Radio Frequency Resonator for Continuous Monitoring of Parallel Microfluidic Droplet Generators

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Introduction

Micro-droplets are nowadays used as a platform to carry out biological assays or chemical micro-reactions in a confined and controlled space.

-Scale-up volume production can be achieved through parallelization. Where hundreds of droplet makers are integrated in a small microfluidic chip.

-Monitoring droplet production is desirable to guarantee narrow size distribution.

Table 1. Properties of Metals & Liquids

Material		
PMMA	ε_r	2.7
Water		80.4
Oil		2.1
Cu	κ (S/m)	5.8E+07
Ag		2.5E+06

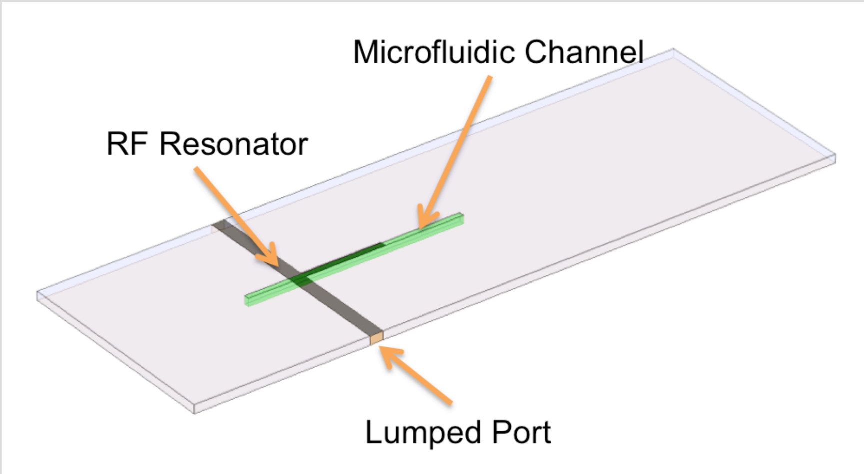

Figure 1. RF T-Resonator Schematics

Computational Methods

The electromagnetic waves, frequency domain (*emw*) interface from the radio frequency package is used to model the frequency response of the T-resonators. The main wave equation solved in this systems is shown below.

$$\nabla \times \mu_r^- 1(\nabla \times \mathbf{E} - k_0^2(\varepsilon_r - \frac{j\sigma}{\omega\sigma_0})\mathbf{E} = 0$$

where E is the electric field, μ_r = to the relative permeability, ε_r is the relative permittivity and k_0 is the wave number of free space.

$$k_0 = \omega\sqrt{\varepsilon_0\mu_0} = \frac{\omega}{c_0}$$

The transmission from port 1 to port 2 can be calculated as:

$$S_{11} = \frac{\int_{\text{Port 1}} ((E_c - E_1)\cdot E_1^*)dA_1}{\int_{\text{Port 1}} (E_1 \cdot E_1^*)dA_1} \qquad S_{21} = \frac{\int_{\text{Port 2}} (E_c \cdot E_2^*)dA_2}{\int_{\text{Port 2}} (E_2 \cdot E_2^*)dA_2}$$

where E_C is the calculated total field, E_1 is the analytical field of the port 1 (excitation), and E_2 is the eigenmode from the boundary mode analysis

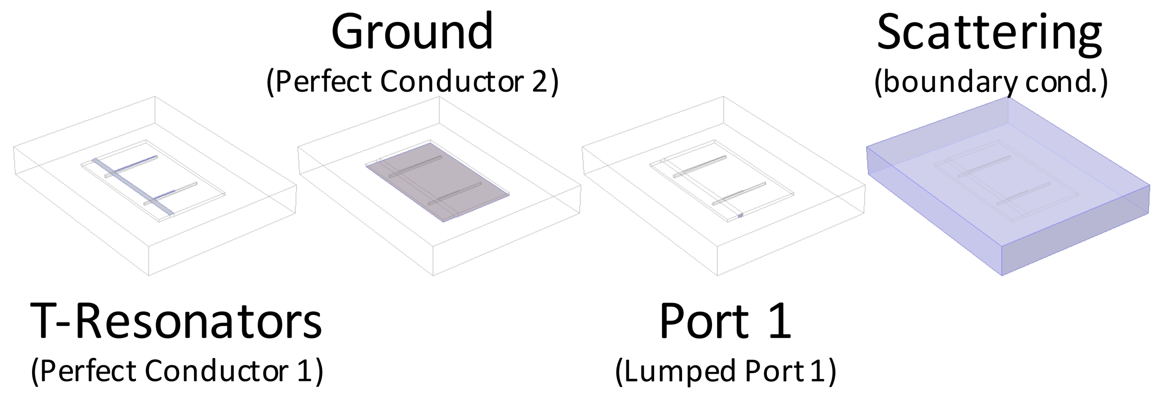

Figure 2. Boundary Conditions

Results

A study of the frequency response was performed for a wide range of values of relative permittivity. Pure oil has a low permittivity (~2.1) as compared to water (~80.2)

