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RESONANT SENSOR CAPABLE OF WIRELESS INTERROGATION

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Biopolymer Based Resonant Sensors

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1. Background of the Invention:

Recently our group has been investigating biopolymers for applications in electronics, photonics and sensors. Biopolymers such as DNA-CTMA and BSA are currently being investigated by our research group for their unique electrical properties. These biodielectrics exhibited voltage tunable dielectric properties at room temperature when tested using our unique test structure at microwave frequencies [1]. Dielectric tunability of more than 50% were measured in DNA CTMA biopolymer and about 40% in BSA-PVA polymer [1]. The voltage dependent dielectric tunability of these polymers offers a unique opportunity to use the polymers in resonant sensor applications. Also, the capacitive test structure currently used in characterization of polymers can be easily modified to a resonant structure by adding an additional inductance in series with the capacitor.

2. Brief Description of the Invention:

The resonant sensor invented is shown in figure 1. The figure shows the topview (a), and cross-sectional view (b) of the resonant sensor. The coplanar waveguide based device consists of a coplanar waveguide transmission lines at the input and output, shunt loaded by a series LC circuit in the middle. The LC resonant circuit acts as a shunt resonator, as the series LC circuit is terminated in a virtual short circuit to ground, due to the large ground pad capacitor in the device. The equivalent circuit of the resonant sensor is shown in figure 2. The capacitor is modeled by a shunt RC circuit, with the shunt resistor modeling the leaky nature of the biodielectric at the frequencies of interest. The series resistor is a parasitic resistance introduced by the inductor, and the electrode contact to the biodielectric film.

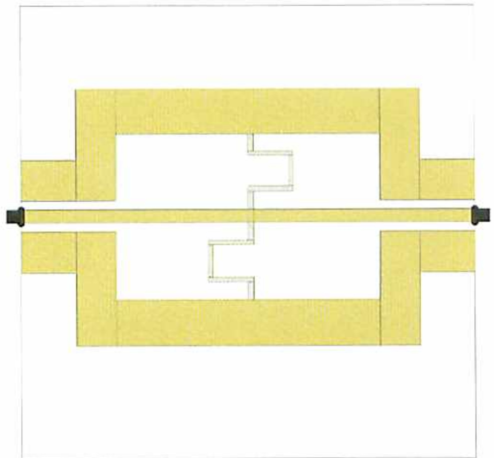

Figure 1a. Layout of the resonant sensor. The resonant sensor consists of CPW feed lines at the input and output and a capacitor loading where the shunt line and the signal conductor overlap. The bottom metal layer consists of ground lines, shunt connected using the inductive line. The top metal layer consists of the Ground, Signal, and Ground (GSG) coplanar waveguide transmission line. The overlap area of the signal conductor (middle line) and the shunt line creates the test capacitor.

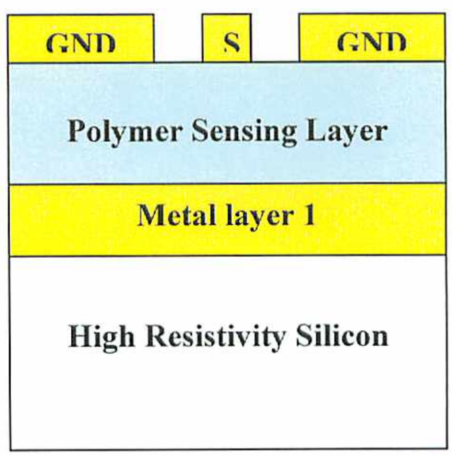

Figure 1b. The cross-sectional view for the resonant sensor, showing the two metal layers. The top metal layer consists of the Ground-Signal-Ground Coplanar transmission line. The overlap area of the signal line and the bottom metal defines the test capacitor.

