Nanoliter Liquid-Mixture Characterization Using Millimeter-Wave Lab-on-a-Waveguide Sensor

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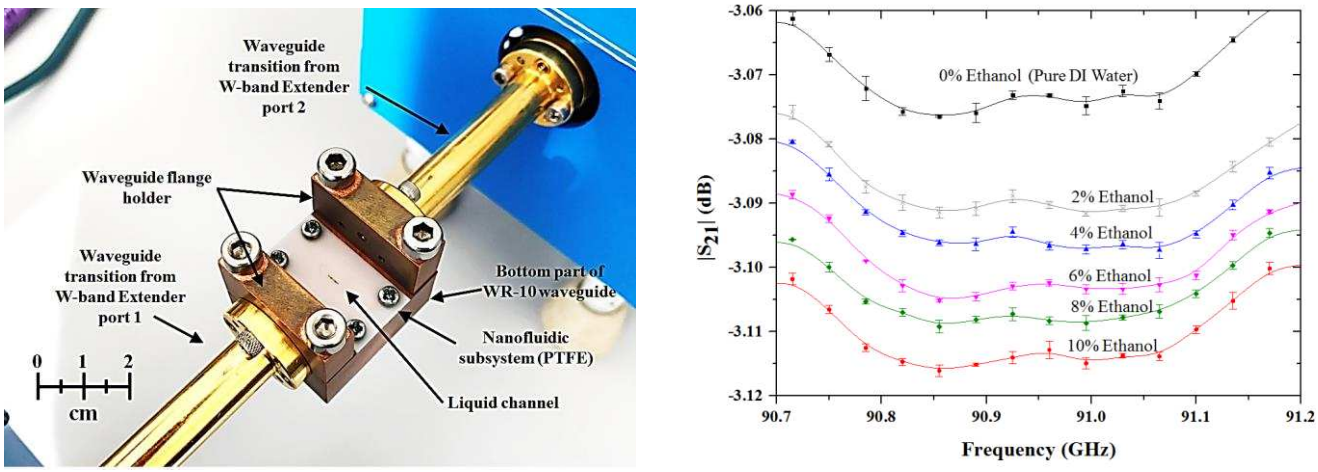
Abstract This paper presents the nanofluidic-integrated millimeter-wave sensor design, which is based on a near-field transmission-line technique implemented by a single loop slot antenna operating at 91 GHz and fabricated into the lid of a photolaser-based subtractive manufactured WR-10 rectangular waveguide. The nanofluidic subsystem, which is mounted on the top of the antenna aperture, is fabricated by using multiple PTFE layers to encapsulate and isolate the liquid sample during measurement. The novel sensor can measure a liquid volume of as low as 210 nanoliters, while still achieving a discrimination accuracy of better than 2% of ethanol in the ethanol/deionized-water liquid mixture.

Keyword Biomedical liquid mixtures, Nanofluidic, Millimeter-wave sensor, Transmission-line method, W-band



(a) (b)

Fig 1 (a) Fabricated sensor after putting the nanofluidic subsystem on top of the microwave subsystem and connecting the sensor to the W-band extender and that to the VNA.

Fig 1 (b) Measured transmission coefficient $|S_{21}|$ in dB with error bar for ethanol concentration in the range of 0%, 2%, 4%, 6%, 8%, and 10% in DI water.

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Nanoliter Liquid-Mixture Characterization Using Millimeter-Wave Lab-on-a-Waveguide Sensor

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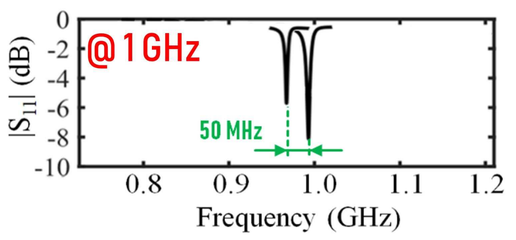
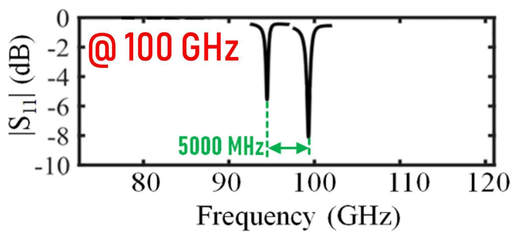
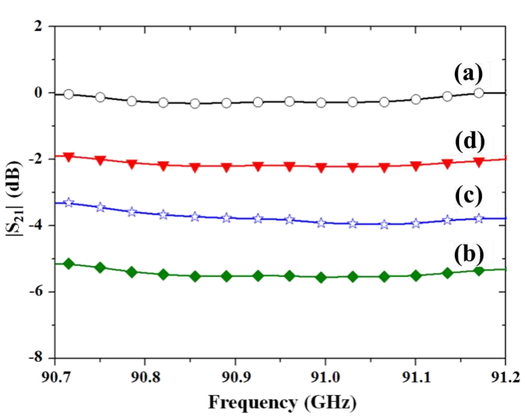
Abstract

