Research Highlight #138

Surface Resonator Arrays for use in In Vivo *Radiation Dosimetry*

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Introduction. The National Biomedical EPR Center at the Medical College of Wisconsin (MCW) designed and fabricated a microwave surface resonator array (SRA) structure to address the problem of *in vivo* measurements to determine radiation dosage in nails during a mass triage event. This problem was a collaborative project between the resonator development team at MCW and the Department of Radiology at Dartmouth Medical Center under Dr. Harold M. Swartz. Our expertise in resonator design was sought out by Dr. Swartz. The Center is in a good position to take on such collaborations and to contribute in fields previously unexplored by our engineers. This project shows promise in creating a system to rapidly assess the radiation levels in soldiers or citizens that may have been exposed to nuclear fallout.

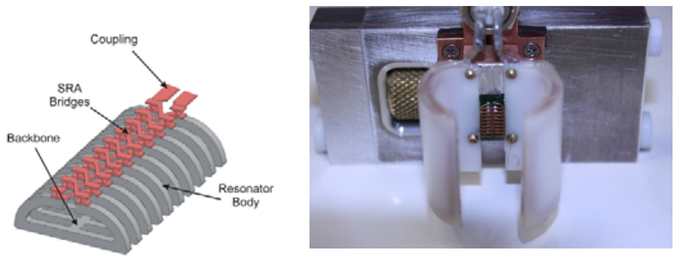

Figure 1: First generation SRA resonator. An illustration (left) shows the resonator body, SRA bridges, backbone and coupling structure. A constructed prototype (right) has shown promising results for *in vivo* experiments.

Methods. The main contribution of this class of resonators is to reduce electric field in the surrounding tissue under and around the sample (fingernails), which will cause losses and degrade resonator efficiency. By concentrating the magnetic field near the surface of the sample, the SRA provides a plane of magnetic field with limited depth sensitivity.

The SRA structure can be modeled as a set of two-conductor transmission lines arranged in parallel. The backbone (Fig. 1) forms a short and provides mechanical support for the structure. The total length of each line is just less than one-quarter wavelength, which makes the line inductive. The rf magnetic field strength is co-sinusoidal along the line and peaked at the short. The inductance of the line resonates with a capacitance formed by conductors on a PC board bridge that connect the transmission lines together in parallel and permit them to be driven by a matching network and input transmission line. Because the lines are alternately driven, the magnetic field reverses direction in every other line. The current flows primarily on the conductor surfaces that face nearby conductors. Using the transmission model in Mathematica, the frequency of a ten-element SRA was calculated and the structure designed in Ansoft HFSS, shown in Fig. 1, illustrating the components of an SRA structure. Ansoft allows us to fully model the fingernails (ε_r=2.1 + j0.0021) and surrounding tissue to optimize the SRA design and calculate EPR sensitivity. The material chosen to represent the surrounding tissue is a tissue equivalent to polyacrylamide gel (ε_r=49.5 + j25.839).

The resonator body was fabricated out of copper using electric discharge machining (EDM) from Integrity Wire EDM (Sussex, WI). The SRA bridges are created from a two-layer polymide PC board 0.005” thick. This reduces wavelength effects between the SRA components. A finished prototype is shown in Fig. 1 (right).

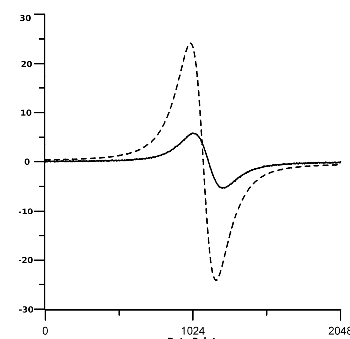

Figure 2: Signal comparisons using a coal sample between a typical Bruker high Q resonator (dashed) and CRC resonator (solid) developed for *in vivo* measurement with tissue equivalent material also present. The ratio of the signals is approximately 5:1.

Results. With a fingernail sample and tissue-equivalent “finger” in place, the Q_0-value of the resonator is measured to be approximately 200. Comparisons using a Bruker High-Q resonator with a coal sample and the CRC resonator with coal and polyacrylamide are outlined in Fig. 2. The experiment shows that the High-Q resonator has a signal intensity of approximately 5:1.

Implications. Advantages include rapid experiment time, no prior preparation of samples, and no mechanically induced signals due to clipping of fingernail samples. This resonator has shown to have good EPR signal intensities, and it is expected that signals can be increased by further optimization of the SRA geometry.

Discussions. Continuation on this project with Dr. Swartz is planned. Recently, the National Biomedical EPR Center has participated in submitting a U19 grant to provide core functionality to the development of this novel resonator as a product for the national stockpile.