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ACOUSTIC TREATMENT OF SMALL SPACES

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Abstract: *Reduction in size of devices used for recording, processing and reproduction of audio information has encouraged and increased the use of acoustically small spaces to perform these actions. This paper presents the disadvantages of small spaces in acoustical terms, as well as parameters one should pay attention to when defining the shape, the dimensions and ways of acoustic treatment of such spaces. At the end, measurement results of acoustical parametrs are shown for two rooms during various phases of acoustic treatment.*

1. INTRODUCTION

The quality of sound to be listened in spaces ment for sound reproduction, e.g. control, editing and listening rooms, is determined with the quality of electronic part of the audio system and acoustical characteristics of the listening space itself. Furthermore, tone balance and sound colour may depend greatly on the positions of the loudspeaker(s) and the listener(s). The main cause of this phenomenon are the oscillating modes of the room. These modes depend on the dimensions, the shape and the acoustic treatment of a given space. Oscillating modes exist in all frequency ranges, but they can most easily be noticed at low frequencies, at which they are the most distinct. If the room is rectangular and of dimensions L_x, L_y and L_z, then the frequencies of the oscillating modes can be calculated as:

$$f = \frac{c}{2}\sqrt{\left(\frac{l}{L_x}\right)^2 + \left(\frac{m}{L_y}\right)^2 + \left(\frac{n}{L_z}\right)^2} \qquad (1)$$

where c is the velocity of sound and l, m and n are non-negative integers.

Large number of modes at middle and high frequencies creates a uniform mode distribution over frequency, so the influence of modes is not as great as at low frequencies. The critical frequency f_c, below which the oscillating modes in the room become dominant and affect the sound distribution in the room, is determined with reverberation time RT_{60} and room volume V:

$$f_c = 2000 \cdot \sqrt{\frac{RT_{60}}{V}} \qquad (2)$$

On the other hand, diffuse sound field becomes dominant in the room above the critical frequency, i.e. a statistical model of the sound field can be used for analysis.

2. ROOM DIMENSIONS

Both the calculations and the measurements in realized spaces have shown that optimal ratios of room dimensions have to be determined rather than absolute values of dimensions, in order to achieve uniform mode distribution. The belief that the optimal dimension ratio is 2:3:5 has been strong for a long time. However, the work of numerous authors over the last 60 years shows that this ratio is only one of the optimal ones.

Various authors have used different criteria in order to determine optimal dimension ratios. Therefore, the conditions set to determine these ratios are also different. Bolt [1] was one of the first to have concluded that there are many different dimension ratios $L_x : L_y : L_z$ which result with a uniform mode distribution. Gilford [2] has assumed the bandwidth of influence for each mode to be 20 Hz, as the criterion of uniform distribution. Bonello [3] has set a criterion for optimal dimension ratio which could easily be checked. He simply counted the number of modes in each ⅓-octave band. The conditions were that the number of modes in a given ⅓-octave band must not be smaller than the number of modes in a lower neighboring ⅓-octave band and that multiple modes are permitted only in ⅓-octave bands with 5 or more modes. Walker [4] has used the criterion of equal spacing between modes as a starting point. All these approaches have used a rectangular room with hard, acoustically untreated surfaces as a model. However, acoustic impedance of treated surfaces changes the frequencies of the modes, so the papers listed above can be used as a solid starting point, but corrections must be made regarding other acoustical parameters of a given space. Cox et al. [5] have presented a model which takes into account the positions of loudspeakers and listeners when determining the optimal dimension ratio.

3. EXAMPLES

In the introductory part of this paper it has been stressed that we will be dealing with treatment of acoustically small spaces. In compliance with recommendations of several radio-broadcasting organizations [6], it has been established that acoustically small spaces have minimal ground area of 20 m^2. Nowadays, private commercial production houses often tend to convert auxiliary technological spaces into acoustically suitable spaces by means of acoustic treatment, in order to achieve satisfactory listening conditions in a given space for a given purpose. In most cases, these spaces are ment to serve as control or editing rooms for video production, so the audio recording is not the only final product. The demands on these spaces are somewhat lenient, since they will be used for recording of speech.
Example 1 shows a studio and a control room intended for synchronization of titles in video distribution. The available ground area for both rooms was only 15 m^2 (Fig 1).

