Wave Propagation in Layered Media using Transient GREEN's Functions – A Discussion of Effects of the Geometry on the Impulse Response

Elfgard Kühnicke*, Mario Wolf, Emanuel Leipner and Christian Kupsch
Measurement, Sensor and Embedded Systems, Laboratory (MSE Lab, TU Bergakademie Freiberg, Freiberg, Germany,
Corresponding Author: elfgard.kuehnicke@et.tu-freiberg.de,

Background, Motivation and Objective

With modern ultrasonic measurement methods, high accuracy can only be achieved by knowing the sound field in a given measurement setup. It has been shown that the accuracy for a simultaneous determination the speed of sound and the thickness of the individual layers of a two-layered medium with annular arrays can be improved significantly by including harmonic sound field information. For method development, fast and accurate simulation algorithms are needed to provide the impulse response as a function of source and layer geometry and their sound velocities.

GREEN's functions provide the field for point sources via integral-transform methods and allow calculating wave propagation over longer distances. Thus, they only require a discretization of the source area instead of the entire volume as would be necessary for fully numerical methods. Previously, algorithms based on transient GREEN's functions have been developed to compute the field of extended sources in half-space or plate. There are also fast approaches to multilayered complex structures based on approximated harmonic GREEN's functions and a separation approach. This algorithm requires the discretization of all interfaces and is well suited for the design of focusing transducers, but cannot provide an exact impulse response. So far, there is a lack of an effective algorithm that uses transient GREEN's functions for layered media to calculate the exact impulse response for an extended source.

Statement of Contribution/Methods

In this paper, a new approach based on transient GREEN's functions for two-layered structures is presented. According to the generalized ray theory a double LAPLACE-HANKEL transform and a CAGNIARD inversion are used to calculate the exact impulse response for the components of the displacement. To simulate wave propagation in two-layered structures, generalized transmission coefficients are implemented in the GREEN's functions and the algorithm is refined for an inverse transformation. The displacement of the extended source is calculated using transient GREEN's functions in combination with point source synthesis and spatial convolution, with a focus on a fast convolution algorithm for circular transducers.

Results/Discussion

The algorithm provides the impulse response, taking into account all wave components (pressure, transverse, interface and head waves) at the observation point. It also captures the influence of mode conversion at the interface. By optimizing the algorithm, using transmission coefficients and a spatial convolution, an efficient tool for the calculation of ultrasonic signals in two-layered structures is developed. This shifts the trade-off between computation time and accuracy of simulation results dramatically. Impulse responses are calculated for a number of two-layered structures. The appearance of the impulse response is discussed as a function of the geometry of the structure, the material of the layers, and the distance between receiver and observation point. For a better understanding, the influence of the various partial waves is discussed in detail.

Keywords: ICTCA 2023; transient GREEN's function; wave propagation; layered media.