ICSV13 - Vienna
The Thirteenth International Congress on Sound and Vibration
Vienna, Austria, July 2-6, 2006

APPLIED VIRTUAL SOURCES METHOD

Sanja Grubesa*[1], Tomislav Grubesa[1], and Hrvoje Domitrovic[1]

[1]Faculty of Engineering and Computing, University of Zagreb, Unska 3, Zagreb, Croatia
sanja.grubesa@fer.hr

Abstract
This paper describes the use of Virtual Sources Method (VSM) for simulation of indoor acoustics. The VS method of simulation is based on mirror image modeling, and it is scalable and suitable for implementation in any programming language. The method is able to provide very precise simulations by choosing an arbitrary number of points in which the calculations of sound pressure will be made. It is also possible to choose the number of reflections as well as the precision of the frequency characteristics of the absorption factor and the sound source itself. However, if the precision is set to high, the time required to complete the simulation rises, making it the biggest problem this simulation method has to face. The convenience of this method is further improved by showing all the results in an easy-to-understand graphic form. This simulation method has been applied to solve a real problem of choosing the right acoustic treatment for a puppet theatre. The theatre itself is a shoe-box type space with raised audience area. Before the implementation of acoustic treatment, the theatre had serious problems with flutter-echo, the reverberation time which was too long, sound focusing, low intimacy etc. The proposed acoustical treatment included the ceiling and the walls of the theatre. Before starting any actual work, the simulation was used to determine the desired acoustical parameters and to choose the right way of acoustic treatment. The graphic results of simulation showed that the proposed treatment of walls and ceiling was well chosen because the fore mentioned problems were solved by implementing it and that the actual acoustical treatment could be carried out.

INTRODUCTION

The Virtual Sources Method for simulation of indoor acoustics is based on mirror image modeling. The important feature of this method is its scalability and suitability for implementation in any programming language. However, the simulation program is written in *Microsoft Visual C++*. The advantage of this method is its ability to provide both course results in a very short simulation runtime, as well as very precise results. This can be done by choosing an arbitrary number of points in which the calculations of sound pressure will be made. Besides that, the number of reflections can also be chosen, as well as the precision of the frequency characteristics of the absorption coefficient and of the sound source itself. However, if high precision is chosen, the simulation runtime grows longer. This is the biggest problem this simulation method has to cope with. This method is very intuitive, since all the results can be shown in an easy-to-understand graphic form. To be more precise, the simulated acoustic field can be presented graphically in a 2D view as a distribution of sound pressure in the room, and the energy-time curve (ETC) can also be presented for each point in space involved in the calculation.

ACOUSTIC TREATMENT

In order to examine the applicability of this method to a real problem, it has been used to determine the proper acoustic treatment for a puppet theatre in the city of Split. The theatre has a shoe-box type space with raised audience area. Prior to implementation of acoustic treatment, the theatre experienced serious problems with flutter-echo, the reverberation time which was too long, sound focusing, low intimacy etc.