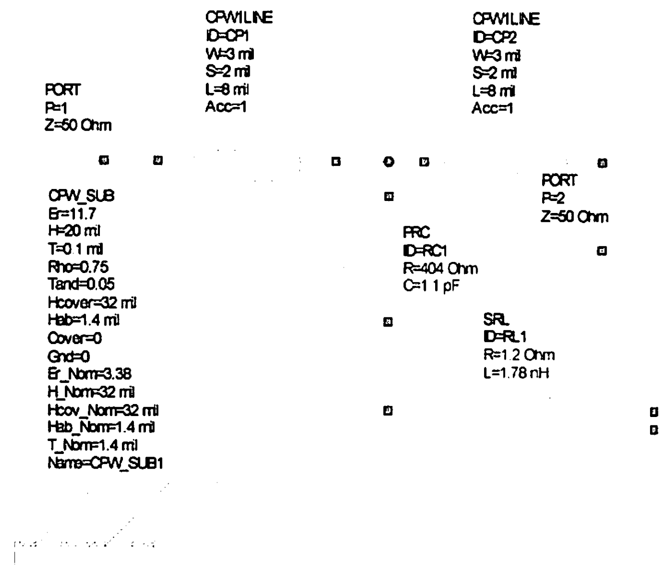

Figure 2. The equivalent circuit of the resonant sensor showing the shunt LC resonance circuit. The values shown are example values for a resonant sensor designed for resonance close to 3.75 GHz.

Applications: Tailored biopolymers could be used as the sensing layer for specific bio-chemicals or chemicals, which can allow for highly sensitive resonance sensors with the potential for high selectivity and high sensitivity. The parameters that could be affected by the analyte are 1. The capacitance of the test capacitor in the shunt resonator, and 2. shunt resistance of the capacitor modeling the leakage conductance of the test capacitor.

Advantages: Potentially higher sensitivity, higher selectivity by the use of functionalized biopolymers, and ease of wireless interrogation by measuring the reflected power from the sensor (i.e., by measuring the scattering parameter S11).

Current State of the Development and Detailed Description: We have modeled the resonant sensor using AWR Microwave Office software tools. The model predicts that very small changes in capacitance can give a large shift in resonance frequency. For example, a 10% change in capacitance results in approximate resonance frequency shift of 200 MHz, as shown in figure 3. Also, increase in conductance of the sensing layer (which results in the decreasing shunt resistance) affects the amplitude of the resonance, as shown in figure 4. When the shunt resistance is reduced to zero-ohms, (from 400 Ohms), the S-parameters change significantly as shown in figure 5. The change in S-parameters can be picked up in a wireless fashion. The change in capacitance also affects the phase of S21 as shown in figure 6. As a result, sensors can be designed with all three measurable parameters, the amplitude of resonance, frequency of resonance, and phase of the S21 (ratio of output power to input power).

