Preliminary Exploration of Digital Acoustic Model Optimization in Radio and Television Media Building

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Abstract. The article mainly explores the issues of digital model optimization in acoustical simulation for radio and television media buildings. Firstly, the importance of acoustical design in radio and television media buildings is introduced. Then, an analysis is conducted on the computational principles, accuracy, and computational efficiency of digital model optimization. Subsequently, the elements of matching and optimizing between digital modeling and the related software Odeon are proposed, elucidating their implementation process. The effectiveness and superiority of this process are demonstrated through practical applications.

Keywords: Studio; geometric acoustics; acoustic model; direct sound; octave band.

1. Introduction

Media and communication buildings integrate modern broadcasting engineering centers, making them complex acoustical system projects. Different-sized studios and language recording rooms within these buildings have close relationships with sound insulation, vibration isolation, air conditioning noise, indoor acoustics, and architectural decoration. This article discusses specific criteria and measures for each acoustically demanding room, including studios, artistic recording rooms, language recording rooms, monitoring rooms, and live broadcasting rooms. Auxiliary technical rooms such as control rooms, transmission rooms, and editing rooms are not discussed in this study.

2. Acoustic Simulation Software

Since the 1960s, the computer simulation technology of indoor sound fields has undergone significant development. On the one hand, the improvement in the performance of modern computers has enabled the realization of complex simulation operations. On the other hand, the continuous refinement of sound field simulation methods and the increasing precision of 3d modeling have created favorable conditions for the practical application of indoor sound field simulation [1]. With the in-depth research of computer simulation technology for indoor sound fields, simulation speed and accuracy have continuously improved, leading to increasingly realistic simulations of the propagation, reflection, and absorption characteristics of sound waves in indoor environments.

Indoor sound field computer simulation technology primarily comprises two types: numerical methods based on the wave equation and numerical simulation methods based on geometric acoustics. Numerical methods based on the wave equation are limited by the simplification of room boundary conditions and the computational speed of computers. Therefore, the direct use of the wave equation to solve the characteristics of indoor sound fields has not been widely applied in practice. On the other hand, numerical simulation methods based on geometric acoustics include ray tracing and the virtual source method. Ray tracing imagines the spherical waves emitted by indoor sound sources as composed of many rays, each carrying a certain amount of energy. These rays propagate in a straight line following geometric acoustic principles, reflecting at interfaces, and experiencing some energy loss [2]. The computer synthesizes the sound field at the receiving point based on the tracking of all ray propagation. The virtual source method, meanwhile, treats the reflection effects of sound waves at interfaces by equivalent virtual sources formed by those interfaces. All reflected sounds in the room are assumed to originate from corresponding virtual sources [3]. Both ray tracing and the virtual source method are based on the fundamental assumption in geometric acoustics that sound waves propagate in straight lines.

The software used for computer sound field simulation analysis in this study is Odeon. Odeon is recognized globally as one of the most reliable architectural acoustics simulation tools. Concerning the simulation and prediction of indoor environmental sound fields, it primarily models parameters such as reverberation time, sound pressure level (SPL) distribution, lateral reflection coefficients, and other relevant factors. Indoor sound pressure level includes both direct sound and reverberant sound. The direct sound is related to the distance between the calculation point and the sound source, following the law of inverse square distance for an ideal point source. As for the reverberant sound energy, Odeon software employs a hybrid method combining the virtual source method and ray tracing, enhancing the reliability of simulation and simulation results.

3. The Establishment and Optimization Process of Digital Models

The steps for conducting indoor sound field computer simulation using Odeon are as follows: Firstly, create a 3d geometric model of the actual room that complies with Odeon requirements. Then, arrange acoustical materials on all 3d surfaces or grids of the geometric model, inputting the material's acoustical property parameter values into the computer software, resulting in a 3d acoustical model. Finally, the software simulates the propagation patterns of sound waves within the auditorium according to geometric acoustics principles, obtaining the characteristics of the sound field.

