Wagner and Bayreuth Festspielhaus

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The Festspielhaus in Bayreuth is the only opera house of the world which was founded and mostly designed by a composer. It is far away from the typical common theater of the times of 1876. The opera house has a special acoustic situation. Especially the sunken-pit design is subject to endless controversial discussions. In this paper, a 3D modeling as well as EASE simulation is conducted to find out the reasons for the acoustic features of Bayreuth Festspielhaus. The result shows that its acoustical quality well fit the need for Wagner's opera.

Keywords: Wagner, Bayreuth Festspielhaus, Room Acoustics

I. HISTORICAL REVIEW OF WAGNER AND HIS MUSIC

Richard Wagner (1813-1883) is one of the world's most influential and controversial composers of Romantic Era. Among his major works are The Flying Dutchman (1843), Tannhauser (1845), Lohengrin (1850), Tristan und Isolde (1865), Parsifal (1882), and his great tetralogy, The Ring of the Nibelung (1869-76).

His advances in musical language, such as "extreme chromaticism" and "quickly shifting tonal centres"[1], greatly influenced the development of classical music. His compositions, particularly from his later period, are best known for their complexity in textures, richness in harmonies and orchestration, and the elaborately using of leitmotifs[2].

Unlike most opera composers, Wagner wrote both the libretto and the music for each of his stage works. Wagner developed his revolutional concept of the Gesamtkunstwerk ("total work of art"), which means to "synthesise the poetic, visual, musical and dramatic arts, with music subsidiary to drama"[1]. Wagner demonstrated these ideas most fully in his four-opera cycle *Der Ring des Nibelungen* (The Ring of the Nibelung).

A. Der Ring des Nibelungen

Der Ring des Nibelungen is Wagner's 4-opera epic story, a 16-hour grand masterpiece. The massive piece structure, the powerful and beautiful music and the philosophical ideas show its importance in the history of music. Since the entire piece took the composer almost three decades to write, the music gets impressively rich and complex. Wagner tells this long story using a huge orchestra, which he intends to "captivate listeners with magical colors and ingenious storytelling devices"[3].

The four operas which make up the cycle are: Das Rheingold, Die Walkure, Siegfried, and Gotterdamerung. It takes four nights to watch, and the performance of this opera needs super amounts of skill and stamina[4].

FIG. 1. The inner perspective of Bayreuth Festspielhaus.

Wagner envisioned a special opera house created especially to perform *Der Ring des Nibelungen*. That was the Bayreuth Festspielhaus, where the full *Der Ring des Nibelungen* was premiered on August 13, 1876.

II. BEYREUTH FESTSPIELHAUS:

From the premiere of *The Ring of the Nibelung* till today, Bayreuth Festspielhaus remains an ideal place to experience the work of only one composer. It was Wagner's life dream to have his own special theater, where his operas could be performed exactly the way he wanted them to be. The theater is full of unique features designed by Wagner, as well as a close collaboration between the composer and the architect, Otto Bruckwald. It was built to accomplish certain acoustical and social goals, to enhance his operas and create a distinctive experience for the audience.

A. Features of Design

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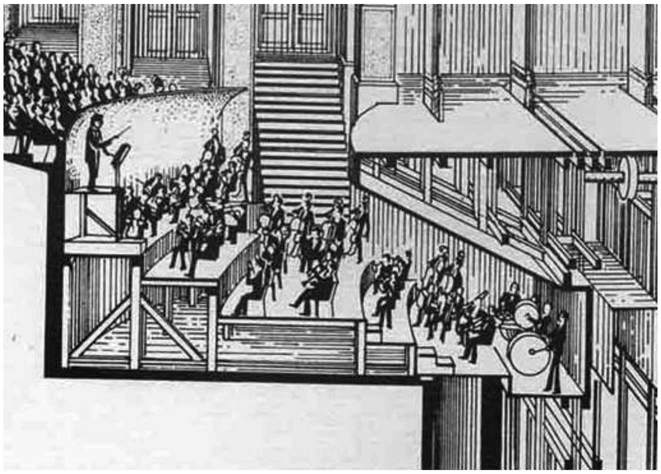

FIG. 2. The design of Wagner orchestra pit.

1. Amphitheater in History

This unique opera house referenced the early Greek and Roman amphitheatres of ancient times. It had amphitheatre seating in a single block with an enveloping stage which combines excellent sight lines and fine acoustic characteristics.