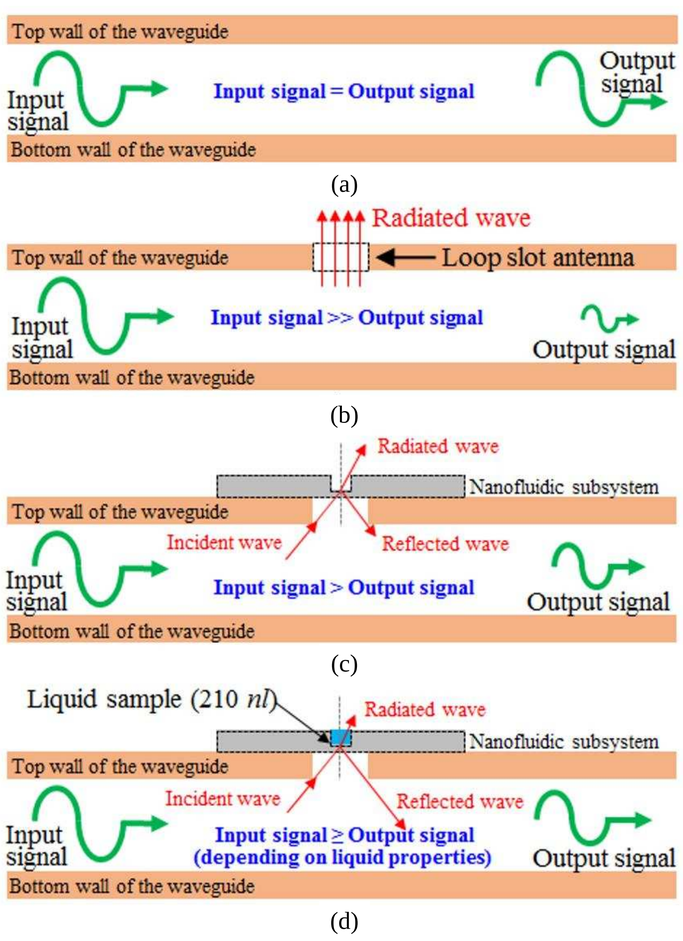
This paper presents the nanofluidic-integrated millimeter-wave sensor design, which is based on a near-field transmission-line technique implemented by a single loop slot antenna operating at 91 GHz and fabricated into the lid of a photolaser-based subtractive manufactured WR-10 rectangular waveguide. The nanofluidic subsystem, which is mounted on the top of the antenna aperture, is fabricated by using multiple PTFE layers to encapsulate and isolate the liquid sample during measurement. The novel sensor can measure a liquid volume of as low as 210 nanoliters, while still achieving a discrimination accuracy of better than 2% of ethanol in the ethanol/deionized-water liquid mixture.