The establishment of the actual auditorium's 3d acoustical model forms the foundation for the entire simulation calculation. Currently, all surfaces accepted by various acoustical software must be planar, requiring every curved surface to be composed of several planes. For structurally complex auditoriums, to avoid affecting the correct judgment of effective sound imaging and the accuracy of various acoustical simulation parameters, the acoustical model established during the Odeon simulation process may not guarantee complete geometric realism compared to the actual construction. Instead, it might lead to inaccuracies in the simulation results due to too many planes and inaccurate judgment of virtual sound sources. Therefore, it is advisable to maximize the size of surfaces that play a significant role in sound reflection, while simplifying some minor surfaces as needed. The optimization process is illustrated in Fig. 1.

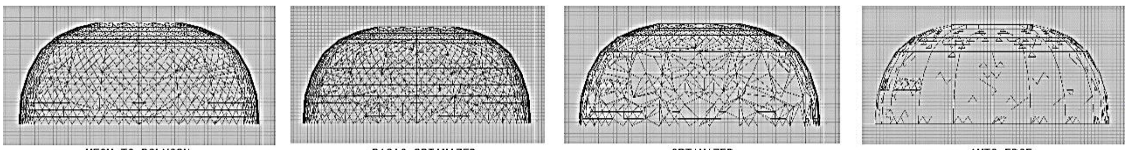

Fig. 1 Optimization and evolution of acoustic model

To ensure the accuracy of simulation results, the correct setting of certain parameters during the software analysis and calculation process is equally crucial [4]. The 3d acoustical model of the actual auditorium can be built using the software's built-in parameter modeling language or with general-purpose software like AutoCAD, SketchUp, Rhino, 3dsMax, etc., which can then be converted into file formats accepted by Odeon, such as dxf or 3ds. Odeon automatically checks the input model, identifies surfaces that do not meet the software's defined 3d standards, and conducts a model closure check. After correcting and ensuring that all 3d surfaces meet the software's requirements, various simulation analyses and calculations can proceed. Parameters such as the type, location, sound power level, directionality of the sound source, as well as the positions of the audience and receiving points, are set based on actual conditions [5]. The acoustical coefficients of the surfaces in the auditorium need to be input, considering absorption and scattering effects when sound waves collide with acoustical materials, following Lambert's cosine law. The software can automatically calculate major acoustical parameters at various receiving points and provide color-coded grid distribution maps for acoustical parameters across eight octave bands' center frequencies from 63Hz to 8000Hz.

Based on some fundamental concepts of establishing the geometric model in Odeon and without compromising simulation accuracy, the model undergoes the following optimization procedures.

- The model consists of single-layer planes, and the outer perimeter, including ceilings, floors, and walls, undergoes complete enclosure to prevent sound energy leakage.
- Various sections of the model are arranged according to actual conditions to maximize the reflection of real-world scenarios.
- Curved surfaces are divided into several planes, maintaining angles between planes within 10°-30°.
- Control the number and size of planes, ensuring that plane dimensions are not smaller than 50mm, with the total number of planes kept within 100,000.
- Simplify doors, windows, and office desks into single planes, neglecting small decorative shapes.

The optimized model is illustrated in Fig. 2 below.