Most Greek and Roman amphitheatres have a circular performing area surrounded by hemispheric seating arcs[6]. To make the actors on stage look more further away like in a magical dream[7], Wagner put another bigger arch around the first proscenium arch (on the sides and above the stage). For him, opera is a spectacular emotional experience and this consideration reinforced his legendary settings.

In "Spartan" theaters of ancient Greece, there are no distinctions between the upper and lower classes. So Wagner had the same at Bayreuth Festspielhaus: there are no boxes or galleries except for the back area on 2nd and 3rd floor like in most theaters, only a wide fan of tiered rows spreading out from the stage. In his innovation of seating arrangement, Wagner fused the boxes with the orchestra seating in a perfect way of resemblance[8].

2. Orchestra Pit Acoustics

The earliest orchestra pit designs for early European opera houses were open or "bathtub" with only a few musicians on a single level pit. It was not until 1870s that Wagner extended the pit below the stage edge in stepped tiers[9]. This changed the former orientation of musicians and vocalists. Wagner buried his orchestra under the stage so as to create an enveloping sound field which he calld "The Mystic Abyss"[6]. The opening between stage and pit where the music floated out was named "mystic chasm"[7].

Wagner put this hidden orchestra on a kind of staircase, with different sections on different vertical levels (Fig.2) so as to make a layered effect from orchestra. The lighter-sounding instruments (strings, flutes) are at the top, while the heavy sounding instruments (tubas, drums) are at the bottom. Combined with the excellent acoustics of the wood building, this design of structure made for a unique and rich orchestral sound[10].

Wagner's breaking through idea also inspired several successful modern pit designs, such as the large "bathtub" style pits in Metropolitan Opera and the "modified Bayreuth" pits in Houston Opera, to name just a few.

B. Evaluations from Critics

Here is an audience's listening tour in Festspielhaus: "The renowned acoustics are indeed amazing, with a distinctive glow of resonance. Voices and diction are quite clear, but warmly embraced and dispersed; the stage house itself seems to add depth and richness to the sound. Thanks to that cove and the steep downward rake of the instrumentalists seating in the pit, the orchestra at first seems to be facing away which it virtually is.This tames and narrows the sound of the brasses, while strings and winds emerge more prominently."[11].

Another comment is from Joseph Wechberg[12]. He said that it is not easy to determine where the sound came from - it might have come from the sides of the auditorium, or the rear, or the ceiling. And he also noted the well blend of the music, the singing and the scene. However, he blamed that the dominated brass did not sound so brassy as it expected to be, and the strings, particularly first violins were "somewhat subdued".

III. 3D MODELING

The whole building consists of a music box, a stage house and a small scale back stage. Compared to other famous theaters, the Festspielhaus is small and plain: an amphitheatrical auditorium with only 1,925 seats. Up to 1500 seats are concentrated in centre box. Other hundreds of seats are distributed in the balcony area on the 2nd and 3rd floor. The auditorium is rectangular but it contains a fan-shaped seating area with the difference being taken up by a series of double columns supported on wing walls. The Sketchup Model is shown in Figure 3. While the structural details are shown in Figure 4.

IV. EASE SIMULATION

A. Project Settings

1. Room Materials

Following Richard Wagner's specifications, its thirty rows of seats are wooden, un-upholstered, and do not

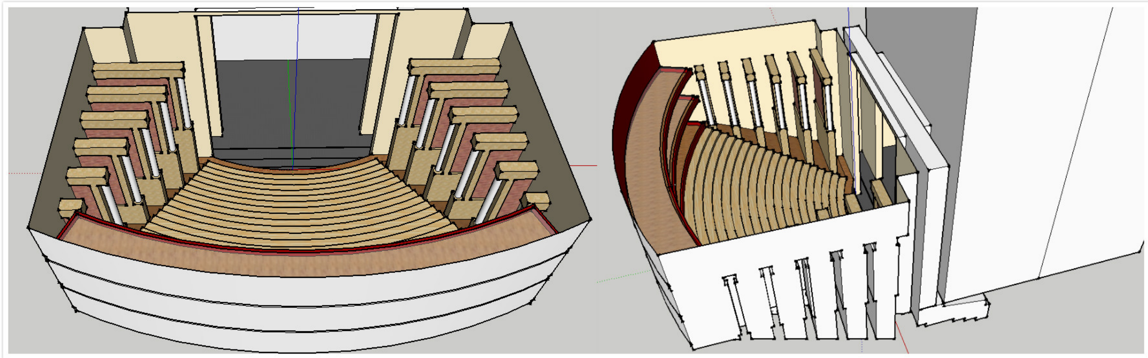

FIG. 3. Sketchup Model from 3rd floor aurience (left) and 3D view (right).