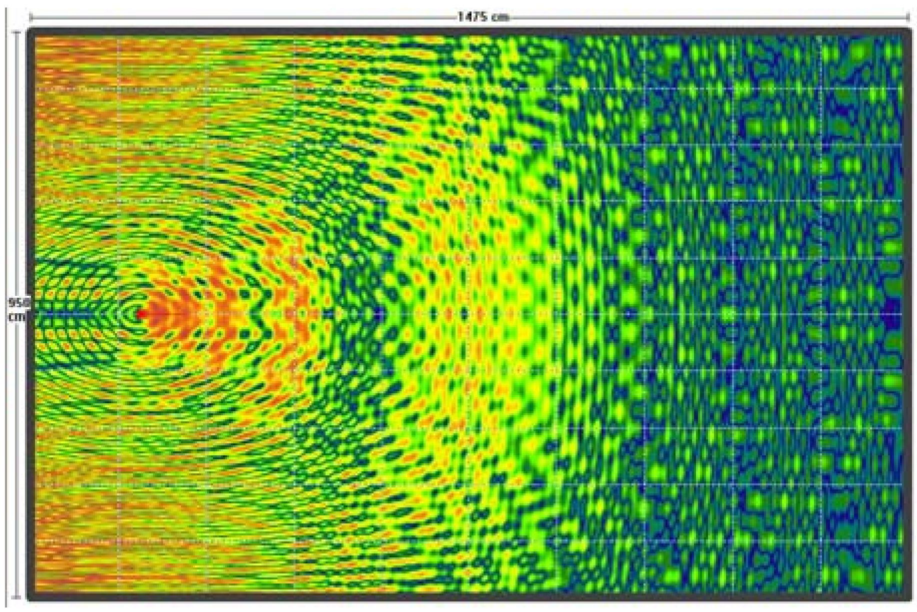

Figure 1 – The sound pressure level distribution in the theater prior to acoustical treatment

Before commencing any actual work, the simulation was used to determine the desired acoustical parameters of the theater and to choose the proper way of acoustic treatment. In Figure 1 simulation results are shown for the theater prior to acoustic treatment. The results clearly show the existence of sound focusing and the non-uniform sound pressure level distribution in the theater. Furthermore, the reverberation time calculated from ETC was too long with respect to the volume of the hall and the intelligibility, also calculated from the ETC, was too low for the intended purpose of this theater.

In order to solve these problems, the proposed acoustical treatment included treating the ceiling and the walls of the theatre.

The treatment of the walls

Acoustic treatment of lateral walls is realized by using several large panels, situated symmetrically on both walls. The applied acoustic treatment is also symmetrical for these walls. Each of the panels is treated in two different ways: the top part of the panel contains a resonator designed and calculated for the frequency band around 250 Hz. The depth of the resonator changes from 2 to approximately 9 centimeters. The fabric material and the sound absorption material are placed behind the perforated panel. The important thing is that the sound absorption material fills only a part of the space behind the panel, while the remaining space, close to the construction wall is empty, i.e. filled only with air. The panels are tilted around the vertical axis for the angle of 4°, thus solving the problem of flutter-echo and achieving appropriate sound pressure level distribution in both front and back part of the audience area.

The back wall of the theatre is constructed as a combination of diffuse and absorptive elements. In order to achieve a certain degree of diffusivity, fourteen quadratic-residue diffusers have been placed two-by-two on seven different spots on the back wall. For this particular purpose, the quadratic-residue diffusers based on prime number N = 7 have been chosen, with respect to the required frequency band in which they will operate and the required depth of the diffuser. Forming the second part of acoustic treatment of the back wall, the sound absorption material is placed around the diffuse elements.

The ceiling

Since the theater has been built on the sea shore of stunning Adriatic see, the ceiling surface has been given a wave-shaped form with the intention to resemble to sea waves. Unfortunately, such ceiling shape can lead to sound focusing. In order to avoid this phenomenon and to achieve certain diffuse properties of the ceiling, the lighting of the theater has been placed in the concave parts of ceiling along with big dolls, which is more than appropriate, considering the object is a puppet theater. The ceiling itself is made of gypsum-cardboard panels, above which the mineral wool is placed.

