Tissue Frequency Dependent Attenuation in Medical Ultrasound Imaging

Bachelor/Master/Diploma Thesis
Studienarbeit/Diplomarbeit

Influence of Frequency-Dependent Tissue Attenuation on Coded Ultrasound Imaging

Medical ultrasound has become one of the most important imaging modalities in modern healthcare due to its real-time capability, portability, safety, and cost-effectiveness. However, image quality remains fundamentally limited by physical effects occurring during acoustic wave propagation through biological tissue. One of the most significant effects is frequency-dependent attenuation, where higher frequency components experience stronger attenuation than lower frequencies, resulting in spectral distortion, reduced penetration depth, and degraded image quality. The research activities of the HybridEcho group focus on addressing such limitations through advanced ultrasound hardware, signal processing, and imaging technologies. [digitalhea...dresden.de]

Coded excitation has emerged as a promising approach to increase transmitted acoustic energy while maintaining safety and hardware constraints. Combined with matched filtering techniques, coded signals can significantly improve signal-to-noise ratio and imaging performance. However, the frequency-dependent attenuation of biological tissue alters the transmitted waveform during propagation, causing a mismatch between the received signal and the ideal matched filter. As a consequence, compression performance may degrade, leading to reduced resolution and image quality.

The objective of this thesis is to investigate the influence of frequency-dependent tissue attenuation on coded ultrasound imaging systems. The work will focus on analyzing attenuation-induced signal distortion and its impact on pulse compression performance, image quality metrics, and imaging depth.

To address these challenges, numerical simulations and experimental measurements will be performed using ultrasound phantoms and representative tissue models. Different attenuation scenarios, excitation schemes, and filter designs will be evaluated and compared. Particular attention will be given to the characterization of image quality parameters such as spatial resolution, signal-to-noise ratio, contrast performance, and side-lobe behavior.

The outcomes of this work are expected to contribute to the development of more robust coded ultrasound imaging techniques and provide insights into attenuation-compensated signal processing methods for future high-performance ultrasound systems. The results will support ongoing research activities in advanced medical ultrasound, signal processing, and digital health technologies pursued within the HybridEcho research group. [digitalhea...dresden.de]

Tasks

- Literature review on ultrasound attenuation and coded excitation techniques
- Development of simulation models for frequency-dependent tissue attenuation

- Analysis of coded signal propagation and matched filtering performance
- Experimental validation using ultrasound measurement setups and tissue-mimicking phantoms
- Evaluation of image quality metrics and attenuation compensation approaches
- Documentation and presentation of results

Expected Skills

- Background in Electrical Engineering, Communications Engineering, Biomedical Engineering, Physics, or related disciplines
- Interest in signal processing, ultrasound imaging, and medical technology
- Experience with MATLAB and/or Python is beneficial
- Independent and structured working style
- Motivation to contribute to interdisciplinary ultrasound research

What We Offer

- Participation in cutting-edge research on next-generation ultrasound technologies
- Access to state-of-the-art measurement equipment and simulation tools
- Close collaboration with researchers from engineering, computer science, and medicine
- Opportunity to contribute to scientific publications and international research projects
- A dynamic and interdisciplinary research environment at HybridEcho and the Else Kröner Fresenius Center for Digital Health at TU Dresden

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Recommended References

- A real-time chirp-coded imaging system with tissue attenuation compensation https://doi.org/10.1016/j.ultras.2015.02.013
- Attenuation Compensation and Estimation https://link.springer.com/chapter/10.1007/978-3-031-21987-0_5