V = 364,000 ft³ (10,308 m³)	S_a = 8,125 ft² (755 m²)	S_A = 9,100 ft² (845 m²)
S_o (pit) = 371 ft² (34.5 m²)	S_P = 1,640 ft² (152 m²)	S_T = 11,111 ft² (1,032 m²)
N = 1,800	V/S_T = 32.8 ft (10 m)	V/S_A = 40 ft (12.2 m)
V/N = 202 ft³ (5.72 m³)	S_A/N = 5.1 ft² (0.47 m²)	H = 42 ft (12.8 m)
W = 109 ft (33.2 m)	L = 106 ft (32.3 m)	D = 111 ft (33.8 m)
H/W = 0.385	L/W = 0.97	ITDG = 14 msec

FIG. 4. Technical detals for 3D modeling (Data from L. Beranek *Concert Halls and Opera Houses, 2nd ed.* Springer-Verlag, New York, 1996).

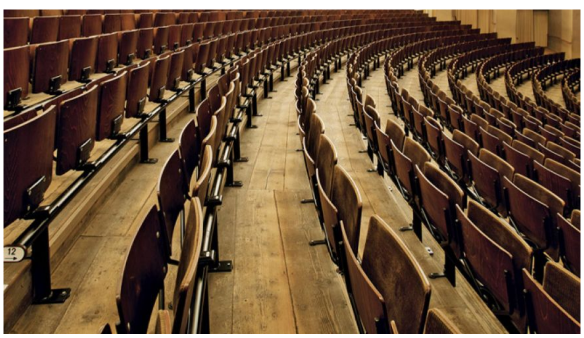

FIG. 5. Wooden rows of seats.

even have arm rests(Fig.5). The floors are also made of wood and, to this day, remain uncovered since the carpeting might absorb the sound and disturb its famous acoustics. The audience seats in wide rows are accessible only from the sides, with very simple low backs and only modest paddings below. Theres no air conditioning either. "In the Wagnerian shrine, art trumps creature comforts"[11]. It is truly a place from another time.

More details are as follows: Ceiling is made of 0.5-in plaster on reeds over 0.5-in wood with wooden carvings used as decorations. Rear and side walls are plaster on brick or wood lath; the round columns and part of their capitals are of thick wood. Seatings: wood with cane bottoms[13].

Figure 6 shows the selected example of wall materials. The upper part shows plastic materials in use, which takes about 31.97% of room surface area. The below part shows wooden materials in use, the blue line represent plain wood floor with low absorption coefficient whild the green line represent for the MTSEAT WOOD which has an absorption rate between 0.2-0.4 at mid-frequency.

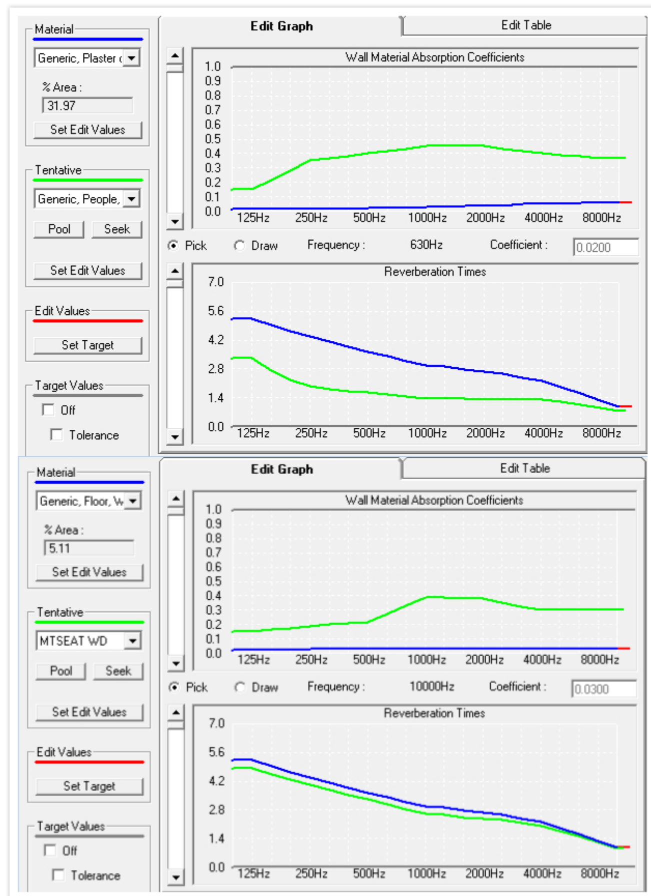

FIG. 6. Main wall materials used for EASE modeling.