I. Liquid-Mixture Discrimination Working Principle

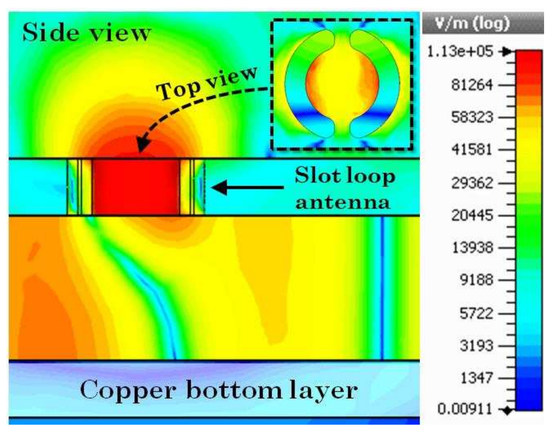


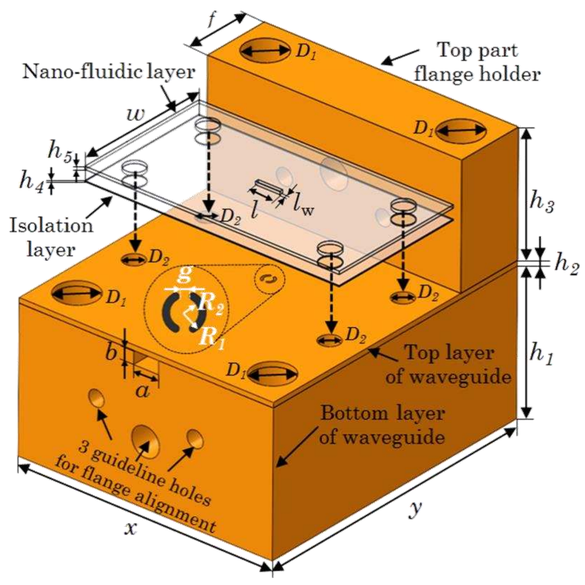


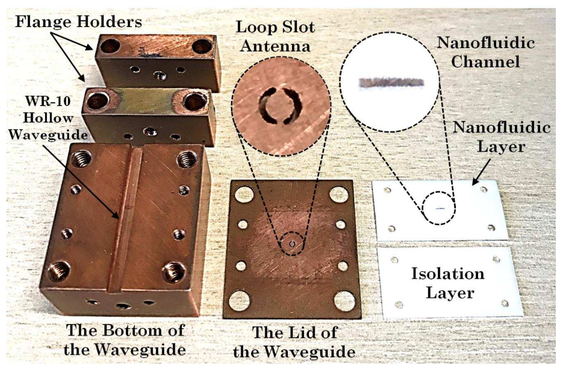


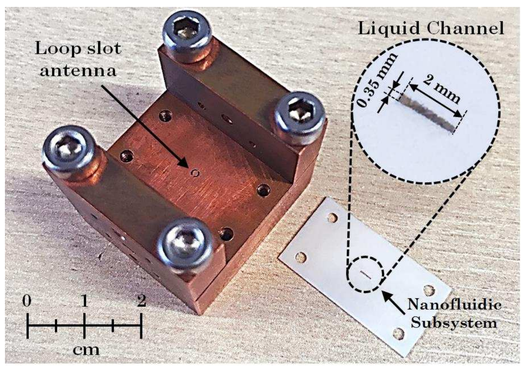


II. Sensor Design and Fabrication



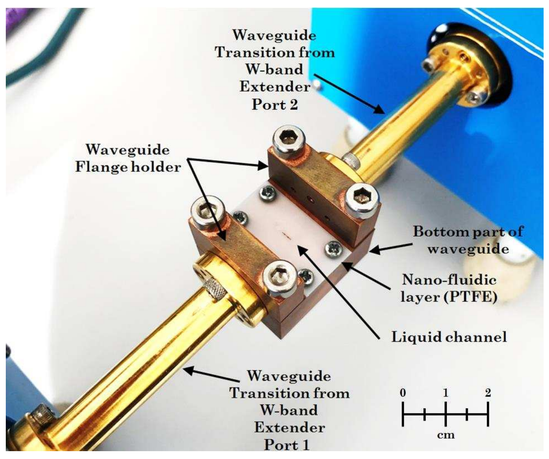


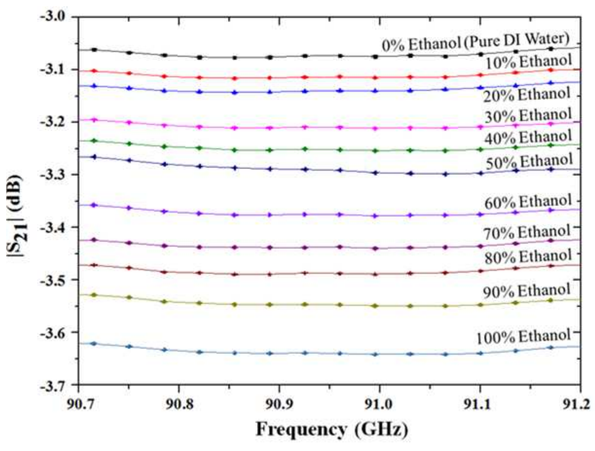


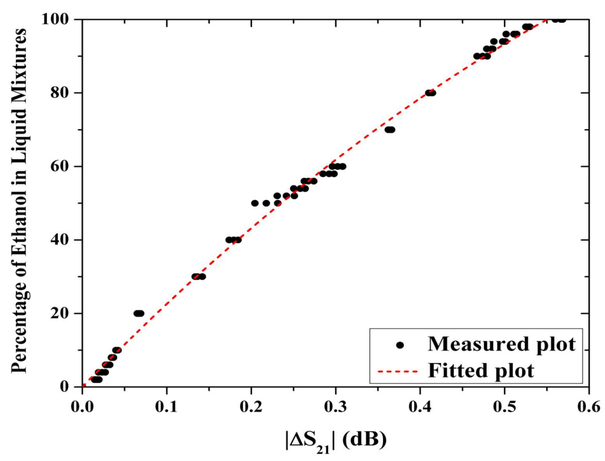


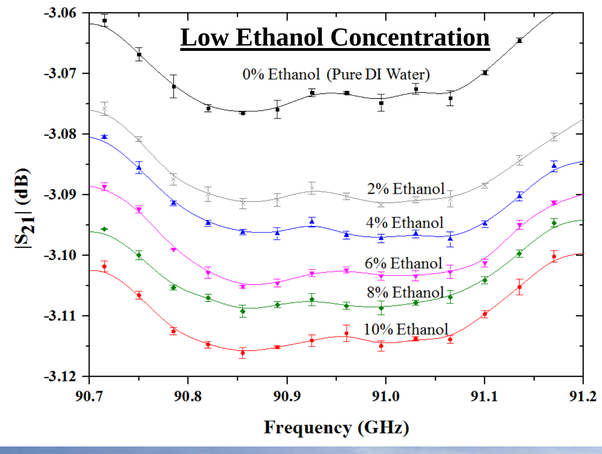
III. Measurement Setup and Results

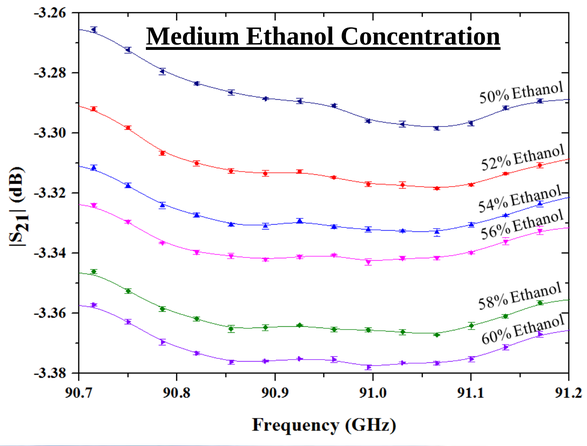
