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The role of mutual screening by vehicle bodies in traffic noise propagation throughout a built-up area

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ABSTRACT

The paper presents the results of investigation of the sound field on a building façade neighbouring a busy road. The field simulation is based on programs which allow control of accuracy in description of a propagation process, as well as accuracy in modelling of a road and its surroundings. Considered interactions are straight-line spreading, reflections, and diffractions. The urban system modelling involves geometry of surrounding buildings and acoustical properties of their walls, road geometry and a traffic structure in lanes. By comparison of the simulation with the field measurements it could be confirmed that a proper accuracy has been obtained. Based on the verified simulation of the sound field, the efficiency of noise abatement means can be predicted depending on urban system parameters.

In the previous investigation, moving vehicles were modelled as omnidirectional point sources (E. Walerian, R. Janczur, M. Czechowicz, J. Smirnowa, Possible improvement of acoustical climate. PART I: Measurements and theoretical description, Archives of Acoustics 35 (3) (2010) 307–332; R. Janczur, E. Walerian, M. Meissner, M. Czechowicz, Application of simulation program to specific urban situation, Applied Acoustics 70 (2009) 973–985). In this way, the required agreement between the simulation and measurement had been obtained for the upper part of façades.

In the presented paper the free emission in the road space is replaced by emission disturbed by other vehicles' presence. To consider their influence, the effect of mutual screening by vehicle bodies is included. The disturbed noise emission, when neighbouring vehicles are treated as semitransparent screens, offers a fully satisfactory agreement with field measurements for the case of a smooth façade. A noticeable improvement has been obtained for a shaped façade with a few meters depression in it. In the last case, the satisfactory agreement with field measurements has been reached when the proper reflection coefficient of the walls has also been assumed.

1. Introduction

The noise hazard for large segments of cities could be evaluated by noise mapping. The applied simulation programs predicting the sound level are of accuracy appropriate for a large urbanized area. Due to this, the details of field in a busy road vicinity are invisible. On the other hand, a lot of noise abatement means are of local character. They are based on an effect of shielding by screens next to a road or shielding elements at a building façade. To predict their efficiency, the problem to be solved is to describe the field in the road vicinity. This is difficult due to complex noise emission by a road and complex propagation process of multiple interactions with road surroundings in real urban systems.

Awareness of importance of the sound level spread over façades directly exposed to road traffic noise results in attempts of its consideration in acoustical climate evaluation [1]. However, the current approach is based on investigation of an effect of a single element in a simplified urban system [2]. Omission of mutual interactions with objects present in the road proximity could yield results different from expected [3]. Thus, the provided information is not sufficient to evaluate the efficiency of the noise abatement means. Besides this there is a second reason. It stems from the fact that noise abatement means other than a source silencing could be of an order or a few decibels. Therefore, only complex solutions combining several means could provide a subjectively noticeable improvement of an acoustical climate. To obtain the efficient complex solution, all possible interventions in noise propagation from a source to a protected zone have to be analysed and assessed.

For a screen placed next to a road, in the simplest systems, where apart from the screen only the ground is considered, the cases of a moving point source and dipole are presented with consideration of discontinuity over an impedance ground surface [4–6]. Also, the case of special interest with included interaction between a screen and protected building façade is analysed [7,8].

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In the above cases the ray tracing [4–7] and boundary element methods are applied [8].

To balconies playing a role of screens next to a receiver at a building façade the ray tracing method is applied [9,10]. There, reflections in balcony space are considered with a potential acoustical adaptation [11]. Similar cases are also analysed with application of the boundary element methods [12,13]. The boundary element methods are especially useful when influence of the screen top-edge shape is analysed [14–16]. The numerical schemes involving application of the Green's function are applied to fields in balcony cavities, as well as to noise transmission between city canyons [17–20]. Noise transmission to courtyards in dependence on roof shapes and their acoustical properties are analysed as a special case [21,22]. In the presented cases of numerical method application, the analysis is reduced to two dimensions. Moreover, the required discretisation makes the methods less efficient with the frequency growth. On the other hand, the heuristic models based on high frequency approximation like ray tracing and the image method are applied due to their effectiveness regarding multiple interactions and ability of physical interpretation. The review of models combining these approaches, accompanied by discussion of their applicability, has been presented in the framework of the HARMONOISE Project [23,24].