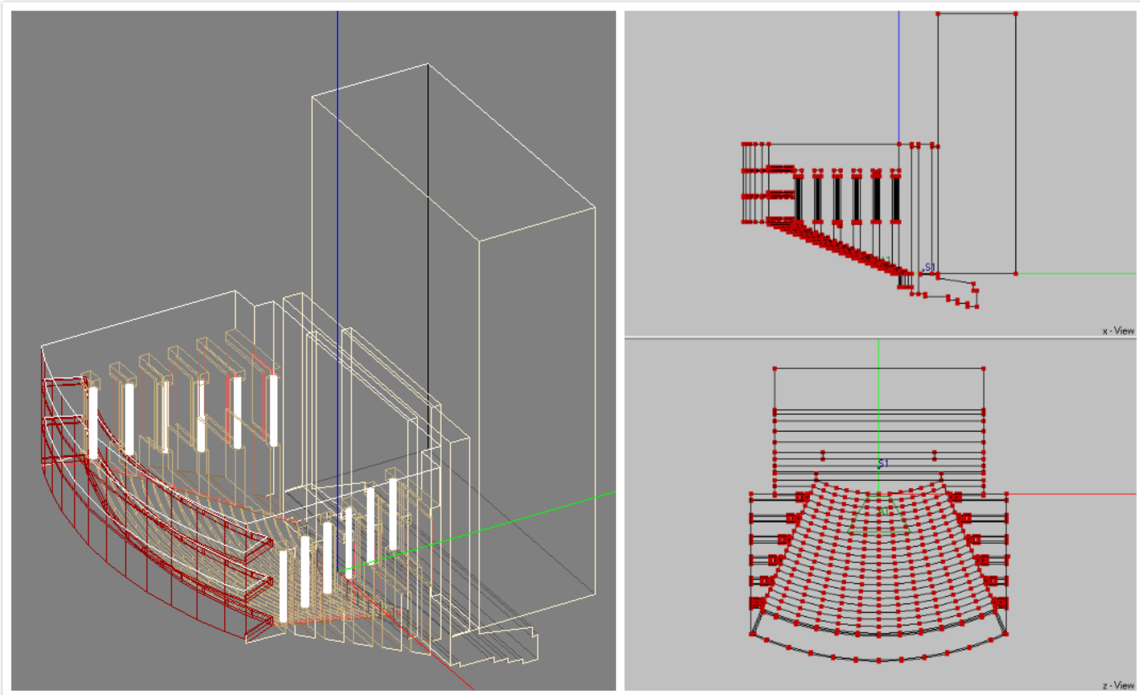

FIG. 7. EASE 3D modeling with listening seat, audience area and loudspeaks.

2. Audience Area and Loudspeakers

Two versions of modeling has been calculated in EASE. The first one is a simpler model only contains necessary structures. While the second one gives more details such as piers, decorations and fences (Fig.7). The audience area was inserted in the centre box that cover most of the fan-shaped area in simple version of model. However, in detailed model, the main audience area reduced to half of that in considering memory capacity. In both models, several selected listening seats are located on 2nd and 3rd floor balconies.

Five loudspeakers (SPX4-94) are inserted in performance area. S1 is 1m right above the center of the opera stage to produce the voice of singers, while the other four loudspeakers all set in orchestra pit for the sound of different part of orchestra.

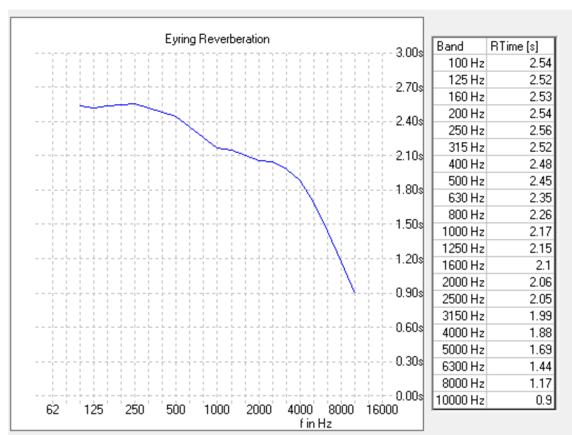

FIG. 8. Reverberation Time for empty auditorium.