Fabricated sensor after putting the nanofluidic subsystem on top of the subsystem and connecting the sensor to the W-band extender and that to the VNA. The measured transmission coefficient $|S_{21}|$ in dB with error bar for ethanol concentration in low, medium, and high ranges in DI water.

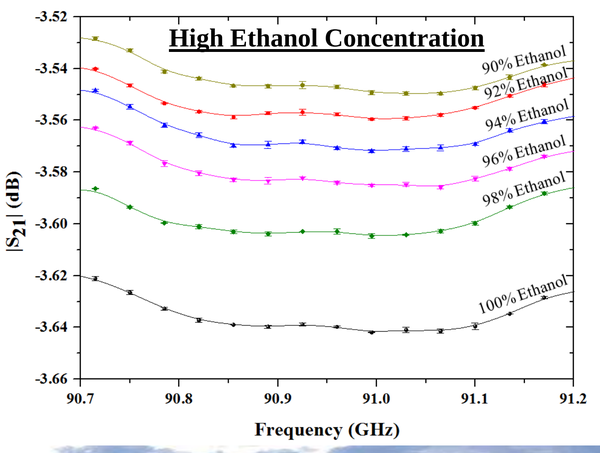












2nd Measurement liquid sample

1st Measurement DI water to set reference

$$|\Delta S_{21}| = |S_{21(measured)} - S_{21(DI\,water)}|$$

$$E_P = -97.277\left(|\Delta S_{21}|\right)^2 + 235.171\left(|\Delta S_{21}|\right) + 0.06448$$

R-square of polynomial equation is 0.99679

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