

A 24-GHz Microwave Microfluidic Sensor Based on the Frequency-Locked Loop for Liquid Concentration Measurement

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A 24-GHz microwave microfluidic sensor based on the frequency-locked loop (FLL) [1] is proposed, as shown in Fig. 1, for liquid concentration measurement. The liquid under test (LUT) is injected into a capillary tube with an inner diameter of 1.2 mm and placed upon the slot gap of the coplanar waveguide (CPW) line. Since the LUT affects the effective dielectric constant, $\epsilon_{r,eff}$, of the CPW line, the transmission phase will be shifted corresponding to the LUT concentration. Namely, the CPW line acts as a phase modulator in the proposed sensor. The kernel component of this microfluidic sensor is a 24-GHz radar transceiver chip for transmitting a microwave signal to pass through a CPW line and receiving the phase-modulated signal caused by the LUT. As the mixer output is connected to the tuning terminal of the voltage-controlled oscillator (VCO), it forms an FLL to transfer the CPW's phase shift to a frequency variation, namely a frequency-modulated signal. The output signal of the FLL-based sensor is measured by a spectrum analyzer.

The 35- μ L water-ethanol and glucose aqueous solutions were used as the LUTs to evaluate the proposed microfluidic sensor performance. The measured results reveal that output frequencies of the sensor monotonically change according to the LUT concentrations. Compared with our previous work in [2], since the operating frequency of the FLL-based sensor increases from 5.8 GHz to 24 GHz, the sensitivity has been significantly improved, leading to decreasing the LUT volume requirement. This talk will thoroughly present the sensor design, sensing mechanism, and measured results of the proposed microfluidic sensor.

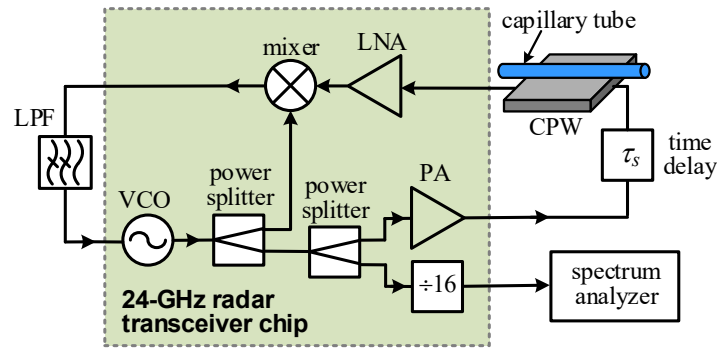


Figure 1. System block diagram of the proposed 24-GHz microwave microfluidic sensor based on the frequency-locked loop.

References

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- [2] C.-H. Tseng and C.-Y. Yang, "Novel microwave frequency-locked-loop-based sensor for complex permittivity measurement of liquid solutions," *IEEE Trans. Microw. Theory Techn.*, **70**, 10, October 2022, pp. 4556–4565, doi: 10.1109/TMTT.2022.3198691.