Evaluation of CMUT for passive monitoring of microbubble-assisted ultrasound therapies

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1) Characterization in transmit mode

- **CMUT**

   - Bandwidth: 7.5 MHz
   - Sensitivity: 120 dB
   - Center frequency: 2.25 MHz

2) Characterization in receive mode

   - **CMUT**

     - Bandwidth: 37x37 µm²
     - Sensitivity: 21.7 dB

**BACKGROUND / MOTIVATION**

Upon suitable excitation produced by ultrasound (US), microbubbles (MB) can permeabilize biological barriers such as the blood-brain barrier (BBB).

- A fine control of US parameters is crucial to avoid vascular damage due to excessive MB activity.

Here, we propose to overcome the restricted bandwidth of piezoelectric (PZT) transducers by exploiting the unique properties of CMUT, used in receive mode only, to ensure the safety of the US protocol through wideband PCD.

**METHODS**

1) **CMUT design**

   - Three CMUT (square shaped, 8x8 mm², 400nm gap) single-elements were developed for comparison with a standard PZT (V306-SU Olympus, Tokyo, Japan) centered at 2.25MHz used as gold standard:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Active surface area</th>
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<tbody>
<tr>
<td>37x37µm²</td>
<td>50 %</td>
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<tr>
<td>32x32µm²</td>
<td>40 %</td>
</tr>
<tr>
<td>27x27µm²</td>
<td>35 %</td>
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</tbody>
</table>

2) **CMUT characterization**

   - **Bandwidth** with hydrophone (HGL200, ONDA Corp, Sunnyvale, CA)
     - 160 µV, pulse width=150ns, pulse repetition frequency=100Hz
   - **Collapse voltage** (Vc) by varying Vpp from 0V to 120V
   - **Limiting frequency** at -20dB (LF-20) determined on bandwidth measurement
   - **Signal-to-noise ratio (SNR)** and fundamental-to-harmonic ratio (FHR) in receive mode as function of the Vpp, and the acoustic pressure

3) **Evaluation of CMUT ability to detect the signal from circulating MB through rat and macaque skulls**

**DETECTION OF CIRCULATING MB**

**Examples of the frequency responses from flowing microbubbles**

**DISCUSSION & CONCLUSION**

- This study validate CMUT technology for the monitoring of cavitation-based ultrasound therapies such as HIFU, sono-permeabilization or PZT opening. Using a CMUT device, we were able to detect a wideband cavitation signal through a skull at subharmonic, harmonic and ultraharmonic frequencies.

- Thicker is the skull bone, more difficult is the detection of high frequency content (as shown in macaque skull data). Usually, lower frequency are used for thick skull such as macaque or human but the detection of high frequency could also be improved by the development of dedicated amplifiers that can be directly integrated on CMUT PCD.

- Future work will be focused on this.

- The results obtained in this study encourage us in pursuing our investigation in vivo and developing CMUT-based PCD for large animal validation.

References:


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**EXPECTED OUTCOMES**

- Development of CMUT technology for the monitoring of cavitation-based ultrasound therapies such as HIFU, sono-permeabilization or PZT opening.

- Improvement of detection of high frequency content through a skull using dedicated amplifiers.

- Encouragement for further investigation in vivo and development of CMUT-based PCD for large animal validation.