Modeling of ultrasound transducers

This Ph.D. dissertation addresses ultrasound transducer modeling for medical ultrasound imaging and combines the modeling with the ultrasound simulation program Field II. The project firstly presents two new models for spatial impulse responses (SIRs) to a rectangular elevation focused transducer (REFT) and to a convex rectangular elevation focused transducer (CREFT). These models are solvable on an analog time scale and give exact smooth solutions to the Rayleigh integral. The REFT model exhibits a root mean square (RMS) error relative to Field II predictions of 0.41 % at 3400 MHz, and 1.37 % at 100MHz. The CREFT model exhibits a RMS deviation of 0.01 % relative to the exact numerical solution on a CREFT transducer. A convex non-elevation focused, a REFT, and a linear flat transducer are shown to be covered with the CREFT model as well. Pressure pulses calculated with a one-dimensional transducer model in combination with Field II are calculated on a circular piezoceramic transducer and a convex 128 element commercial transducer. The pulses are shown to be predictable within ±2 dB of the amplitude which is excellent for this modeling. Intensity profiles are shown to be predicted with a RMS deviation of 5.5 % to 11.0 %. Finite element modeling of piezoceramics in combination with Field II is addressed and reveals the influence of restricting the modeling of transducers to the one-dimensional case. An investigation on modeling capacitive micromachined ultrasonic transducers (CMUT)s with Field II is addressed. It is shown how a single circular CMUT cell can be well approximated with a simple square transducer encapsulating the cell, and how this influence the modeling of full array elements. An optimal cell discretization with Field II’s mathematical elements is addressed as well. The error in modeling CMUT cells as squares or flat circular plates instead of curved circular cells is also addressed.