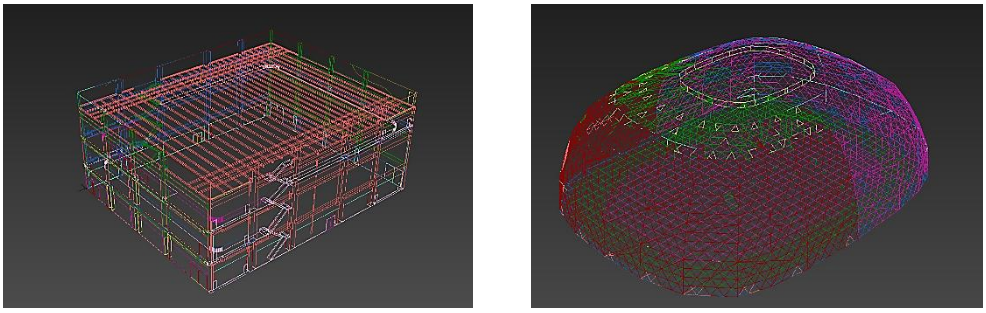

Fig. 2 Perspective view of acoustic model

4. Key Data Output and Analysis

4.1 D50 Introduction to the Acoustic Model

The acoustic simulation of the broadcast studio, a cubic internal space within a 3:4 rectangular floor plan of approximately 2000 square meters and a net height of 10 meters, was conducted using Odeon software. The interior surfaces featured acoustically designed configurations with diverse materials such as rubber for the floor, glass wool attached to metal perforated panels for the ceiling, glass wool behind wooden perforated panels for absorbing walls, glass wool behind FC perforated panels for additional absorbing walls, aluminum panels for reflective walls, wooden veneer for hard walls, and glass wool for the stage's absorbing ceiling. Simulation results provided key insights, particularly in SPL, SPL direct sound, STI, EDT, T30, D50, and C80 parameters.

4.2 D50

D50 refers to the logarithmic ratio of sound energy within 50 milliseconds to the total sound energy. It is used to characterize the clarity of speech and is positively correlated with the STI index. The maximum value for D50 is 1, and as it approaches 1, the clarity of speech in the hall increases. Figure 3 shows the bar distribution data of D50 for various measurement points within the broadcast hall.

4.3 C80

C80 represents the logarithmic ratio of sound energy within 80 milliseconds to that after 80 milliseconds. This acoustic metric is used to measure the clarity of music. Generally, for classical symphonic music, a smaller C80 is preferable, possibly being 0 or negative. For pop and electronic music, C80 is generally a positive number, and a relatively larger value is suitable. Figure 4 presents the bar distribution data of C80 for various measurement points within the broadcast hall.

D50 values, representing the speech intelligibility based on the percentage of early sound energy, were generally high across measurement points. Similarly, C80 values, indicative of the clarity of sound, showed positive results, emphasizing the suitability of the studio for various broadcast applications. STI values, reflecting the intelligibility of language within the space, consistently showed positive results across measurement points.

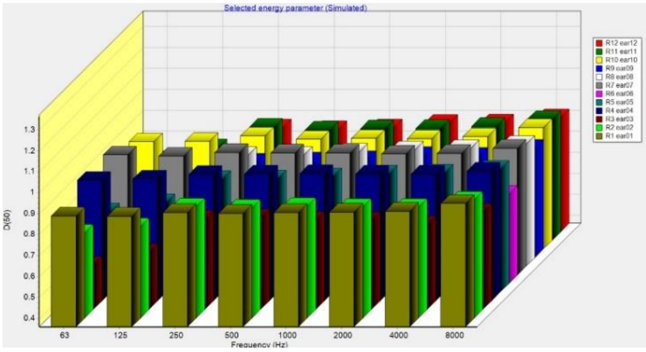

Fig. 3 D50 bar distribution at measurement points

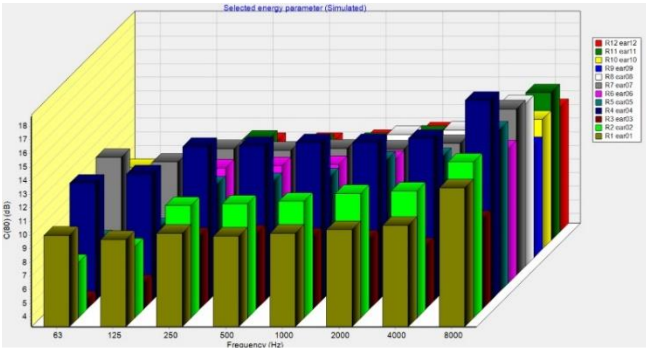

Fig. 4 C80 bar distribution at measurement points

4.4 Reverberation Time T30

Reverberation time refers to the time it takes for the sound pressure level to decrease by 60 dB after the sound source stops emitting sound, denoted as T60. Typically, indoor sound fields cannot achieve a well-defined decay curve within 60 dB, so reverberation time is often represented as T30. This involves linear fitting of the sound pressure level decay curve between -5 dB and -35 dB to obtain the slope, which is used to estimate the reverberation time, T30. Figure 5 illustrates the bar distribution data of T30 for various measurement points within the broadcast hall.