B. Acoustical Metrics

In this part, the result calculated in detailed version model is compared to that of the simple model. Also, a comparison between main audience area and 2nd, 3rd floor is conducted.

1. Reverberation Time (RT)

The Eyring reverberation time is shown in Fig.8 For the empty room situation, RT is around 2.5 sec at low frequency, while at mid-frequency between 1kHz to 4kHz, RT is around 2.1 sec. RT is still above 1sec at high-frequency of 8kHz. However, after changing seats into “people occupied”, the room RT reduced 0.2-0.3sec in general.

2. Total Sound Pressure Level (SPL)

The total SPL (Fig.9) is 82.8dB at 250Hz and is around 80dB at 1kHz, 75dB at 4kHz. As for the 2nd and 3rd floor, the total SPL is largely the same at low frequency, however, at middle and high-frequency, the total SPL is

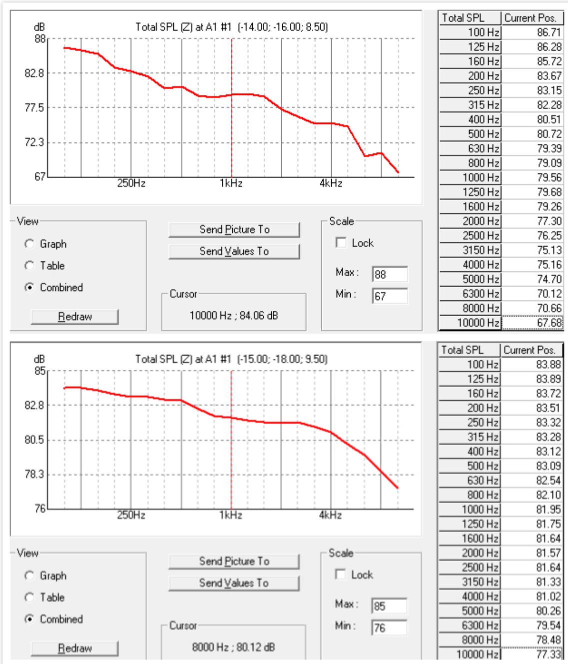

FIG. 9. Comparison of Total SPL between 1st floor (upper) and 2nd, 3rd floor (below).

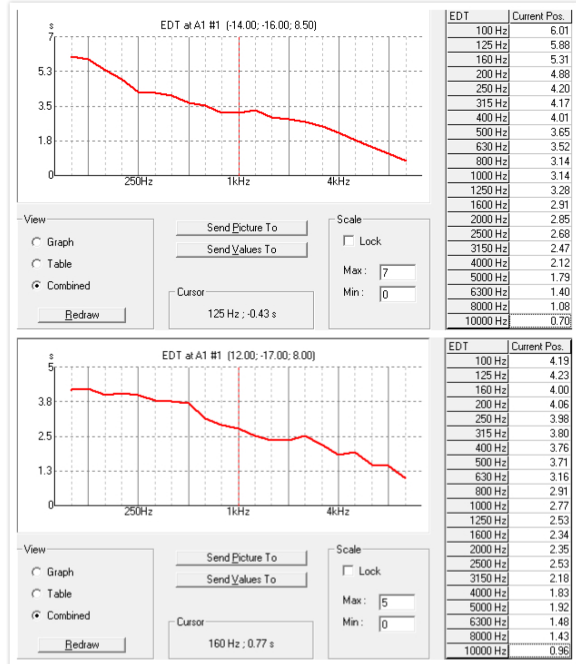

FIG. 10. Comparison of EDT for complete model (upper) and simple model (below).

greater at 2nd and 3rd floor than that in fan-shaped area.

3. Early Decay Time (EDT)

Early Decay Time is also an important room acoustical version of the RT. EDT figures are more related to the subjective RT impression a listener gets in a room. In complete model, the early decay time is around 3.5 sec at mid-frequency and is 1sec at high-frequency of 8kHz (Fig. 10). However, compared to the simple model, this is much longer. It turns out the reflective plastic piers and fences all contribute to the reflections and thus increase the decay time.

