Electronic Supplementary Material (ESI) for Lab on a Chip.

Lab on a Chip

Supplementary Information

Title: Label-Free High-Throughput Detection and Content Sensing of Individual Droplets in Microfluidic Systems

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S1.System Overview

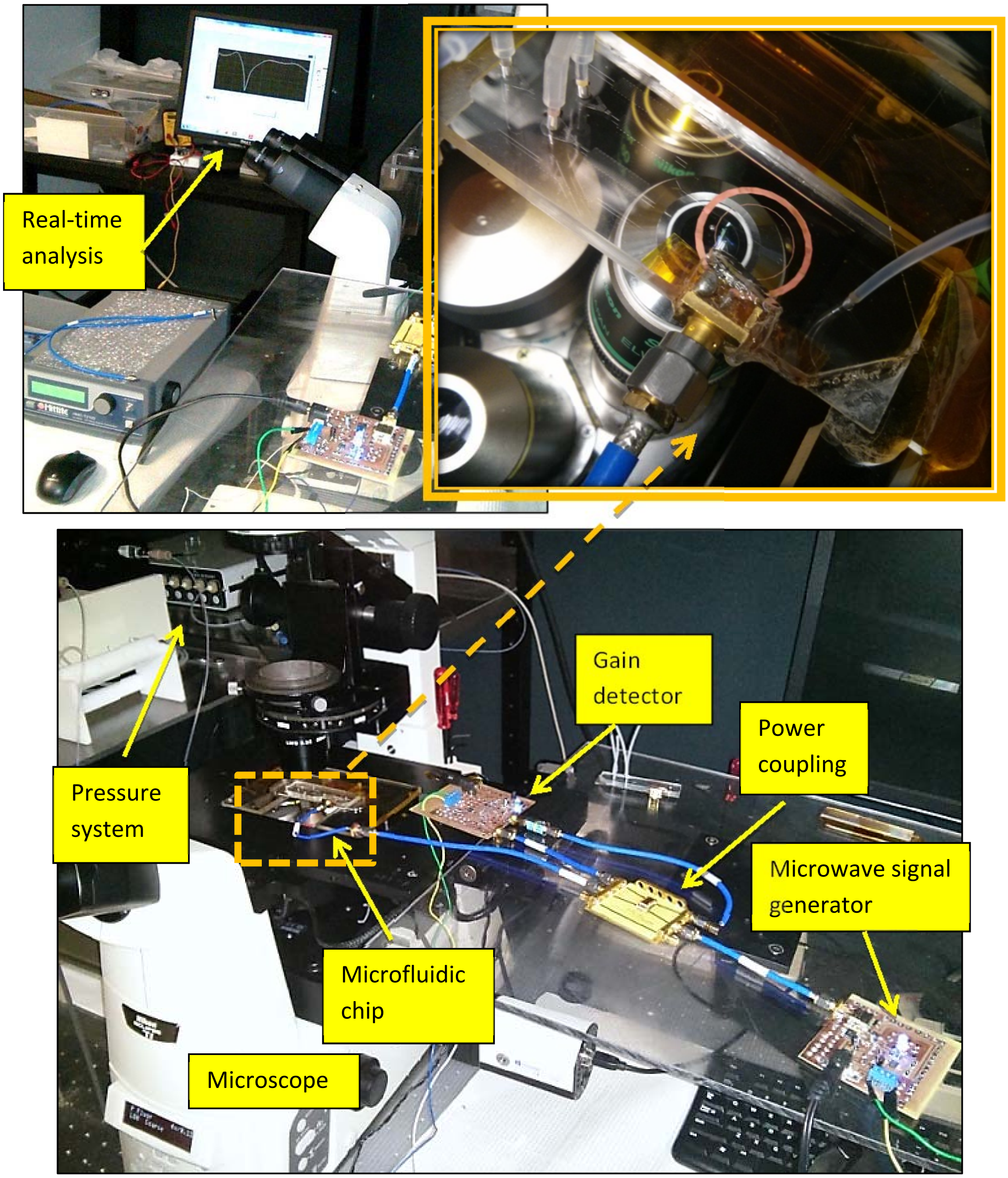


Figure S1. An image of experimental setup and assembled module of microwave custom circuitry.

