ABNORMAL ACOUSTIC PHENOMENA IN A CINEMA HALL WITH A *DOLBY SURROUND* SOUND-RECORDING SYSTM

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ABSTRACT

The maximum sound energy in a reconstructed cinema hall increases by 5 – 7 dB at the frequencies of 125 – 500 Hz. This occurs only in the time interval from 0 to 140 ms. At 1000 – 4000 Hz, the energy increase amounts to 4-8 dB and takes place in the time interval of 0 – 100 ms. This means that abnormal phenomena occurs only under the balcony and only in the initial period of the sound energy decay.

As the hall's absorption increases considerably after reconstruction, an increase and not a decrease in the absolute energy is observed under and in the balcony. The increase depends on frequency and varies in an inverse proportion to the length of the time interval used for measurement of the absolute sound energy. This phenomena, however, does not occur in all rows of the stalls.

1. INTRODUCTION

Spatial sound may be produced in cinema halls due to digital sound reproduction technologies. *Dolby* laboratory has worked out acoustical requirements that are essentially different from those applied earlier. Depending on the hall's volume, reverberation time must be short. Intensive early reflections are to be suppressed and air volume resonances must be eliminated. It is only under such conditions that an electronic system, for which certain requirements are set as well, may operate satisfactorily.

It appeared upon installation of the new system in several cinema halls of the country that the sound level is too high at all seats in the hall, especially when the speech or music is loud. The purpose of investigation is to determine changes in a cinema hall's acoustics after reconstruction.

2. CHARACTERISTICS OF THE HALL

The investigation was carried out in a hall 24.5 m long (stalls), or 28.3 m including the balcony. The height of the hall at the screen is 9.5 m. The depth of the balcony is 7.4 m, the maximum height is 5 m. The ceiling has been divided into 6 planes, which are inclined by about 10° in relation to the horizontal line. The volume of the hall is 3306 m^3. Fig. 1 shows the layout and the cross section of the hall.
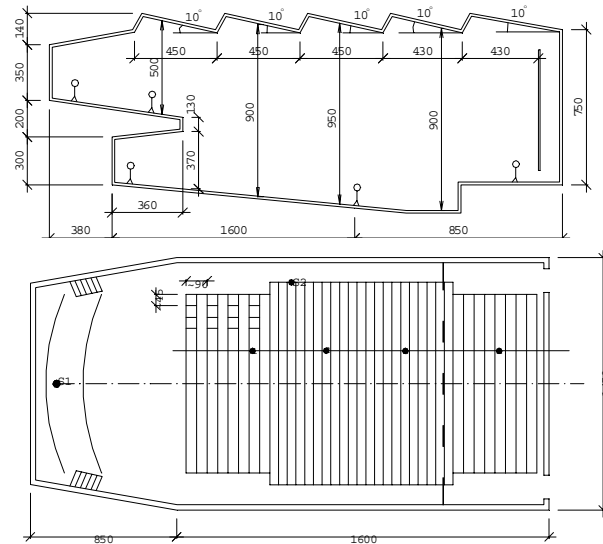

Fig. 1. Layout and longitudinal cross section of the hall showing the placement of measurement points.

Prior to reconstruction the lateral walls and back wall of the hall were covered with *Akmigran* slabs affixed directly to the wall without an air gap. The slab absorption coefficients are 0.05 and 0.15 at low frequencies 125 and 250 Hz. At medium and high frequencies, sound absorption increases, with the coefficients equal to 0.25 and 0.75. The ceiling of the hall is made of wood shaving slabs 20 mm thick, with the absorption coefficient equal to approx. 0.25 at 125 Hz and to approx. 0.1 at medium and high frequencies. The hall has wooden floor. The chairs are semi-upholstered; the hall with the balcony has 630 seats in all.

New and much more effective sound-absorbing materials with the sound absorption coefficients of 0.4 to 0.8 were used for reconstruction. These materials cover the ceiling, the back and the lateral walls entirely. The floor is covered with carpeting and all chairs are upholstered.

3. RESULTS OF INVESTIGATION INTO REVERBERATION TIME

Dolby laboratory has formulated requirements for reverberation time linked to the hall's volume and stating maximum/minimum reverberation time values [1]. It is believed that the sound of music will be good upon installation of the Dolby system if the reverberation time values do not exceed the set values throughout the frequency range. Measurements of reverberation time were carried out in accordance with the set requirements [2, 3, 4].

