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Non-linear Ultrasonic Computed Tomography (USCT) for soft and hard tissue imaging

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This paper presents the theoretical, numerical and experimental frameworks for breast and bone imaging. The difficulties raised are somewhat different as, in soft tissues, the very small fluctuations to be quantified suffer from their very low values. This poor echogenic index generally induces low detection probability, for instance in the case of large diffuse masses. In bone imaging, the difficulties arise from the very high contrast that alters the propagation of the ultrasonic waves.

(2) Material and Methods

Solutions consist in optimally assessing these non-linear effects in an iterative approach aiming at local linearization. The Near-Field USCT method based on the use of the first-order Born approximation, applied to the case of an homogeneous and constant background is describe. The unknown object function is linearly related to the field measured using the Elliptical Fourier transform. This technique is suitable for breast inspection where the probe is either in contact with the skin or located within a near field distance when using a coupling device. The first-order Born USCT has some limitations when dealing with highly contrasted scatterers such as bones.

(4) Discussion and Conclusion

An overview of the performances and the limitations of these tomography methods applied to breast and bone imaging problems are presented and discussed.

(3) Results

When the problem can be reduced to the study of a fluid-like cavity buried in an elastic cylinder surrounded by water, the Compound USCT is proposed as an extension of the classical USCT, by taking into account physical phenomena such as wave refraction. The main limitation of the method is the heavy experimental-costs involved (multiple iterative experiments). We have then suggested a purely numerical non-linear inversion algorithm, and the minimization procedure between the full recorded and simulated data is solved using a conjugate-gradient method mainly developed in non-destructive testing domain, or an efficient quasi-Newton technique mainly developed in seismology (full waveform imaging method).

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