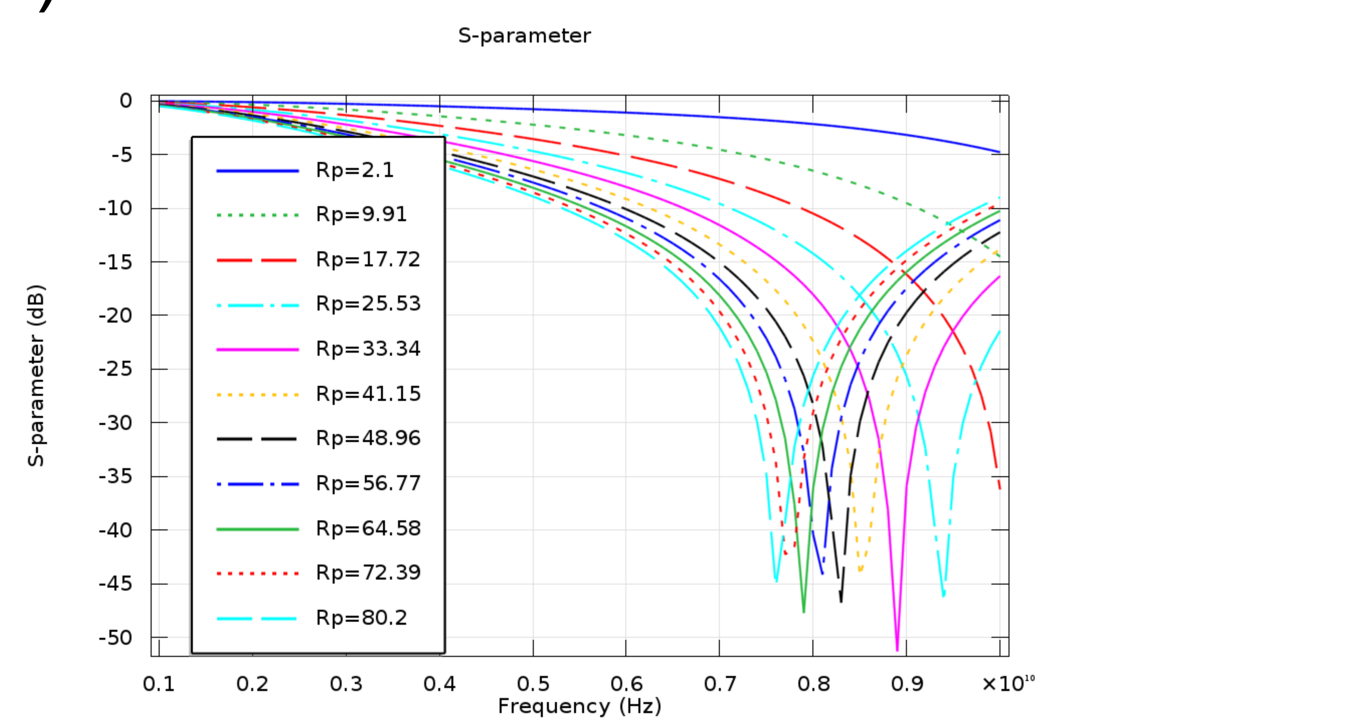

Figure 3. S_{21} parameter as function of R. permittivity

By selecting two or more different T-resonator stub lengths, one can design a parallel sensor with independent resonance for each channel.

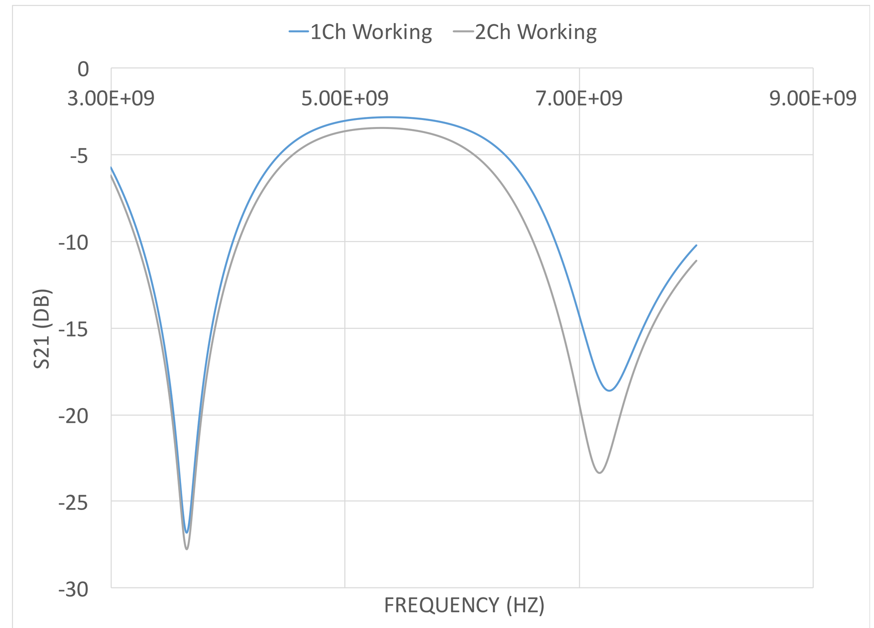

Figure 4. Monitoring of two channels

Conclusions: RF monitoring is a promising approach for parallelizable systems. Since the T-resonator resonates at odd integer multiplies of its quarter wavelength frequency, there can be interference. A change as low as 5% in the concentration of water, produced up to 50MHz shift in the resonant frequency of the device.

References

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