GFDM for MIMO Ultrasound

Bachelor/Master/Diploma Thesis
Studienarbeit/Diplomarbeit

Problem Statement

Medical ultrasound imaging increasingly benefits from advanced transmission schemes that enable the simultaneous operation of multiple transmit channels. Within the HybridEcho imaging approach, multiple transmit elements can be activated concurrently, allowing for more flexible imaging strategies, improved energy efficiency, and increased frame rates. However, the separation of overlapping signals remains a fundamental challenge and requires robust multiplexing and signal processing techniques.

Current approaches include Time Division Multiplexing (TDM), Frequency Division Multiplexing (FDM), and Code Division Multiplexing (CDM). While Orthogonal Frequency Division Multiplexing (OFDM) has demonstrated promising performance in previous work, next-generation communication-inspired waveforms may offer additional flexibility and improved spectral efficiency.

Generalized Frequency Division Multiplexing (GFDM) represents one such candidate. Through its flexible block-based structure and pulse-shaped subcarriers, GFDM offers an attractive framework for multi-user and multi-channel communication systems and may enable novel multiplexing concepts for medical ultrasound imaging.

The goal of this thesis is to investigate the suitability of GFDM for MIMO ultrasound imaging and compare its performance against established multiplexing approaches. The work will include waveform design, simulation-based evaluation, and experimental validation using ultrasound imaging measurements.

Tasks

- Literature review on multiplexing techniques for ultrasound imaging
- Development and implementation of a GFDM framework for medical ultrasound systems
- Design of GFDM transmission schemes for simultaneous excitation of multiple transmit elements
- Numerical comparison with established TDM, FDM, CDM, and OFDM approaches
- Analysis of separation performance, image quality, and computational complexity
- Experimental validation using wire phantom measurements in a water tank
- Investigation of image reconstruction performance under realistic conditions
- Outlook and first feasibility studies using tissue-mimicking phantoms

Research Questions

- Can GFDM enable robust separation of simultaneously transmitted ultrasound signals?
- How does GFDM compare to OFDM regarding imaging performance and system complexity?
- Which waveform parameters are most relevant for MIMO ultrasound imaging?
- Can communication-inspired waveforms improve future ultrasound imaging systems?

What We Offer

- Work on an emerging research topic at the intersection of communications engineering and medical ultrasound
- Access to state-of-the-art ultrasound hardware and measurement facilities
- Collaboration with researchers in signal processing, wireless communications, and biomedical engineering
- Opportunity to contribute to publications and future research activities
- A dynamic and interdisciplinary research environment focused on next-generation ultrasound technologies

Desired Background

- Electrical Engineering
- Communications Engineering
- Information Systems Engineering
- Biomedical Engineering
- Physics or related disciplines

Knowledge of digital communications, signal processing, MATLAB/Python, or OFDM-based systems is beneficial but not required.

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Recommended Reference

- GFDM - Generalized Frequency Division Multiplexing: https://doi.org/10.1109/VETECS.2009.5073571