Non-linear Ultrasound Imaging - DTU Orbit (28/12/2018)

**Non-linear Ultrasound Imaging**
The theory for modeling non-linear acoustic propagation is addressed in the dissertation. The solutions to both the linear and non-linear wave equations have been found by an angular spectrum approach (ASA), in which an analytical expression can be derived. This makes the calculation complete without iteration steps. The ASA is implemented in combination with Field II and extended to simulate the pulsed ultrasound fields. The simulated results from a linear array transducer are made by the ASA based on Field II, and by a released non-linear simulation program- Abersim, respectively. The calculation speed of the ASA is increased approximately by a factor of 140. For the second harmonic point spread function the error of the full width is 1.5% at -6 dB and 6.4% at -12 dB compared to Abersim. To further investigate the linear and non-linear ultrasound fields, hydrophone measurements are performed under water by two geometrical focused piston transducers. It can be seen that the time pulses measured from a 0.5 inch diameter transducer and linearly simulated using the ASA are fairly comparable. The root mean square (RMS) error for the second harmonic field simulated by the ASA is 10.3% relative to the measurement from a 1 inch diameter transducer. A preliminary study for harmonic imaging using synthetic aperture sequential beamforming (SASB) has been demonstrated. A wire phantom underwater measurement is made by an experimental synthetic aperture real-time ultrasound scanner (SARUS) with a linear array transducer. The second harmonic imaging is obtained by a pulse inversion technique. The received data is beamformed by the SASB using a Beamformation Toolbox. In the measurements the lateral resolution at -6 dB is improved by 66% compared to the conventional imaging algorithm. There is also a 35% improvement for the lateral resolution at -6 dB compared with the sole harmonic imaging and a 46% improvement compared with merely using the SASB.

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