Mechanical Engineering Doctoral Defense

High-Frequency Ultrasound Analysis of Soft Material Characterization

School for Engineering of Matter, Transport and Energy

Koushik Paul

Advisor: Dr. Leila Ladani

Abstract

Ultrasound has become one of the most popular non-destructive characterization tools for soft materials. Compared to conventional ultrasound imaging, quantitative ultrasound has the potential of analyzing detailed microstructural variation through spectral analysis. Because of having a better axial and lateral resolution, and high attenuation coefficient, quantitative high-frequency ultrasound analysis (HFUA) is a very effective tool for small-scale penetration depth application. One of the QUS parameters, peak density had recently shown a promising response with the variation in the soft material microstructure. Acoustic scattering is arguably the most important factor behind different parametric responses in ultrasound spectra. Therefore, to evaluate peak density, acoustic scattering at different frequency levels was investigated. Analytical, computational, and experimental analysis was conducted to observe both single and multiple scattering in different microstructural setups. It was observed that peak density was an effective tool to express different levels of acoustic scattering that occurred through microstructural variation. The feasibility of the peak density parameter was further evaluated in ultrasound C-scan imaging. The study was also extended to detect the relative position of the imaged structure in the direction of wave propagation. To this purpose, a derivative parameter of peak density named mean peak to valley distance (MPVD) was developed since peak density was not found effective for that purpose. The study was then focused on detecting soft tissue malignancy. The histology-based computational study of HFUA was conducted to detect various breast tumor (soft tissue) grades. It was observed that both peak density and MPVD parameters could identify tumor grades at a certain level. Finally, the study was focused on evaluating the feasibility of ultrasound parameters to detect asymptotic breast carcinoma i.e., ductal carcinoma in situ (DCIS) in the surgical margin of breast tumor. In that computational study, breast pathologies were modeled by including all the phases of DCIS. From the similar analysis mentioned above, it was understood that both peak density and MPVD parameters could detect various breast pathologies like ductal hyperplasia, DCIS, calcification during intraoperative margin analysis. Furthermore, the spectral features of the frequency spectrums from various pathologies also provided significant information to identify them conclusively.

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Zoom Link: https://asu.zoom.us/j/86949980018