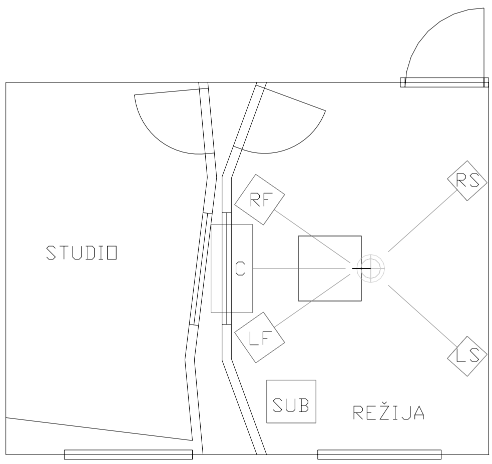

Fig.1. Ground plan of the studio and the production room

Additional sound insulation has been implemented in the existing space using gypsum-cardboard panels. With regards to the defined height, the remaining two dimensions of the studio have been chosen to comply to optimal dimension ratios stated in the recent literature [5].

The remaining space has been used to form the production room and has been shaped with two independent dry-mounted walls made of gypsum-cardboard panels. The shape of the production room has been formed to suit the existing equipment in the possession of the investor. Room dimensions obtained in this manner do not comply to optimal dimension ratios stated above. The TDS diagram of the sound pressure in the production room before acoustic treatment was implemented is shown in Fig.2.

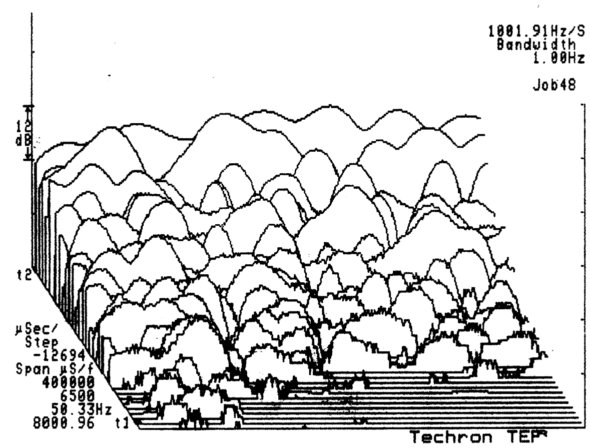

Fig.2. TDS diagram recorded in the production room prior to acoustic treatment

Apart from too long reverberation in the room (RT_{60} = 0,8 s in the octave band around 500 Hz), the round-off at frequencies correspondent to room modes can clearly be seen in the diagram. The influence of room modes can also be seen on the frequency characteristic of the direct sound (line marked with t2).

The goals of acoustic treatment were: 1. to reduce reverberation time down to 0,25 s in the octave band around 500 Hz, and 2. to reduce the influence of room modes, thereby achieving uniform frequency distribution of sound at the position of the tonmeister. This acoustic solution has implemented diffuse elements at the back side of the production room. The elements themselves have been realized as QRD diffusors. The intended lower limiting frequency of the elements was set to 800 Hz, which actually enables the diffuse effect to be achieved at frequencies strating from 500 Hz.

The result of TDS measurement taken in acoustically treated production room is shown in Fig.3. It is clear that sound decay is uniform at all frequencies and the frequency distribution of the direct sound at the position of the tonmeister is also uniform. Thorough check of ETC data at the same position has revealed that early reflections within the first 50 ms are suppressed by 12 dB or more, which complies to the demands for reflection-free zone.

