Implantable LC Sensor for Tissue Characterization

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The focus of this research is the development of a wireless telemetry link for tissue characterization using an implantable planar LC sensor that consists of a micro-inductor and interdigital capacitor (K.G. Ong, C.A. Grimes, C.L. Robbins and R.S. Singh, Sensors and Actuators A, 93, 2001). Since interdigital capacitors are very sensitive to the dielectrics properties in which they are embedded, they are well suited for permittivity characterization.

In the present work, the LC sensor is implanted in multiple biological tissue layers; which cause a change in capacitance and therefore a shift in the sensor resonant frequency. Simulations have been performed to study the effect of the thickness of the tissue layers on the sensor resonant frequency. As the thickness d of the first tissue layer increases (Fig. 1a), it is shown that the resonant frequency of the sensor varies, until the capacitor reaches saturation, after which additional tissues layers have no effect. This allows for the sensor to be implanted at a depth where it is only affected by the properties of the layer in which it is embedded.

Under these conditions, an analytical formulation has been developed to extract the permittivity ε_{r1} of the first biological tissue from the sensor resonant frequencies f_{FS} in free space and f_{tissue} in the tissue. The final equation is given in (1)

$$\varepsilon_{r1} = (1 + \varepsilon_{rs})\left(\frac{f_{FS}}{f_{tissue}}\right)^2 - \varepsilon_{rs} \quad (1)$$

where ε_{rs} is the substrate permittivity of the sensor.

An experimental work has been conducted with a telemetry link consisting of an external antenna and an LC sensor fabricated on Rogers RT/duroid 5870 (ε_r = 2.33) (Fig. 1b). It is demonstrated that additional layers do not affect the sensor resonant frequency when it is placed at the expected saturation depth. From the measured resonant frequencies with the sensor in free space and embedded in multiple dispersive dielectric layers, the permittivity of the first layer has been extracted using the formulation in (1). The results are in good agreement with measured permittivity obtained using the 85070E Agilent dielectric probe. All the above results have also been validated through simulation using SONNET.

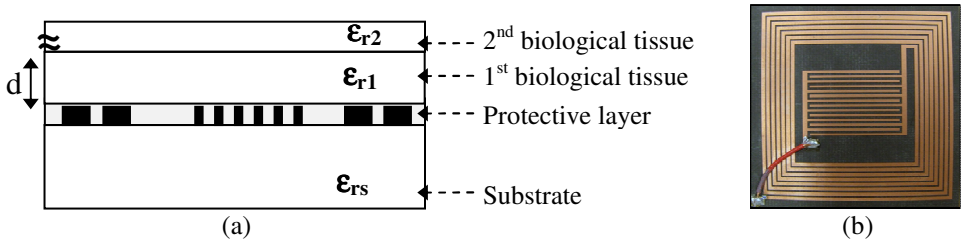

Fig 1: Planar LC sensor with Interdigital capacitor
a) LC Sensor embedded in multiple tissue layers b) Fabricated LC sensor