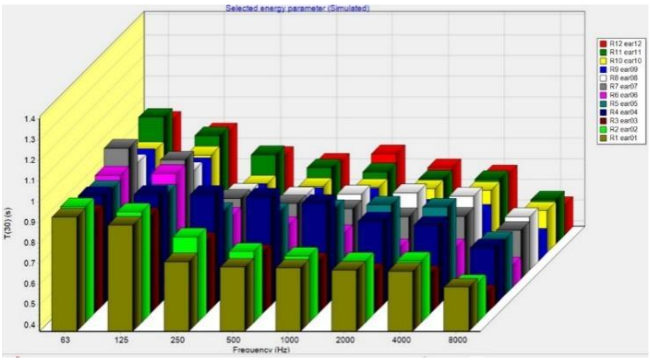

Fig. 5 T30 bar distribution at measurement points

The frequency distribution analysis of EDT and T30 presented encouraging outcomes. The distribution exhibited uniformity across frequency ranges, ensuring that reverberation times were within acceptable limits, contributing positively to the overall acoustic quality. The EDT results indicated a well-balanced acoustic environment, with favorable decay times contributing to speech and music recording suitability.

4.5 SPL and SPL (A)

The logarithmic representation of the effective value of sound pressure indicates the intensity of sound, known as the sound pressure level (SPL). SPL (A) is the A-weighted sound pressure level designed to mimic the A-weighting network's response to sound, emphasizing lower frequencies that are less sensitive to the human ear, with a slight amplification of higher frequencies. A-weighted measurements closely approximate human auditory perception and are easy to measure. Therefore, this simulation data also utilizes A-weighted sound levels as one of the acoustic indicators. Fig. 6 displays the distribution data of A-weighted sound levels at various points within the hall.

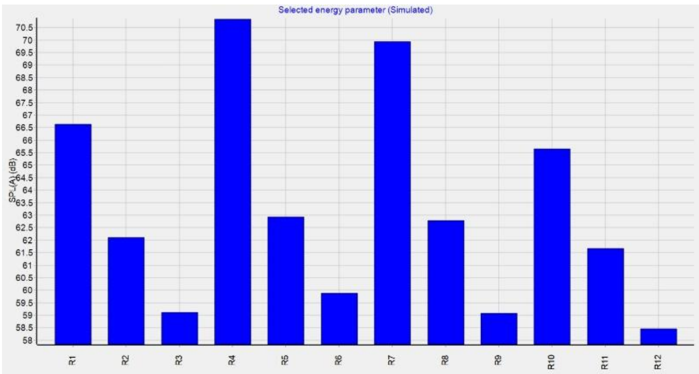

Fig. 6 Distribution of A-weighted sound levels at measurement points

The Sound Pressure Level (SPL) analysis revealed favorable results, showcasing a balanced distribution of sound across various points in the room. Both SPL and SPL direct sound values demonstrated the uniformity essential for a broadcast studio, ensuring consistent sound levels at different locations.

4.6 Conclusion

The acoustic simulation of the broadcast studio indicates an overall positive and suitable environment for its intended purposes. The consistent SPL values, balanced frequency distribution, favorable STI results, and controlled reverberation times contribute to the studio's adaptability for both speech and music applications. The D50 and C80 parameters further affirm the clarity and intelligibility of sound within the space. These optimistic outcomes suggest that the designed acoustic configurations effectively cater to the requirements of a broadcast studio, providing a high-quality and versatile environment for audiovisual recording.

5. Summary

The technical rooms in radio and television media buildings demand high acoustic performance. Establishing a suitable digital acoustic model for such recording and broadcasting studio building during the early design phase, along with conducting simulation and research, aids in predicting various acoustic scenarios. This significantly reduces maintenance and retrofitting costs later on. By optimizing the digital acoustic model, the precision and efficiency of acoustic design in radio and television media buildings can be greatly enhanced. It will also improve the indoor sound environment, meeting the specific acoustic requirements of the industry. The article emphasizes the crucial role of digital technology in modern architectural design and demonstrates how these technologies can be applied to meet the acoustic needs of specific buildings, achieving better acoustic effects and environmental control.

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