3-D Super Resolution Imaging using a 62+62 Elements Row-Column Array

Current 2-D Super Resolution (SR) imaging is limited by the slice thickness determined by the elevation focus. The fixed, geometric elevation focus is often poor due to its high F-number. SR images are, thus, a summation of vessels across the elevation plane without the possibility to track scatterers in 3-D for full visualization. 3-D SR imaging has been obtained by translating the probe, but this does not remove the elevation summation. Full 3-D can be acquired using 2-D matrix probes, but the equipment is expensive, and the amount of data is excessive, when channel data are acquired over thousands of elements for minutes. This paper demonstrates that full volumetric SRI can be attained using a 62+62 channels Row-Column (RC) probe with a high frame rate and with µm precision. Data were acquired by a 3 MHz 62+62 PZT RC probe with λ/2 pitch connected to the SARUS scanner. A synthetic aperture scan sequence with 32 positive and 32 negative emissions was employed for pulse inversion (PI) imaging with an MI of 0.3. The pulse repetition frequency was 10 kHz for a 156 Hz volume rate. A PEGDA 700 g/mol based hydrogel flow-microphantom was 3-D printed by stereolithography. It contains a single cylindrical 200 µm diameter channel placed 3 mm from the top surface of the phantom. After a 5.8 mm long inlet, the channel bends 90° into a 7 mm long central region before bending 90° again into the 5.8 mm outlet. The flow channel was infused at 1.61 µL/s with Sonovue (Bracco) in a 1:10 dilution. The received RF signals from the 62 row elements were beamformed with PI to yield a full volume of 15 x 15 x 15 mm³. The interpolated 3-D positions of the bubbles were estimated after local maximum detection. The reconstructed 3-D SR volume clearly shows the 200 µm channel shape with a high resolution in all three dimensions. The center line for the channel was found by fitting a line to all bubble positions, and their radial position calculated. The observed fraction of bubbles falling outside the channel was used for estimating the location precision. The precision was 18.5 µm in the y − z plane and 23.0 µm in the x − z plane. The point spread function had a size of 0.58 x 1.05 x 0.31 mm³, so the interrogated volume was 15,700 times smaller than for normal volumetric B-mode imaging. This demonstrates that full 3-D SRI can be attained with just 62 receive channels. The SA sequence has a low MI, but attains a large measured penetration depth of 14 cm in a tissue mimicking phantom, due to the large RC probe size. The 156 Hz volume rate also makes it possible to track high velocities in 3-D in the volume.