Simulation and experimental results from 3-D vector flow estimations for a 62 × 62 2-D row–column (RC) array with integrated apodization are presented. A method for implementing a 3-D transverse oscillation (TO) velocity estimator on a 3-MHz RC array is developed and validated. First, a parametric simulation study is conducted, where flow direction, ensemble length, number of pulse cycles, steering angles, transmit/receive apodization, and TO apodization profiles and spacing are varied, to find the optimal parameter configuration. The performance of the estimator is evaluated with respect to relative mean bias B̃ and mean standard deviation σ̃. Second, the optimal parameter configuration is implemented on the prototype RC probe connected to the experimental ultrasound scanner SARUS. Results from measurements conducted in a flow-rig system containing a constant laminar flow and a straight-vessel phantom with a pulsating flow are presented. Both an M-mode and a steered transmit sequence are applied. The 3-D vector flow is estimated in the flow rig for four representative flow directions. In the setup with 90° beam-to-flow angle, the relative mean bias across the entire velocity profile is (−4.7, −0.9, 0.4)% with a relative standard deviation of (8.7, 5.1, 0.8)% for (vx, vy, vz). The estimated peak velocity is 48.5 ± 3 cm/s giving a −3% bias. The out-of-plane velocity component perpendicular to the cross section is used to estimate volumetric flow rates in the flow rig at a 90° beam-to-flow angle. The estimated mean flow rate in this setup is 91.2 ± 3.1 L/h corresponding to a bias of −11.1%. In a pulsating flow setup, flow rate measured during five cycles is 2.3 ± 0.1 mL/stroke giving a negative 9.7% bias. It is concluded that accurate 3-D vector flow estimation can be obtained using a 2-D RC-addressed array.
3-D vector flow imaging, Blood flow, Medical ultrasound, Row-column addressed arrays, Transverse oscillation