Two ways of thinking are possible to predict the efficiency of noise abatement means for a chosen building façade under conditions characteristic for an urban system where a selected building is placed. One is to intuitively identify the phenomena dominating in the field creation, available description in adequately simplified urban systems can be applied. Otherwise, analysis can be based on the field description of a general character. Its ability of accuracy adjustment allows formal establishing of a simplified urban system appropriate for the case under consideration.

The authors developed an environmental noise model as a basis for simulation programs of controlled accuracy [25–28]. In the simulation programs addressed to city area, the propagation space of interest is a half-space with obstacles of different shapes and acoustical properties whose dimensions and distance from a road are in the range of few dozen meters. Weather conditions are omitted and the propagation in ideal gas at rest is assumed. A road as a noise source is represented by point sources spread over road lanes. A uniform propagation description based on the image method was developed. The image method, as well as the ray tracing method, is based on high frequency approximation. The image method is an alternative to the ray tracing method. It differs in that it becomes more accurate when the interaction order grows higher. Contrary to this, in the ray tracing method, due to approximate spatial resolution, the larger travelled path, the less accurate the final result.

Accuracy control is enabled at the level of individual interaction descriptions, as well as at the level of a road and its surroundings modelling. The defined procedure of software preparation allows harmonizing accuracy at different levels of approximation and avoiding the partial accuracies above the required degree. By means of successive tests and introduction of corrections in modelling, the obtained simulation program is time efficient and involves only a limited set of input data. When in the process the acceptable agreement with field measurements is obtained, then the assumed model can be accepted as adequate for the case under consideration.

The goal of the paper is to investigate the influence of a vehicle mutual screening on the sound level spread over a building façade neighbouring a busy road. The idea stems from the observed discrepancy between the predicted and measured sound levels in the range of lower floors when free emission in a road space has been assumed [29–32]. The investigated façades with a vertical depression was of a special interest [30]. The sound level measured at the depression back-wall showed satisfactory agreement with the simulation assuming free emission in a road space. For this range, the depression efficiency as a noise protector was analysed depending on the urban system parameters [33].

To extend validation of field simulation for the whole façade correction in modelling has to be introduced. Overestimation of the sound level in the range of the lower floors inspired searching of the reason why it appeared. It seems to be the result of partially blocked noise emission by vehicles. Up to now, the road space was treated as a free half-space with equivalent point sources representing vehicles moving in lanes. Now, the road space has been incorporated into the propagation space. At first, road lanes between the noise source and observation point have been treated as semitransparent screens creating a geometrical shadow [34]. Due to not fully satisfying results, as a second option, propagation in the road space is assumed in the same way as in the space surrounding the road. It means that propagation is in a space with several obstacles. In the road surroundings they are buildings, in the road space these are semitransparent screens which represent vehicles appearing in lanes. The second option provides an acceptable agreement with measurements.

The simulation procedure is briefly presented in Section 2. The two models of mutual screening by vehicle bodies are described in Section 3. The field-collected data involving a building with a smooth façade and a building with a shaped façade of a few meters depression have been compared with the results of simulations in Section 4. Based on the presented examples, it is shown when and why mutual screening by vehicle bodies has to be considered. The given quantitative information presents the importance of mutual screening by vehicle bodies in the identified cases. In other cases, when the effect is unimportant, its omission is advised to spare calculation time.

2. Sound field simulation in built-up area

2.1. Environmental noise model foundation

The environmental noise model as a basis for simulation programs has a propagation model and a source model as independent parts [25–28]. Since any source can be made-up of point sources, an urban transfer function is used for description of propagation in the space defined as a half-space with obstacles. The obstacles can be made-up of panels of defined acoustical properties, joined at angles allowing consideration of their shapes.

A wave due to the point source can reach the observation point by different paths. On the travelled path it undergoes a chain of arbitrary number of interactions that include transmissions, reflections, and diffractions. The total field results from pressure summation over the wave's different paths. The descriptions of individual interactions are based on high frequency approximations of the canonical solutions [35]. The same concerns the ray tracing method but the here-applied method differs in the diffraction concept. Contrary to Keller diffraction theory [36], the applied Rubinowicz concept [37] relates the diffraction wave to the wedge active point (defined by the shortest travelling path) which emits the wave of a cylindrical character and specific directional characteristics. The applied approach, allowing the use of the image method, results in a uniform propagation description. The applied image method becomes more accurate with the growth of the interaction order, while, due to an approximate spatial resolution, the ray tracing method becomes less accurate with the growth of the travelled path.

The general character of the environmental noise model and its structure allow its application for different noise sources met in an urban area and different buildings' arrangement. Consideration of