S2. Microwave Component Fabrication

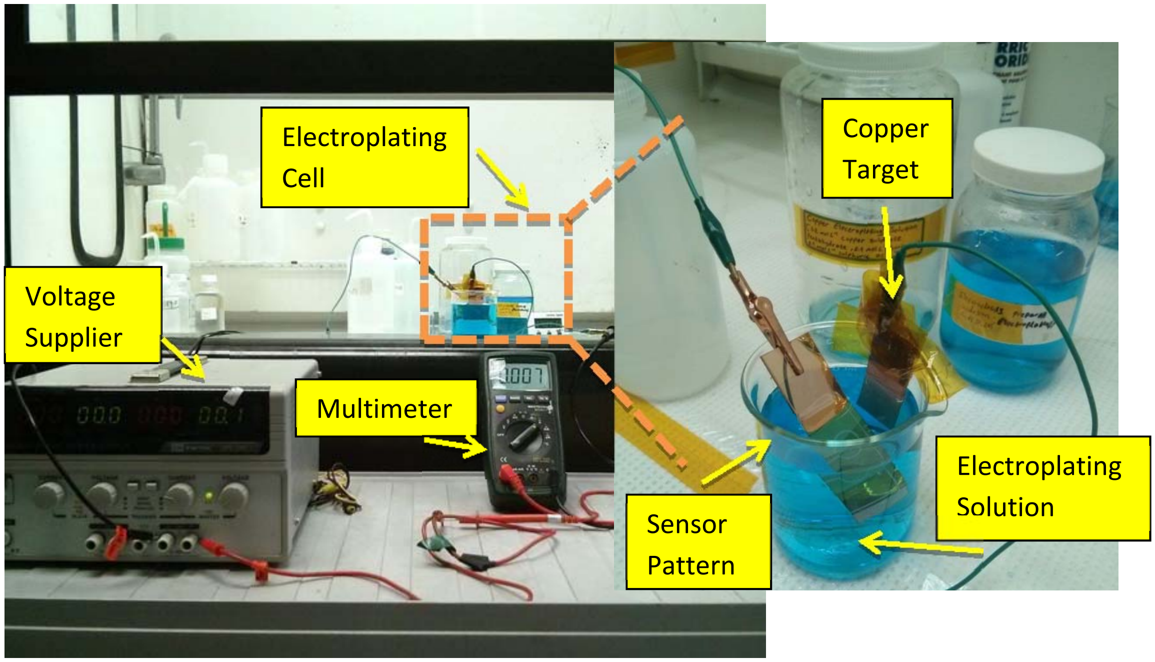
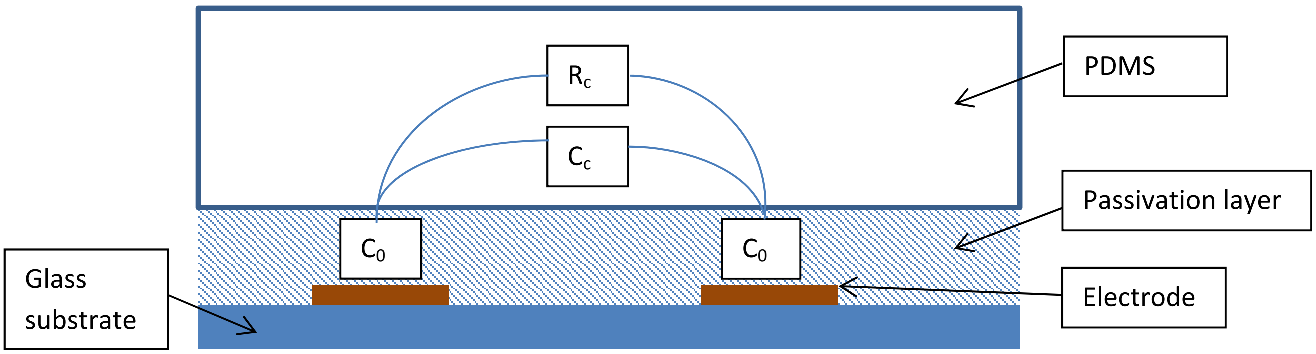


Figure S2. Microwave sensor fabrication through electroplating process.