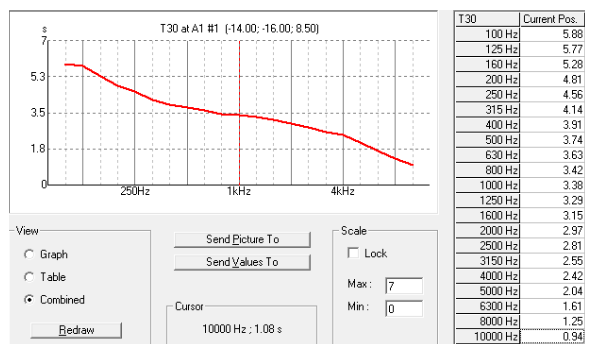

FIG. 11. T30 for main audience area .

4. T Measures

Figure 11 shows an T30 for the first floor main audience area in complete model. The result is similar to that of EDT.

5. Clarity

The C80 curve is shown in Figure 12, where we can notice positive values at all one-third-octave bands with a clear rise at the higher frequencies. Any value above 0 dB in a room with normal reverberation represents good intelligibility. In rooms with higher than normal reverberation, any value above -5 dB is considered good. It is not always desirable to have C80 values as high as possible, because the higher the value of C80 the lower the effect of the diffuse field, whose existence under proper control is needed in many cases of music reproduction.

The comparison shows that the non-decorated room has a more concentrated C80 curves between -3dB to 3dB, while in the complete model, the curve goes from -4dB to 4dB at frequency from 250Hz to 4kHz. It seems that the additional detail of decorations increase the discrimination of clarity.

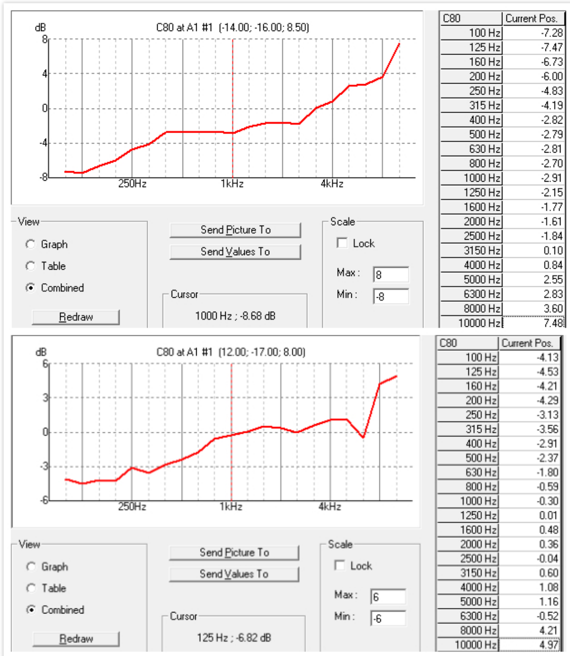

FIG. 12. Camprison of C80 curve between complete model (upper) and simle model (below).

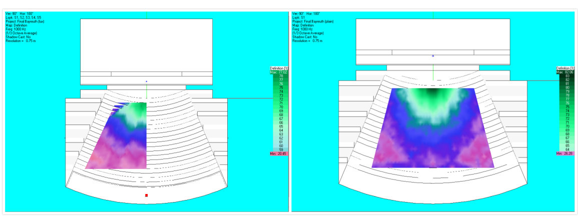

FIG. 13. Camprison of definition between complete model (upper) and simle model (below).

6. 3D Mapping

Definition is one of a number of different energy measures used in room acoustics. It defines what percent the energy in the first 50 ms after the first arrival is of the total energy. For good intelligibility a considerable part of the total energy (more than 50%) should arrive within this first 50 ms period.

3D mapping of definition (1kHz) is shown in Figure 13. The front rows enjoys a greater definition than the back rows. The non-decorated auditorium has a general larger percentage in terms of definition. It shows that additional room reflection faces can give sound a much more mixed feature.

C. Auralization

To make auralization, a ray tracing impact was first calculated in complete version of model (the simple one is skipped in this section). Three listener's seats were respectively selected from the center of fan-shaped main audience area, second floor and third floor, with five loudspeakers all in use. The impact control is set to be 400 ms. To produce a good impact file, the reflection order is set to be 10, with the time frame approximately 500 msec. To make it more accurate, rays per loudspeaker is set to be 20000, which makes an impact chance of 80%.

