The Controller Synthesis of Active Noise Reduction System in Authorized Emergency Vehicles

Warning signals generated by sirens of authorized emergency vehicles should be audible and recognizable to all road users. Currently, there is no legislation in Poland defining sound pressure levels (SPLs) of audible warning signals generated by sirens of authorized emergency vehicles. Measured A-weighted SPLs of those signals range between 104 and 108 dB. An audible warning signal on one side is a source of important information and its A-weighted SPL is acceptable for road users, on the other hand it may be a source of annoying noise to an emergency vehicle crew. A-weighted SPLs inside an authorized emergency vehicle with an enabled siren can exceed 90 dB, which has an adverse impact on the working conditions of the driver and the crew. Therefore, it is necessary to find a method of improving the acoustic comfort of the crew and, at the same time, maintaining the informational function of audible warning signals. Considering its informational function, it is not possible to reduce a SPL of the emitted signal. Sound insulation improvement of a driver's cab is not, in this case, an appropriate solution as well, because besides noise of a signalling device, other usable and important signals which reach a driver from outside of a vehicle, would be muffled. Relocation of the audible warning device from the vehicle's roof lightbar to the engine compartment is an incorrect solution, which in extreme conditions, may prevent the perception of the warning signal, and thus significantly reduce the on-road emergency vehicle safety.

Use of active methods to noise reduction is a solution which can find effective application in this case. Active noise reduction (ANR) is based on the phenomenon of mutual compensation of acoustic waves leading to a decrease in the sound pressure level at a given point in space. A compensating acoustic wave is created by means of an additional sound source. The acoustic compensation wave has to have in the point of space (point of observation) the same amplitude as the acoustic noise wave and opposite phase. The main issue in the application of ANR systems in authorized emergency vehicles is ensuring stability of the ANR system operation and at the same time a highly effective active noise reduction.

The main goal of the dissertation is to develop an algorithm of ANR for use in authorized emergency vehicles and integrate functions of the warning signal generation and noise reduction in one device. In the dissertation, a solution of the ANR system has been presented. The ANR system is controlled with the use of NOTCH filters with quasi-Fixed-Parameters determined by a genetic algorithm (GA). In this case, the audible warning signal is reduced but only when it reaches the driver.

The ANR system was tested by numeric simulations and laboratory tests. Numeric simulations included the implementation of the algorithm to Matlab software. In this part of the study, parameters of GA and theoretical efficiency of ANR system were analysed. Efficiency of ANR system, defined as difference in sound pressure levels of a signal under headphones, before and after switching on the ANR system. The numeric simulations has been revealing that efficiency of ANR system is different for different types of warning

signals: 37 dB for Yelp and 43 dB for Hi-Lo and Wail. After numeric simulations laboratory model of ANR system was developed. The model consists of a controller, active headphones, a source of warning signal. During previous research the active headphones and the source of warning signal were developed. The controller base on the Analog Devices evaluation kit - ADSP-21992-EZ-KIT. The algorithm of ANR system was implemented to the controller through VisualDSP++ environment. In part of the laboratory tests an electric signals from the controller and efficiency of ANR system was analysed. The laboratory tests of controller has been revealing that efficiency of ANR system is equal to 36 dB for Yelp and Hi-Lo and 26 dB for Wail. The laboratory tests with KEMAR Manikin shows that it is possible to develop a running ANR system for use in authorized emergency vehicles which connects functions of the warning signal generation and noise reduction.

Application in practice of the described system might improve of acoustic comfort for drivers of authorized emergency vehicles. Improvement in acoustic comfort will influence positively the level of drivers' concentration during rescue actions, better perception of acoustic stimuli reaching them (e. g. information from other road users) and road traffic safety.