S3. Resonance Frequency Shift with Conductivity Change



The circuit model of the structure can be described as capacitor due to the passivation layer (C_0), the capacitor through the channel (C_c) and a resistor or conductance due to the conductivity within the channel (R_c). The equivalent impedance of such a circuit is

$$Z_r = \frac{2 - \omega^2 C_0 L + j\omega R_c (C_0 + 2C_c - \omega^2 C_c C_0 L)}{j\omega C_0 - \omega^2 C_c C_0 R_c}$$

The resonance frequency for such a structure can be defined as the frequency at which the reflection coefficient is minimum. For such a load, when the capacitances and inductance are assumed to be 1, the resonance frequency as a function of $1/R_c$ (which is the conductivity and increases as the KCl concentration increases) becomes as the shown in Fig.S3 below

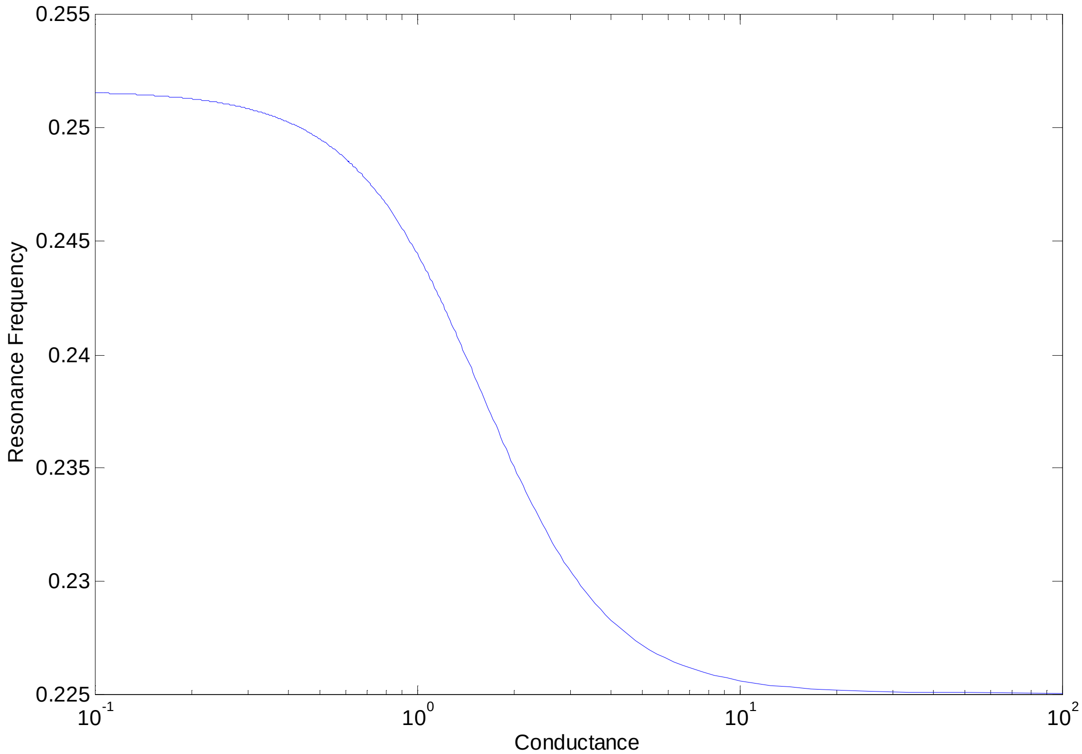


Figure S3. Resonance frequency vs. conductance.

As a result, there is slightly reduce in the resonance frequency by increasing the conductance in the circuit. In physical terms this means that, even if the dielectric constant of the fluid within the channel is not changed, increasing the conductivity of the fluid slightly reduces the resonance frequency.