It has been established by investigations that, before reconstruction, the early reverberation time T_{10} greatly exceeded the upper limit value at 63-500 Hz. This is because the Akmigran slabs are poor sound absorbers at low frequencies.

After reconstruction of the hall the early reverberation time T_{10} does not exceed the upper limit value in all rows of the stalls and the balcony, except for the frequency range of 250-1000 Hz, where it is shorter than the lower limit value. However, Dolby laboratory allows increasing the upper value and reducing the lower value.

Fig. 2 depicts the values of reverberation time in the hall before the reconstruction where the sound field decay is approximated from 0 to –30dB. The adopted decay values are 0 to – 15 dB at 63 Hz and 0 to – 20 dB at 125 Hz. This is because the signal/noise ratio is insufficient at these frequencies [2,3,4].
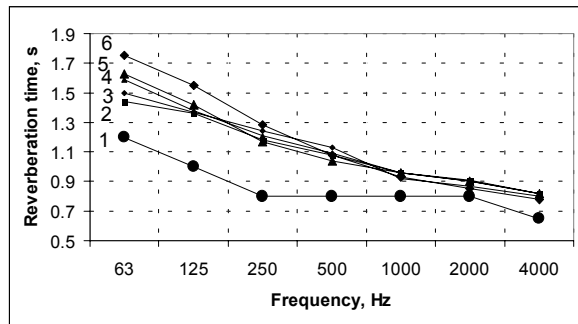

Fig. 2. Dependence of reverberation time T_{10} on frequency and measurement point. Hall before reconstruction. 1 – upper limit value; 2 – under the balcony; 3,4,5,6 – in the stalls and in the balcony.

Before reconstruc6tion of the hall, the values of reverberation time T_{30} are much higher that permitted, particularly at low and medium frequencies, because the surfaces are covered with sound-absorbing materials with poor acoustic properties.
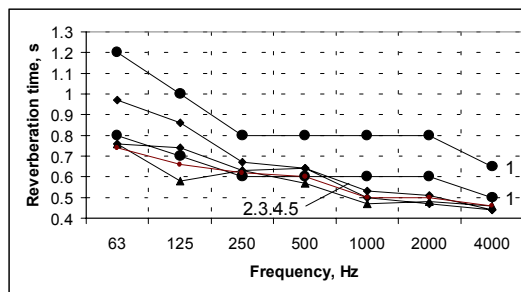

Fig. 3. Dependence of reverberation time T_{30} on frequency and measurement point. Hall after reconstruction. 1 – lower and upper limit values; 2 – under the balcony; 3,4,5,6 – in the stalls and in the balcony.

These results show that the reverberation time was reduced considerably through the use of new effective sound-absorbing materials. It does not exceed the maximum values at any frequencies. At 125, 1000 and 2000 Hz the reverberation time values are slightly smaller than recommended, however, the difference is not significant.

4. CHARACTERISTIC FEATURES OF DECAY OF SOUND FIELD ENERGY

A decreasing sound field may indicate what processes take place in the hall at various moments of time. Fig. 4 shows the sound field decay in the stalls and in the balcony.
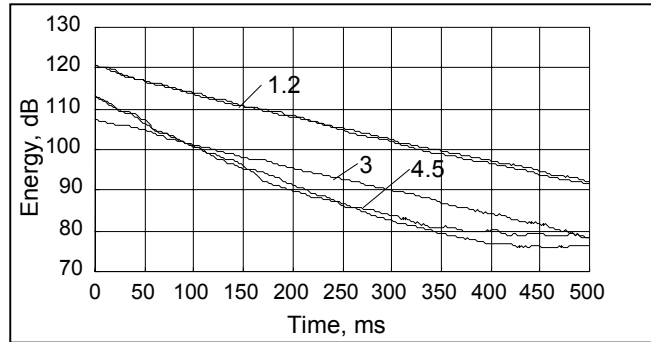
Fig. 4. Decay of sound field energy in the stalls and balcony of a cinema hall. Hall before reconstruction: 1,2 – in the stalls at the distance of 14 m and 17 m from the sound source; 3 – in the balcony 23 m from the sound source. Hall after reconstruction: 4,5 – in the balcony 23 m and 26 m from the sound source.

