Abstract

Determination of sound intensity based on synchronized sound pressure signals

author: mgr inż. Michał Raczyński

supervisor: dr hab. inż. Witold Mickiewicz, prof. ZUT

The intensity methods (i.e. based on sound intensity measurements) are an interesting alternative to the pressure methods (based on sound pressure measurements) which are most commonly used in acoustics today. Visualization of sound intensity field, allow to observe the flow of the acoustic energy around the sources. In many cases it gives more information about the mechanism of sound generation and its propagation than measuring only the scalar quantity - sound pressure. Unfortunately, the measurement of sound intensity requires the use of specialized measuring instruments (e.g. *PP* probes). The critical element of *PP* probes is a pair of microphones with extremely similar frequency responses (especially phase responses), which affects high price of the probe. For this reason, intensity methods have not become popular among a wide range of acousticians. In this dissertation, an attempt is made to investigate the properties and give potential applications of an alternative method of sound intensity measurement that does not require the use of expensive intensity probes. It is a modified version of the *PP* probe, but using only one microphone. The measurement is performed twice, placing the microphone in positions corresponding to the positions of the microphones in the *PP* probe. The determination of the sound intensity based on the recorded signals is possible thanks to their synchronization. This can be done in different ways. The synchronization can be performed during the measurement (direct synchronization) or after the measurement by using an additional reference signal (indirect synchronization). This approach (using only one microphone) is supposed to eliminate the error caused by the lack of similarity of frequency responses of microphones in the *PP* probe (phase mismatch and amplitude mismatch error). Thus, a simple pressure microphone can be used for the measurement. Of course, the measured signals must be periodic, which limits the application of the proposed method.

In the introductory part of the dissertation, the basic information about the acoustic field were systematized. Then, the review of currently used methods of sound intensity measurement was made. The methods of compensation of the phase mismatch error in the *PP* probes are also presented.

In the research part, measurements using the proposed method are presented. They were carried out for several real sound sources and different channels of the reference signal used to make synchronization. Then, based on the obtained results, the errors occurring in the proposed measurement method were analyzed. The error associated with the nature of the measured signal was described and its mathematical model was created. As a result, the limits of application of the proposed method (in the variant with indirect synchronization) were determined. An effective method of minimizing the synchronization error resulting from the discretization of reference signals has been proposed.

In the further part of the dissertation, the original measurement system is presented which allows visualization of the acoustic vector fields with the use of the proposed measurement method (now in version with direct synchronization). The presented solution uses direct synchronization of acquisition and generation processes. The results of measurement of acoustic energy distribution around the active loudspeaker set are presented.

The work ends with a summary containing perspectives for further development of the proposed measurement method.

Keywords: sound intensity, *PP* probe, acoustic energy, acoustic vector field visualization, intensity probes, phase mismatch error