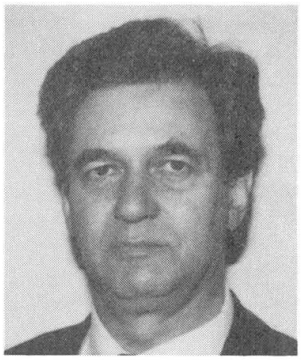
Complex room acoustics analysis methodology for large lecture theatres

Complex Room Acoustics Analysis Methodology for Large Lecture Theatres

Hans-Peter TENNHARDT
Dipl.-Ing.
IEMB
Berlin, Germany



Hans-Peter Tennhardt, born 1942 studied at the Technical University Dresden from 1962 until 1968. Research Scientist and vice head of department at the Building Academy of the GDR, Berlin from 1968 until 1990. From 1991 group leader Room Acoustics at the Frauenhofer Institute of Building Physics. Since 1992 head of Building Physics section at the Institute for Maintenance and Modernisation of Buildings (IEMB e.V.) in Berlin.

Summary

The room acoustical function securing of important concert halls and large auditoriums is tied to the achievement of optimal audibility parameters the realising of which assumes a direct influence upon shape, surface and furnishing of the presentation room. To avoid bad investments and cost intensive remedial works, a quality safeguarding complex-method was developed further, which is based upon fundamental analyses of the primary structure of the auditorium by means of a computer simulation and detail analyses of the secondary structure through a measuring method with the aid of a size reduced model of the interior on the basis of the system theory.

1 Complex room acoustics analysis methodology

The complex analysis methodology for the design of large auditoriums (e.g. concert halls, music and speech theatres, congress centres) determines on the basis of the system theory in advance the room acoustical parameters of an unknown room (black box) with an adequate degree of accuracy. With the room acoustical design of large, high class auditoriums or with rooms of complicated shape (e.g. cylindrical rooms) a combination of two methods for the determination of the room pulse response, the mathematical and the physical model technique is applied. For the principle clarification of questions of the primary structure of the room (basic shape) the for this purpose more efficient computer simulation is applied. The questions of the secondary structure (surface creation, shaping) can with the required accuracy be clarified on the physical model only by means of the metrology.

Comparable objective and subjective analyses in the completed room show that the achieved accuracy of the room acoustics criteria between model and actual room is below the significant threshold of perceptibility.

1.1 Design method of the computer simulation

The methods applied at present are based upon the geometrical room acoustics:
-Image source method:
Each reflected sound ray originates from a secondary sound source which reproduces the image of the original sound source.

-Ray tracing method:
From the position of the original sound source numerous sound particles are reflected which describe the spreading of a sound energy pulse in energy quantum's according to the intended directional characteristic.

- Some methods can allow for diffuse sound reflections, but not the frequency dependent sound refraction.
-The fundamental disadvantages of the above mentioned individual methods have led to the development of efficient combinations.

1.2 Design method of the model metrology (physical model)

The room pulse response is obtained in the reduced interior room model (suitable scale 1:20) of the presentation room by application of the model laws. At the location of the sound source (stage, rostrum, orchestra pit, loudspeaker) a sound pulse is reflected. At the reception positions the acoustical reaction (response) of the room is simultaneously received through an artificial head with ear replica (see fig. 1). Special scale loudspeakers serve as simulations of a speaker or singer, of an orchestra with the instrument groups and as loudspeaker
The analysed frequency range is between 5 kHz to 200 kHz at model scale, i.e. 250 Hz to 10 kHz within the original range.
All physical sound processes like, amongst others, refraction and dispersion are shown frequency true.
The achieved accuracy is at present far above computer accuracy. The methods can answer questions of balance analyses in music presentation rooms, of the electroacoustics and of the directional effect of wall and ceiling textures equally at model scale.

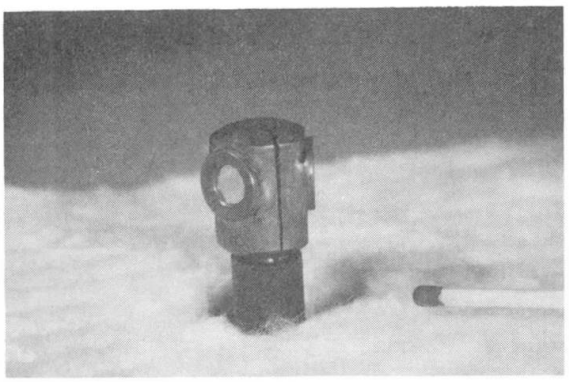


Fig. 1: artificial model head

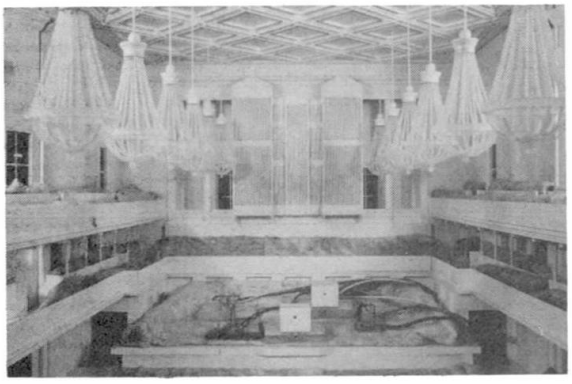


Fig. 2a: model " Konzerthaus Berlin"

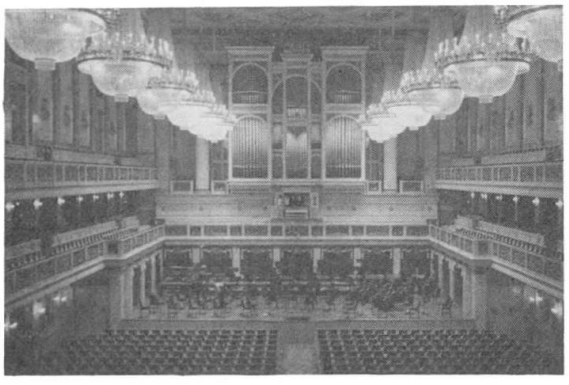


Fig. 2b "Konzerthaus Berlin" large auditorium

2 Auralisation

The binaural and head related room pulse responses obtained from the analyses on the mathematical and physical model can with the aid of music and speech programmes be "folded" and thus facilitate a "listening in" into the in reality not yet existing room. The derivation of building construction changes is not yet altogether possible.