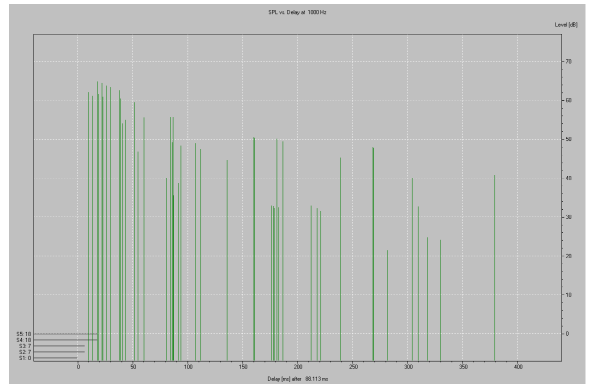

FIG. 14. Time response refelctogram.

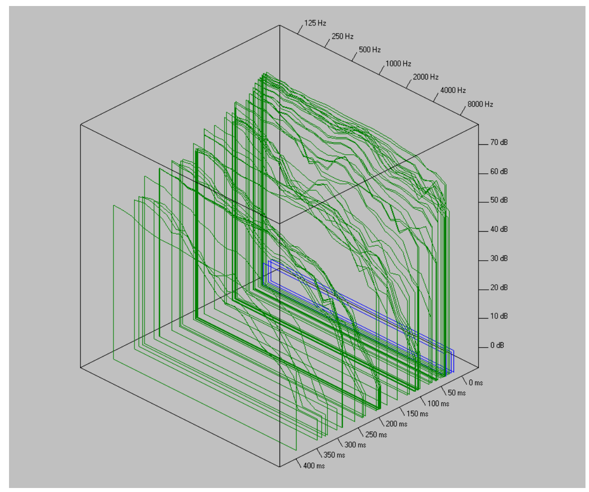

FIG. 15. Time response waterfallgram.

When the simulation is complete, a probe acoustical analysis is conducted. Take the third floor center seat as an example. The calculated time response reflectogram are shown in Figure 14. While Figure 15 is a waterfall display of this time response energy level at different frequency. The result of the calculated impulse response, energy time curve, and frequency response cure shows the impact response of time delay. A peak of impulse response appears during 30-50 msec (Fig.16). The energy time curve shows a 60dB reamining in the first 100 msec and decay during the next 300 msec (Fig.17). Frequency response shows the sound pressure level to be 80dB from 500Hz to 8,000Hz (Fig.18).

Auralization is the process of converting the acoustic and electro-acoustic data generated by EASE into an au-

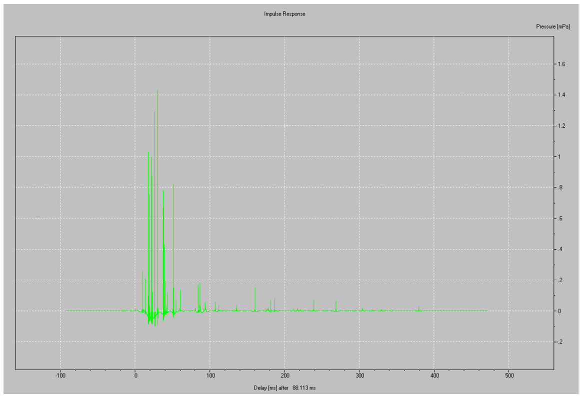

FIG. 16. Impulse Response (IR) display.

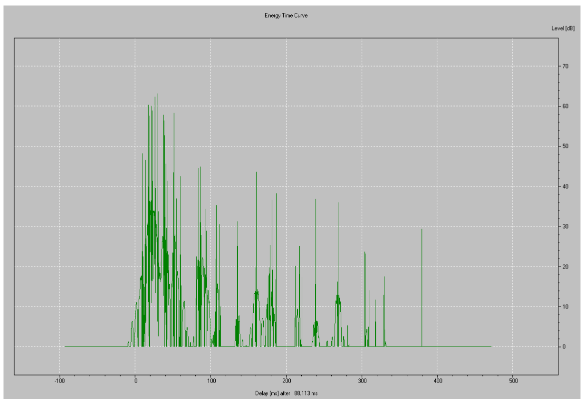

FIG. 17. Energy Time Curve (ETC) display.

dio signal that can be heard and evaluated. It adds subjective listening to the evaluation process. EARS is a binaural auralization program that used to take into accout both the acoustical properties of the room and the hearing characteristics of the human head.