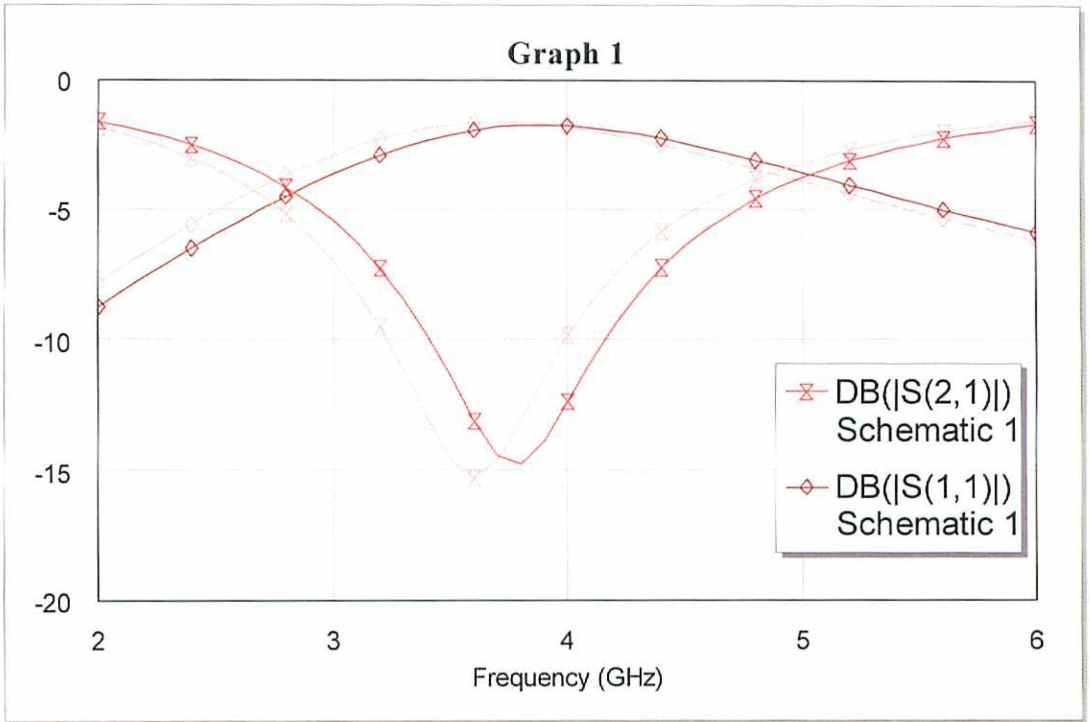

Figure 3. Change in resonance frequency for 10% change in test capacitor values, from 1.1 pF to 1.0 pF.

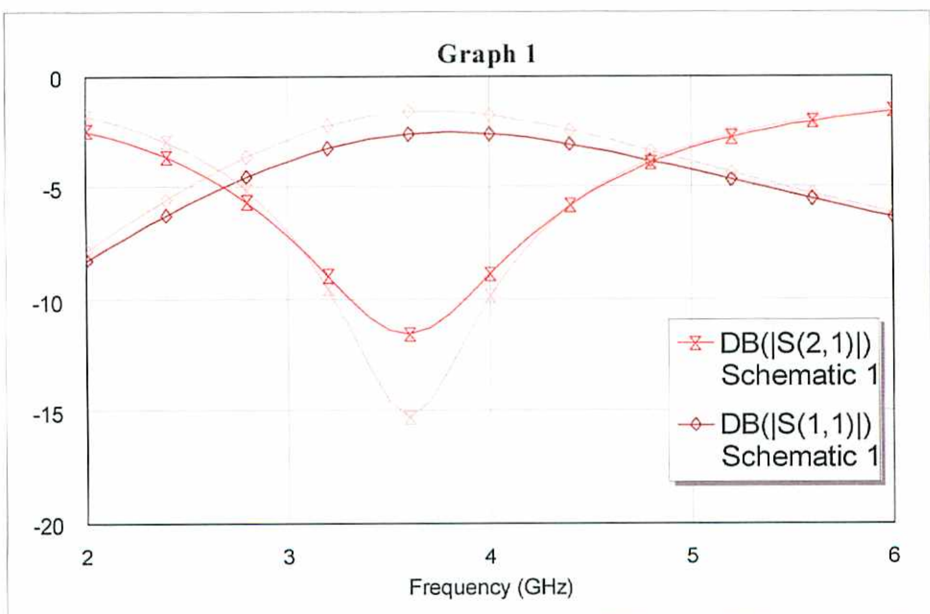

Figure 4. Effect of change in shunt resistance on swept frequency S-parameters. 50% change in shunt resistance of the test capacitor changes the amplitude of S21 by approximately 3 dB.