S4. S-parameter versus Frequency Characterization

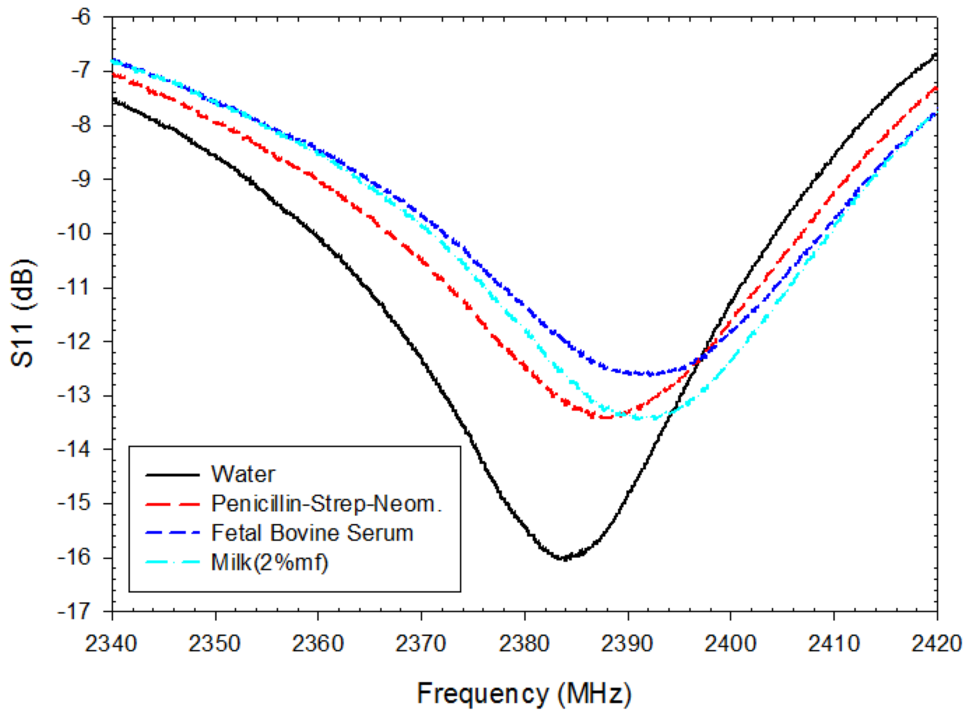


Figure S4: S-parameter vs. frequency behavior of biomaterials used in the droplet content sensing experiments.