Before the reconstruction, the energy decay in the middle of the stalls is uniform over the first 500 ms. The same trend is observed in the balcony but the field is less energetic by approx. 12 dB as compared with the stalls. A different situation is seen in the balcony after reconstruction. In the initial period of energy decay, the field is more energetic during the first 70 ms as compared with the decay before the reconstruction. One would expect a contrary result because during reconstruction all the surfaces in the hall were covered with sound-absorbing materials. The decay of energy in the early period at 125 Hz is depicted in Fig. 5.
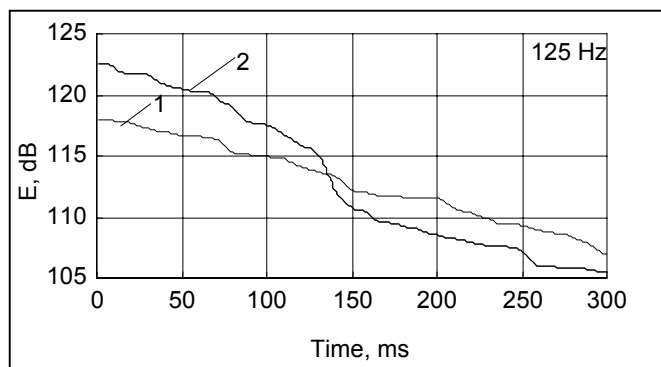

Fig. 5. Dependence of the sound field decay on time and on changes in the hall's acoustics. Balcony, 4th row. Frequency 125 Hz. 1 – before reconstruction, 2 – after reconstruction.

At 63 Hz, the maximum sound field after reconstruction (i.e. upon increase in overall hall absorption) is more energetic by 10 dB compared with the situation before reconstruction, though the result should be inverse. Similar results are obtained under the balcony, whereas in the stalls there is an energy decrease upon increase in absorption. The same tendency is observed at other frequencies as well.

At 125, 250 and 500 Hz, there is a 5-7 dB increase in the maximum energy after reconstruction, within the time interval from 0 to 120-140 ms. At 1000 and 2000 Hz, the increase amounts to 4-5 dB and takes place before 50 ms. At 4000 Hz, the increase amounts to 7-8 dB before 100 ms.

These results show that the abnormal phenomenon is only observed under and in the balcony in the initial period of decay that occupies the time interval up to 140 ms. Early reflections prevail in this interval. It is difficult to explain, however, why the early reflections are more energetic when the surfaces are covered with more effective sound-absorbing materials. One

may suppose that this results from the interaction between the volume of the balcony with the rest volume of the hall.

Analysing of absolute energy may be useful for this purpose. The change in absolute energy for an unfiltered signal is shown in Fig. 6.
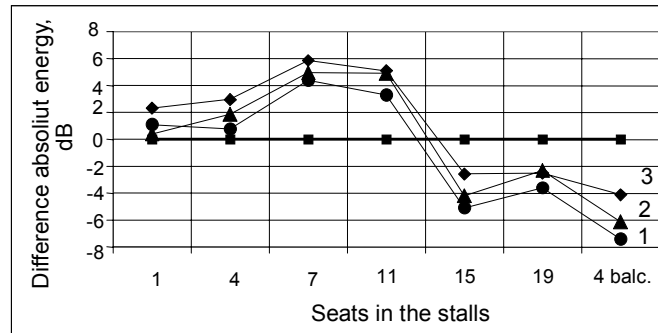

Fig. 6. Dependence of differences in absolute energy of an unfiltered signal before and after the hall's reconstruction upon time interval and distance to the sound source. 1 – time interval from 0 to 50 ms; 2 – from 0 to 100 ms; 3 – from 0 to 200 ms. Negative values mean an energy increase.