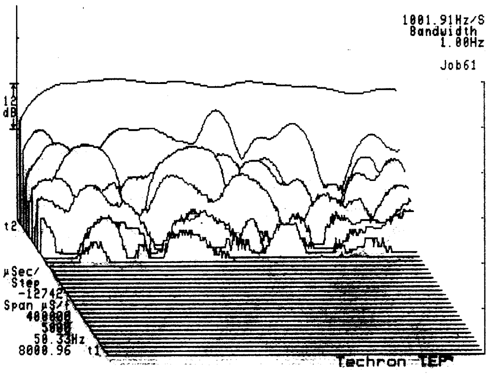

Fig.3. TDS diagram recorded in the production room after acoustic treatment

Example 2 shows an editing room with a ground area of only 10 m^2, used for recording of announcements and supporting text for finalized video clips. The editing room itself is very specific, because the position of electronic equipment is conditioned with the position of the window between the editing room and the speaker studio and the position of air-conditioning devices and doors. The size of the room did not allow the diffuse elements to be put into it, so the only possible way to achieve a diffuse sound field was to set the listening axis along the diagonal of the room. For this reason, the positions of the loudspeakers in the room were modified in relation to the original solution suggested by the investor (Fig.4).

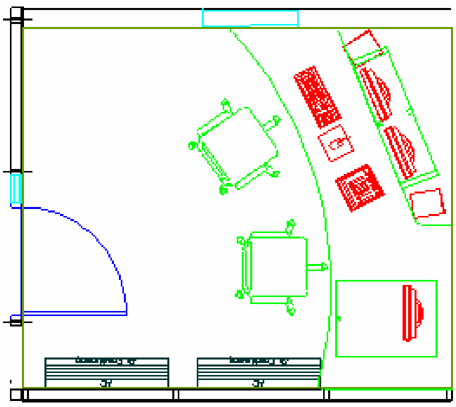

Fig.4. Ground plan of the editing room

Major part of acoustic treatment has been realized by hanging the absorption elements on the walls and putting bass-traps in the corners for low-frequency absorption. Additional low-frequency absorption has been achieved by means of a perforated ceiling. The ceiling was constructed to be the lowest at the line representing the listening axis (ground plan diagonal) and to rise towards the walls with a slope of 10°.
Upon the completion of acoustic treatment, actual measurements were taken. The resulting TDS diagram is show in Fig.5. It shows that there are no major modal oscillations in the treated space. The reverberation time in the octave band around 500 Hz has been reduced to 0,25 s. Mean reverberation time for a frequency band from 200 Hz - 2,5 kHz equals 0,23 s and meets the condition that $RT60_{200\text{-}2k5} = 0{,}2 \pm 0{,}05$ s. Even in acoustic conditions as unfavourable as these, the early reflections were suppressed by 12 dB or more by implementing proper acoustic treatment and placement of the loudspeakers.

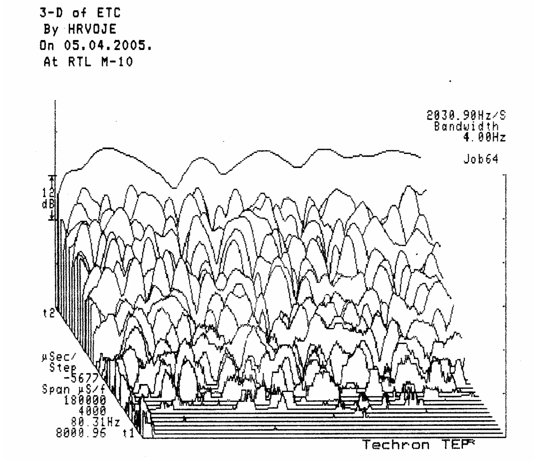

Fig.5. TDS diagram recorded in the editing room after acoustic treatment

CONCLUSION

Acoustical properties of small spaces are determined with modal frequencies and the positions of loudspeaker(s) and listener(s). The goal of acoustic treatment is to suppress the influence of the listening space on the quality of sound listened to in that space, i.e. the sound image of the recording. The selected examples show that acceptable acoustic conditions for less demanding audio processing can be achieved even when starting conditions are very bad.

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