Evaluation of Chirp and Binary Codes based Excitation Pulses for 3D USCT

M. Zapf, B.F. Derouiche, N.V. Ruiter
Forschungsinstitut Karlsruhe (KIT), Institute for Data Processing and Medical Imaging, Karlsruhe, Germany

Background
- At Forschungsinstitut Karlsruhe we are developing a new imaging method for early breast cancer detection
- 3D ultrasound computer tomography (3D USCT)

USCT concept
- 3D SAFT with unfocused spherical waves emitted and received by single transducers
- multistatic ellipsoid aperture 12 cm x 12 cm
- long traveling distances in 3D apertures
- for wide opening angles of transducers small active transducer area
- in designated medical application strong frequency damping

Challenge: low signal SNR
- unfocused emission and reception
- long traveling distances in 3D aperture
- for wide opening angle of transducers small active transducer area
- in designated medical application strong frequency damping

Approach
- advanced coded excitation techniques known from radar
- to overcome low SNR by prolonging the excitation pulse for higher energy, followed by pulse compression
- matched filtering optimal filter for pulse compression
- usage of frequency modulated chirps
- usage of phase encoded binary codes: Golay codes
- usage of complementary binary codes: Golay codes

Methods

Measurement setup
- water filled container (dimensions 34 x 8 x 8 cm³)
- 3D USCT 2nd generation prototype transducer with 2.8 MHz resonance frequency and 0.5 MHz (6 dB) bandwidth
- 3D movable hydrophone arm (Order HNO-400)
- LabWindows based CDS and control-software
- PC based SAGE digitisation card (25 MHz)
- Technologies ARG 201 (digital waveform generator)

Results

Evaluation
- applicability of the USCT setup and designated medical application is evaluated with well-established metrics SNR, GSNR, PSL, and ISL

Table 1: Scores for different excitation pulses and phantom measurement setup, signal center frequency 1 MHz and bandwidth 0.25 MHz, measurements were averaged 512 times

<table>
<thead>
<tr>
<th>Phantom</th>
<th>Code 1</th>
<th>Barker</th>
<th>Golay</th>
<th>Sine</th>
<th>Pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty measurement      0.5</td>
<td>-10.0</td>
<td>-10.0</td>
<td>-10.0</td>
<td>-10.0</td>
<td>-10.0</td>
</tr>
<tr>
<td>Phantom measurement with castor oil      0.5</td>
<td>-10.0</td>
<td>-10.0</td>
<td>-10.0</td>
<td>-10.0</td>
<td>-10.0</td>
</tr>
</tbody>
</table>

Discussion
- Technique are suitable for the USCT setup and designated medical application
- Usage of complementary binary codes is a promising option for extending SNR, but bandwidth doubled measurement time
- Barker in also a promising option without the downside

Outlook
- Further evaluations are required for analyzing the tissue dependent frequency dispersion