

Single use flexible resonant loops for L-band tooth EPR

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Target audience: EPR instrumentation research and development personnel

Purpose: In accidental radiation exposures, stable free radicals are created in the crystalline structure of the tooth enamel. The amount of free radicals can be measured by electron paramagnetic resonance, enabling the back calculation of exposed radiation dose (1,2). The instrumentation for the measurement of the amount of free radicals in teeth has been under development for several years(3,4). The instrument uses a resonant wire loop, placed next to the tooth, as the sensing probe. The wire loop is typically constructed from pure silver and is permanently attached to the instrument. In this work, we consider a potentially detachable, flexible resonant loop which is conformal for a better fit to patient dependent variable incisor teeth geometries. This single use resonant loop eliminates the need for cleaning between subjects and increases the throughput by allowing placement of the resonator prior to positioning the subject in the magnet. The flexible resonant loops can be fabricated using high volume, lower cost manufacturing methods.

Methods: The single use resonant loop was designed as a 10mm diameter loop with an integrated parallel plate capacitor. The design was modeled in HFSS (ANSYS, Canonsburg, PA) and the size of the parallel plates was adjusted for resonance at 1.15GHz (L-band). The dielectric material between the parallel plates was modeled as 89um thick layer of Teflon (dielectric constant 2.1).

A flexible copper clad substrate (Taconic TLY-0-035, 89um thick substrate, 18um thick copper) was used in the manufacturing. The loop and capacitor metal patterns were created through subtractive photolithographic etching and the resulting copper areas were plated with 1000 Å thick layer of titanium to prevent oxidation.

For proof of concept, the resonant loop was soldered to half wavelength coaxial cables and connected to the microwave bridge of dosimeter developed by Dartmouth College. The resonant loop was placed on irradiated teeth samples (ex-vitro) and the radiation induced signal was measured. Each tooth was measured six times and the data plotted as a function of the administered dose of radiation.

Results: Fig 1 shows the HFSS model of the resonant loop. Resonance frequency of 1.145GHz was achieved when the capacitor pad sizes were 3mm × 3mm. The quality factor (Q) was 343. The manufactured flexible resonators are shown in Fig 2. The resonators were manufactured in batches of four frames and each frame contained 36 loops.

The radiation induced signal amplitudes acquired from the flexible resonators for non-irradiated and 10Gy and 30Gy irradiated teeth are shown in Fig 3. The data show a linear increase in the signal amplitude as a function of the radiation dose, demonstrating the feasibility of using signal amplitude acquired from flexible resonator to predict radiation dose.

Discussion: The flexible resonant loops may significantly advance the implementation of rapid point of care radiation dosimeters, potentially improving accuracy (conformal to the surface of the tooth), throughput (placed prior to positioning of the subject in the magnet) and lowering cost (eliminating the need for pure silver wire loops). Concepts for detachable connection of these loops to the microwave bridge are under development and will enable the single use and effectiveness in emergency triage applications.

References: 1.Swartz HM, Burke G, Coey M, et al. 2007;42(6-7):1075-1084.2.Williams BB, Dong R, Kmiec M, et al.. Health Physics. 2010;98(2):327. 3.Hirata H, Walczak T, Swartz HM., Journal of Magnetic Resonance. 2000;142(1):159-167.4.Salikhov I, Hirata H, Walczak T, Swartz HM., Journal of Magnetic Resonance. 2003;164:54-59.

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Figure 1 Model of the flexible resonator: Loop and capacitor plates (top metal - left), capacitor plate (bottom metal - right)

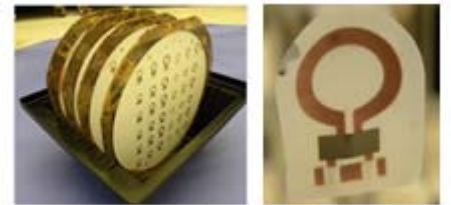


Figure 2 Manufactured resonators (left), close up of single loop (right). Each frame contains 36 flexible resonators.

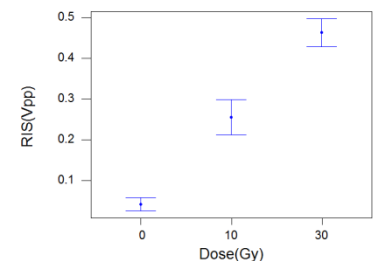


Figure 3 Radiation induced signal (Volts, peak to peak), acquired from irradiated teeth using the flexible loop. The error bars denote standard error of the mean at each dose level.