Fig. 6 shows that, along with the increase in the time interval under consideration, the difference in absolute energy before and after reconstruction increases too. In the time interval from 0 to 50 ms, the difference is just 1 dB in the first rows and 4-6 dB in the middle rows. An increase in energy by 4-8 dB is even observed under and in the balcony after reconstruction. As sound absorption is increased considerably due to reconstruction, there should be a decrease, and not an increase, in absolute energy – just as in the stalls.
Fig. 7 depicts the frequency dependence of changes in absolute energy in the 18th row of the stalls under the balcony.
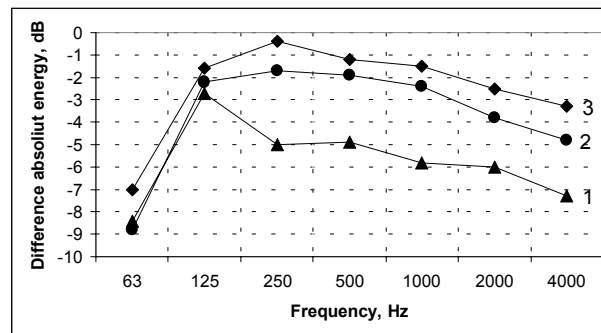

Fig. 7. Dependence of differences in absolute energy before and after the hall's reconstruction upon frequency and time interval. Measured at the 18th row under the balcony. 1 – time interval from 0 to 50 ms; 2 – from 0 to 100 ms; 3 – from 0 to 200 ms.

As the overall sound absorption in the hall increases, an increase in absolute energy at the back row of the stalls under the balcony is observed; it is inversely proportionate to the length of the time interval used for the assessment of the sound field decay. In the time interval from 0 to 50 ms, there is a 9 dB increase in absolute energy at 63 Hz, and a 5-7 dB increase at 250 – 4000 Hz. The longer the time interval, the smaller the increase in absolute energy upon increase in the overall hall absorption.

The frequency dependence of changes in absolute energy at the 4th row of the balcony is shown in Fig. 8.
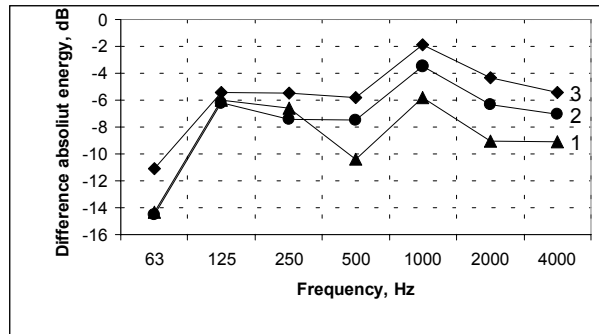
Fig. 8. Dependence of differences in absolute energy before and after the hall's reconstruction upon frequency and time interval. Measured at the 4th row of the balcony. 1 – time interval from 0 to 50 ms; 2 – from 0 to 100 ms; 3 – from 0 to 200 ms.

The results are similar to those obtained in the 18th row under the balcony. In all cases, there is an increase in the absolute energy throughout the frequency range in inverse proportion to the length of the time interval. At 63 Hz, the increase amounts to 11-15 dB and in the frequency range of 125-4000 to 8-10 dB.

CONCLUSIONS

1. After reconstruction of the hall both early and standard reverberation times are reduced throughout the hall.

2. Before reconstruction, the values of the early sound energy of an unfiltered signal are larger in the stalls than in the balcony. After reconstruction, when sound absorption of the hall is much larger, the values of the maximum energy under and in the balcony are larger than in the stalls. As the overall hall absorption increases throughout the frequency spectrum from 63 to 4000 H, up to 50-250 ms the sound field is more energetic under and in the balcony compared with the stalls, whereas an opposite situation was observed in the hall before reconstruction.

3. After a considerable increase in the hall's overall sound absorption due to reconstruction, an increase in the absolute energy under and in the balcony is seen, though one should expect a decrease. The increase depends on frequency and is inversely proportionate to the time interval used for the assessment of absolute sound energy. However, an opposite phenomenon is observed at all the rows of the stalls: the absolute energy decreases upon increase in the hall's overall sound absorption.

REFERENCES

1. Dolby stereo. Technical Guidelines for Dolby Srereo Theatres, 1994, 67p.

2. ICO 3382:1997(E). Acoustics – Measurement of the reverberation time of rooms with reference to other acoustical parameters.

3. W. T. Chu. Comparison of reverberation measurements using Schroeder'spulse method and decay-curve averaging method. // J. Acoust. Soc. America, 63 (5), May 1978.

4. M.R. Schroeder. New method of measuring reverberation time // J. Acoust. Soc. Amer. 1965, – v. 37, – No 3, p. 409-412.