Slitted Microstrip Fabrication Using Laser Micromachining for Small Sample Detection

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Recent work has shown that miniaturization of probes in NMR can improve mass-limited sensitivity [5]. Researchers have used a variety of approaches to make solenoids around capillary tubes [4] [6] [3] or microfabrication techniques to create planar coils on semiconductor/glass substrates [2] [7]. We have devised a new geometry for miniaturizing probes called a slitted microstrip. This is a conventional, microstrip line that has a small ($\ll \lambda$) slit cut out of it. Localized to the slit is a highly homogeneous B_1 magnetic field that to first order produces no extra electric field component in the vicinity of the sample. This structure produces a high quality factor inductance with no extra lead termination resistances or proximity effects. Since the structure is much smaller than any wavelength used in magnetic resonance, it can be scaled from mm scales to μm scales. This structure was constructed at both 5mm and 300 μm to understand scaling. For the 300 μm probe, pure water and sucrose have been analyzed. A 32 nL observe volume produced a linewidth of 1.8 Hz and a signal to noise ratio of 1023/umol/$\sqrt{Hz}$ at 500 MHz, more than twice the best published result in planar microcoils [7] (scaled to 500 MHz) using complex microfabrication techniques. This was done without any susceptibility-matching fluid or apodization in a single shot. For 0.6M sucrose, the preliminary anomeric proton SNR is 939/umol/$\sqrt{Hz}$ scaled to 600 MHz. This was acquired using 16 scans, 1.28s each, with 0.6Hz line broadening. This is comparable to published work using solenoids of 1530/umol/$\sqrt{Hz}$ for a 620 nL probe, but less than that from a 5 nL probe with SNR of 5580/umol/$\sqrt{Hz}$ [1]. With susceptibility matching, optimization and scaling, this geometry has the potential to surpass these results. By comparing the results to the same probe at 5mm, we can experimentally verify the 1/d scaling of this detector, supported by FEM plots that predict nutation curves at each scale. From these experiments, high RF homogeneity is observed, measured to be A_{270}/A_{90}=0.76. For both scales, the measured Q is greater than 250 at 500 MHz, greater than the published literature for either planar or solenoidal microcoils.

This probe was constructed at 300μm using conventional printed circuit board fabrication techniques where the slit was made using a laser micromachining center in about 5 seconds. A homebuilt probe was made to house the circuit board. Since this geometry is simpler than previously demonstrated techniques, fabrication can be automated for arrays and is inherently scalable to small sizes. The planar nature of the device makes it ideal for integration with microfluidics, transceivers and applications such as cell/neuron chemistry, protein arrays and HPLC-NMR on pico to micromoles of sample.

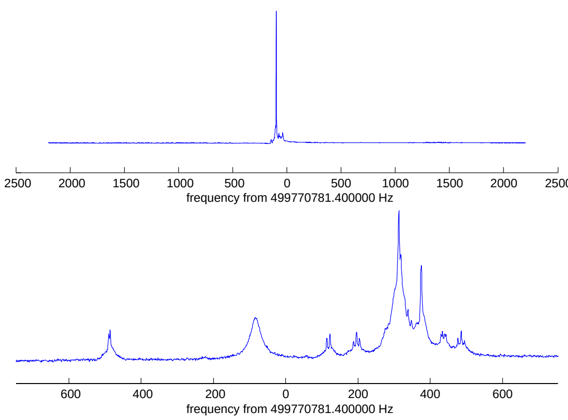

FIG. 1: The top plot represents 32 nL of deionized H_20 from the 297 μm probe. This is a single shot signal acquired in 1s, with linewidth of 1.9Hz, SNR=1819. The second plot represents 14.4 nmols of sucrose, representing 16 scans acquired in 20s. The signal to noise ratio of the anomeric proton is 43.3.

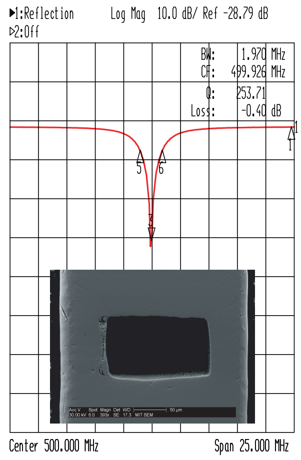

FIG. 2: S_{11} plot for the probe showing a high Q of 251. Inset is a scanning electron microscope (SEM) image of a 297 μm wide microslit microfabricated using a laser micromachining center and postprocessed using mechanical abrasion.

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