which is 2 MHz for adjusting motion of live sample. [4] In our EPR detection system, electronically automatic control V_T, V_M compensates the patient motion, which induce shift of resonance frequency of resonator, during in vivo measurement.





(Left) Figure 1. Schematic diagram of electronically controlled tunable resonator. (Right) Figure 2. The picture of fabricated tunable resonator.

Reference

[1] H. M. Swartz et al., “In-vivo EPR dosimetry to quantify exposures to clinically significant doses of ionizing radiation”, Radiation Protection Dosimetry, Vol. 120, 2006

[2] Lawrence J. B. & Narasimha, L. P. Measuring Oxidants and Oxidative Stress in Biological Systems. Biological Magnetic Resonance 34, 195-197 (2020)

[3] H Sugawara, H Hirata, Sergey Petryakov, Piotr Lesniewski, Benjamin B. Williams, Ann Barry Flood, and Harold M. Swartz, Design and Evaluation of a 1.1-GHz Surface Coil Resonator for Electron Paramagnetic Resonance-Based Tooth Dosimetry. IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING 61, 1894-1901 (2014)

[4] R Nakaoka, Denis A. Komarov, S Matsumoto & H Hirata, Impact of the Characteristic Impedance of Coaxial Lines on the Sensitivity of a 750-MHz Electronically Tunable EPR Resonator. Applied Magnetic Resonance 49, 853-867 (2018)

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