Since the reflectogram has already been created, the next step is to combine the reflectogram with the charateristics of human hearing. This creates the binaural signal used in the final convolution. To make binaural

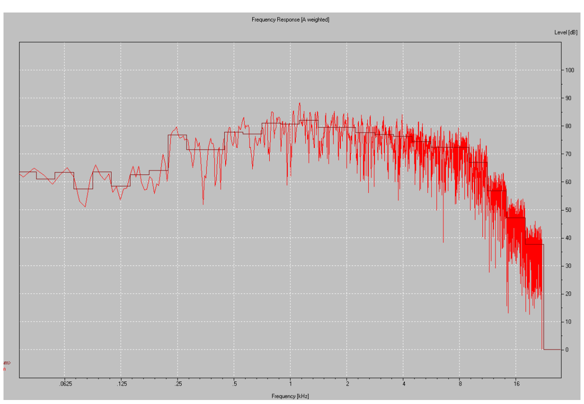

FIG. 18. Frequency Response curse display.

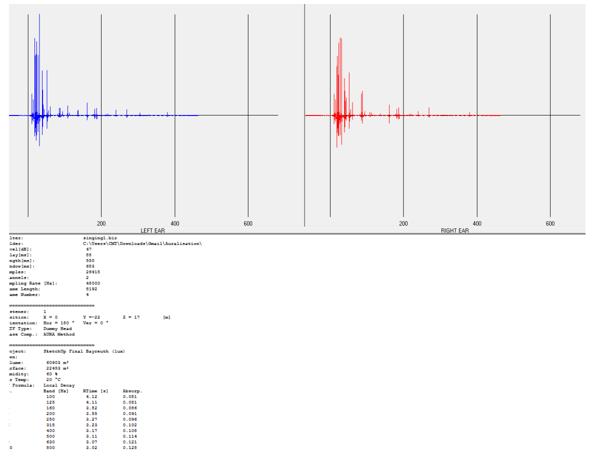

FIG. 19. Binaural response filter for convolution.

response (BIR) file, a head Transfer Function (HRTF)is used to make simulation of a dummy head, and FFT (Fast Fourier Transform) is used for the convolution. When the filter is completed, seperate left and right ear files are shown in Fig.19. In EARS convlover window, the “offline” method is selected to create a file that can be stored and replayed. In this step, a recording of anechoic female opera singing is used as an example.

V. DISCUSSION

The average height of the ceiling above the sloping floor of the Festspielhaus is high enough to make the reverberation time long. It is 2.0 sec at middle frequencies when the theatre is fully occupied, which is especially favourable to Romantic Wagnerian music. The horizontal ceiling contributes short-time-delay reflections at most seats. The projecting wings on the sides of the hall give a desirable mixing of the sound in the house.

The sunken-pit design of orchestra area is controversy. Most conductors love to perform in the Bayreuth pit since its a relatively small space with only a throttle let out sound from orchestra pit. Sound can well blend before coming out from under the opera stage (Fig.20). The configuration of the pit, which was deepened and partially covered, directed some of the orchestral sound back toward the actors. This device may mute the orchestral sound heard by the audience, however, the musicians can thus be alowed to play at full volume out of sight of the audience. It also changed the loudness of the strings with respect to the horns, and improved the balance between the singers and the orchestra[8].

Just as Ned A. Bowman said, “It was the masterful integration of the technology of illusion in the Bayreuth Festspielhaus which was worthy of repetition in hundreds of succeeding theatre buildings throughout the Western World”[14].

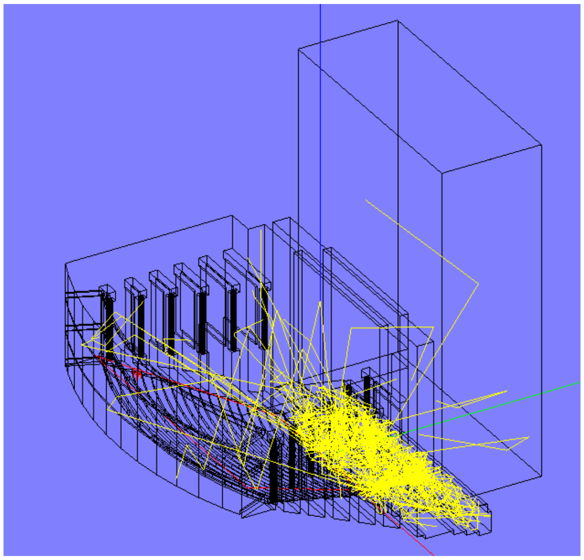

FIG. 20. Ray tracing.

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