S5. Water-Water Droplet Pair

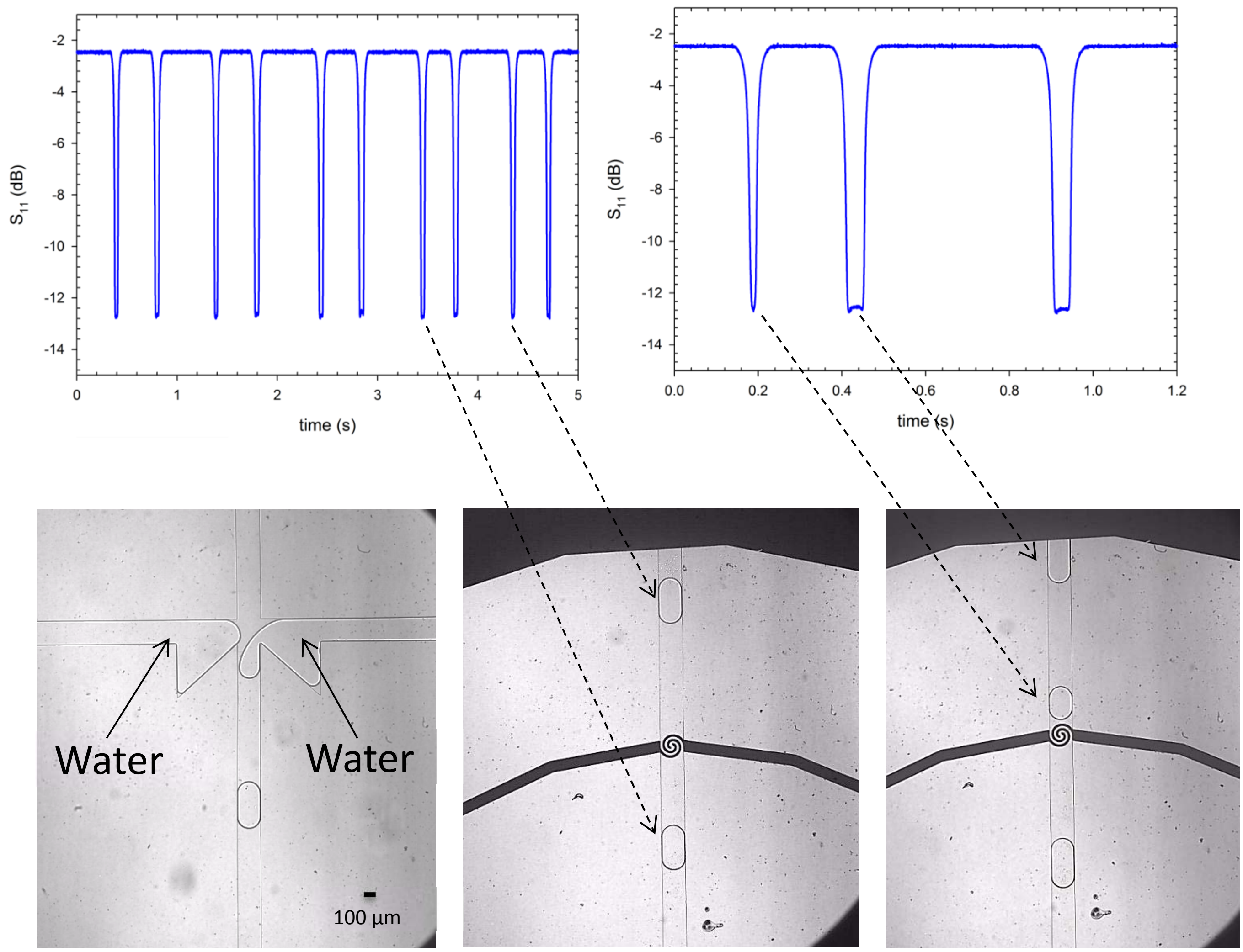
