28.01.2023

Abstract of the dissertation "Active Global Control of Time-Harmonic Sound Waves" by Matthias Wolfram Ospel

This thesis deals with the active global control of time-harmonic sound waves. The theoretical foundations of the modelling of the problem in the frequency domain, the underlying inverse problem and the minimum sound power of isotropic source pairs are described. Transform domain adaptive filters, which are used in practice for the real-time solution of the inverse problem, are then derived from the gradient descent method. A brief literature review of active noise control systems with the objective of controlling the wave fields in infinite domains is given. This work was carried out in the context of noise pollution by ferries at berth.

A direct boundary element ansatz for the simulation of active noise control near-field array systems based on speaker models was formulated and its limitations were investigated in an experimental setting. The choice of boundary conditions for the underlying Neumann problem was validated via laser Doppler measurements of the speaker's membranes. This is followed by a comparison of the experimentally determined and simulated radiation characteristics. The technical implementation of a near-field multichannel active noise control system is then described. The hardware and iterative transform domain algorithms for the identification of the frequency response functions in the system and controlling the acoustic wave field in real-time, as implemented on a field programmable gate array, are presented.

The results of a field measurement in a port environment, investigating the sound emission from dominantly time-harmonic noise sources of a ferry at berth, are shown. A large boundary element model was created to simulate the sound emission. Based on the experimentally validated model of noise pollution in the port environment, the performance of a near-field active noise control array system is simulated for an adjacent residential area. From regularisation analyses it is deduced that the iterative solution of the inverse problem can be advantageously sought with the constraint of equal phases of the actuators in this system configuration. Therefore, the performance of a near-field multichannel control system based on a single-input multiple-output control strategy was investigated numerically and experimentally. Limitations due to phase disturbances of the actuators, velocities of the actuator membrane, optimal microphone positioning etc. are simulated using the previously formulated direct boundary element ansatz. The experiments conducted with the single-input multiple-output prototype system are presented. Experimental results of tests of the system in the laboratory are shown. Average reductions of the signal energy up to 23 dB have been measured for the frequency range <600 Hz at several microphone positions around the control system. The iterative transform filter algorithm used for the real-time calculation of the source strengths of the actuators in the near-field control system converged rapidly within <0.1 s.