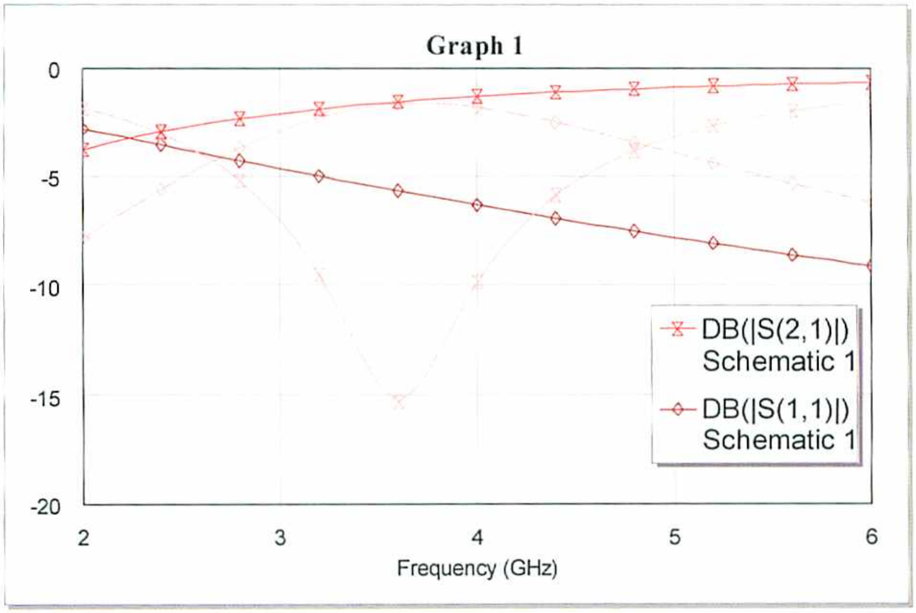

Figure 5. Effect of change in shunt resistance when the shunt resistance goes to zero ohms (a complete short). The S21 changes by more than 12 dB, and the S11 changes by approximately 4 dB.

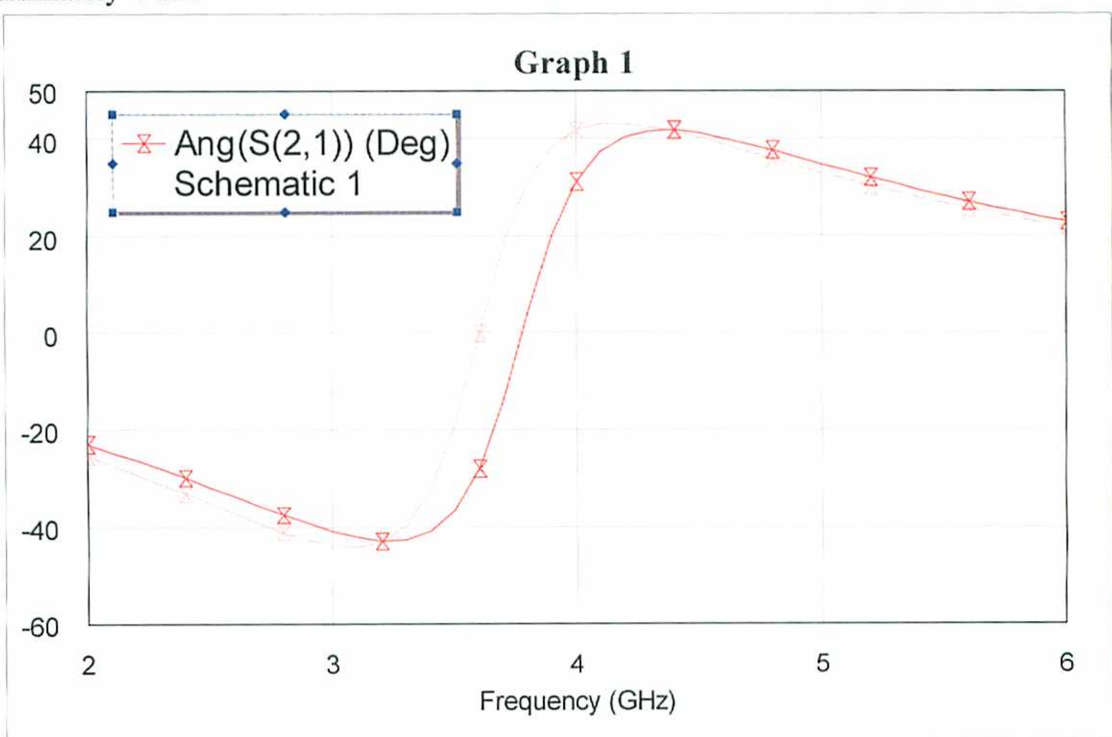

Figure 6. The effect of change in capacitance by 10% on the phase of S21. Close to 30 degrees of phase shift observed at 3.7 GHz.

Applicability: The resonant sensor is applicable for sensing bio-chemicals, trace chemicals in solid or gaseous form, as functionalized biopolymers will be used as sensing layers. The analytes being sensed will result in changes in dielectric properties or electrical conductance of the sensing layer. The impedance changes in the device could result in wireless passive sensing. Example analytes could be odors, ammonia, TNT etc.

Functions: Bio-chemical sensing, trace chemical sensing, functionalized biopolymers for sensors, wireless chem-bio sensing.