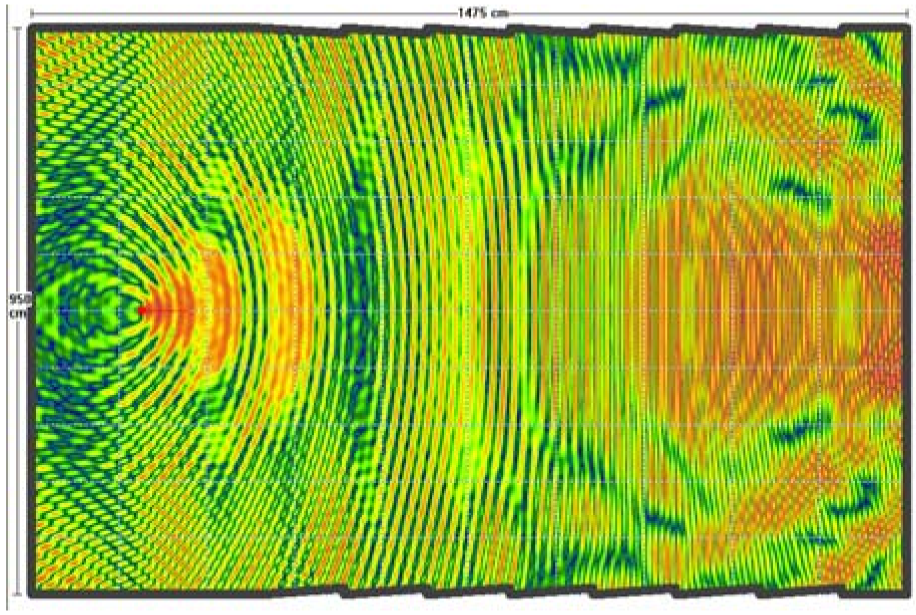

Figure 2 – The sound pressure level distribution in the theater prior to acoustical treatment

The results of the simulations conducted for acoustically treated space are shown in Figure 2. Each point in the room involved in the simulation is plotted in different color. The color is calculated from the sound pressure level estimated in that particular point. The highest sound pressure level is shown in red, while the lowest one is shown in blue. The sound pressure level is calculated in decibels relative to the sound pressure of the sound source, which is considered the highest in the room.

The graphic results of the simulation show that the proposed treatment of walls and ceiling was well chosen because the fore mentioned problems have been solved by implementing it and that the actual acoustical treatment could be carried out.

THE THEATER AFTER ACOUSTIC TREATMENT

As the actual acoustic treatment of the theater interior is currently in the final stage, the final measurements have not been done yet. However, the subjective opinion of actors after a few rehearsals conducted without using the sound reinforcement system is more than favorable. The speech intelligibility is now excellent throughout the entire audience area and the speech pronounced on the stage maintains its articulation having reached the listener/viewer position. The sound distribution now shows a much more uniform character, since there is no sound focusing or damped zones.

Although the stage lighting has not yet been installed above the back part of the audience area, the concave parts of the ceiling produce reflections of minor significance, noticeable only in the sitting row located directly underneath. In the front part of the audience area, above which the lighting has already been installed, this phenomenon is not present, suggesting that this problem will be resolved in the back part of the hall by finishing the installation of the lighting and the hall as a whole. A picture of the theater, taken upon the completion of acoustic treatment of walls, is shown in Figure 3.

Figure 3 – A photograph of the theater interior

CONCLUSIONS

The Virtual Sources Method for simulation of indoor acoustics has proved to be of great use for estimation of acoustical properties and quality of a given space prior to acoustic treatment. Furthermore, this method enables the designer to try out different acoustic treatments in a certain space without physically implementing it, thereby reducing the costs and the possibility of certain problems emerging. The results of the simulation show high degree of correlation with actual measurements conducted in actual spaces, making the simulations based on this method a useful tool for evaluation of any given space.

REFERENCES

[1] Talaske, R.H, Boner, R.E., "Theatres for Drama Performance: Recent Experience in Acoustical Design", ASA Publication (1987).

[2] Jauk S., Domitrovic H.,"Software For Simulation Of Indoor Acoustics Fields" Proceedings of Region 8 EUROCON 2003, (2003).

[3] Jauk, S., Grubesa, T., Domitrovic H., "Virtual Sources Method For Simulation Of Indoor

Acoustics”, Proceedings ELMAR, 283-288 (2004).
[4] Kuttruff, H., “Room Acoustics“, Elsevier Science Publishing Co, INC, (1991).
[5] Jelaković, T., “Sound, hearing and architectural acoustics“, School book, Zagreb, (1978).
[6] Somek B., “Electroacoustics-Technical encyclopedia“, Croatian lexicographical department, Zagreb, (1983).