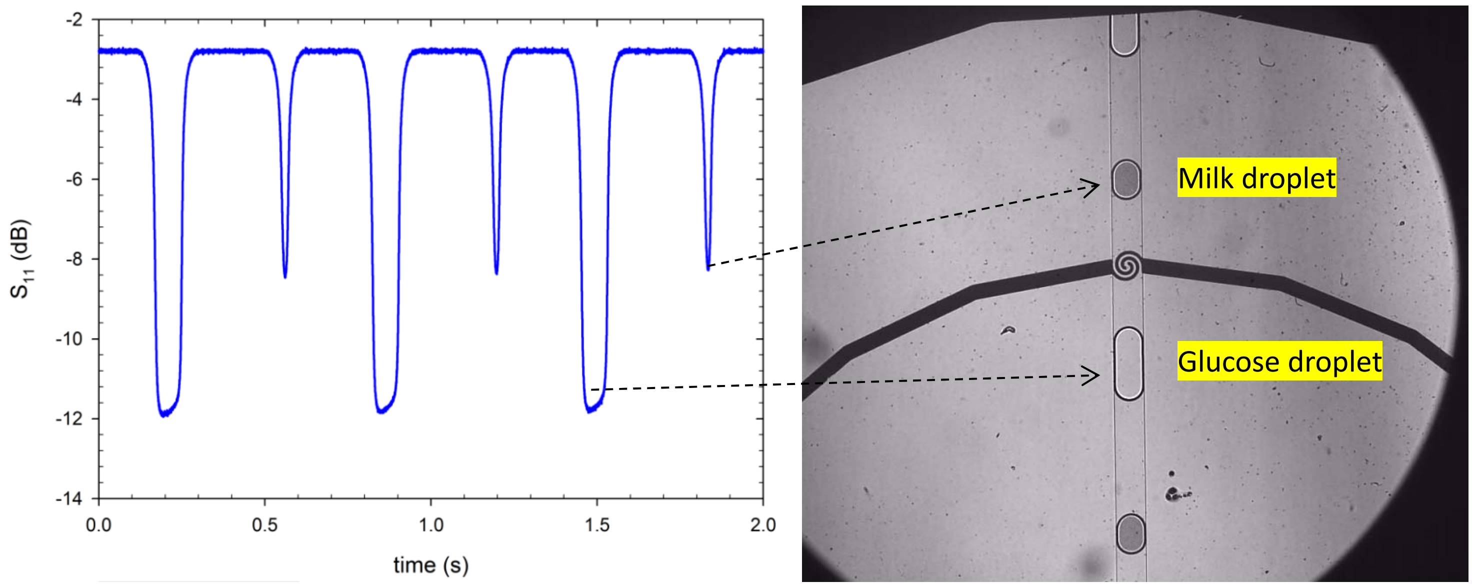
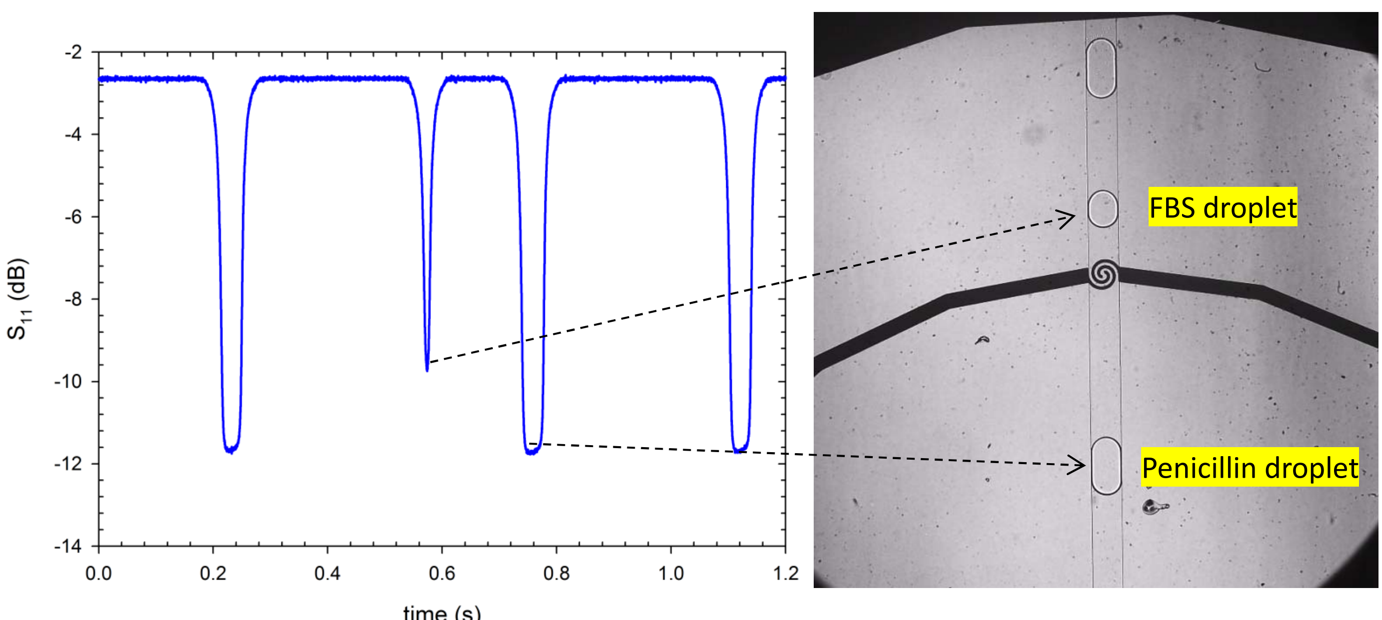


Figure S5: Alternating droplet pair generator using an opposing two T-junction configuration. Ultra-pure water droplets were employed in both droplet generators; as expected same peak was obtained for both water droplets (top left). Longer and shorter water droplet pair was formed. Again, same signal amplitude was monitored that droplet length has no effect on reflection coefficient (top right). In other words, the response of the resonator is not caused by droplet geometry. Considering that the electromagnetic field is accumulated in the sensing region, and the droplet width and height is confined with the channel, droplet size has no effect on the reflection coefficient as long as its length is longer than the sensor region. These backward experiments ensure that the sensor is sensitive to dielectric property variation only.

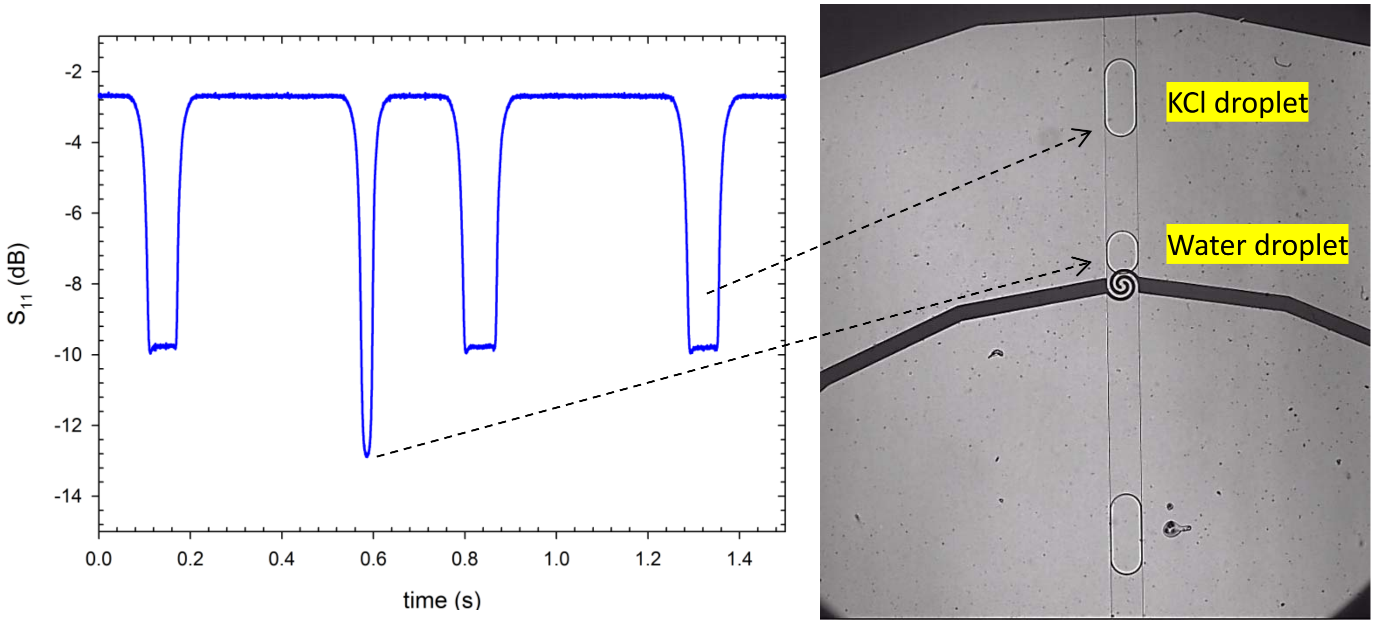
S6. Longer-Shorter Droplet Pairs



(a)



(b)



(c)

Figure S6: All droplet content sensing experiments were repeated as pairs of longer and shorter droplets in order to provide backward control. There is no amplitude change in S-parameter, and only wider signal is obtained for the longer droplet which is coherent that droplet residence time on sensing region is longer. The content of droplets was distinguished very sensitively: Milk-Glucose droplets (a), FBS-Penicillin droplets (b), Water-KCl droplets (c).