Investigation of acoustical properties for a studio designed by Békésy

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ABSTRACT - The paper describes the investigation of a studio designed by Békésy. The studio which was inaugurated in 1935 is still the rehearsal room for the Symphony Orchestra of the Hungarian Radio and one of the frequently used studio for sound recordings. Besides measured reverberation time - which is the classical room acoustic parameter - more newer parameters were investigated. These new specified parameters like Centre Time, Clarity and Early Decay Time correspond to the subjective investigations and there are more sophisticated. The results of the acoustical measurements are presented and compared with the predicted values.

1. Introduction

In the field of concert hall acoustics intense research activity in recent years has resulted some consensus regarding what aspects are important in listeners' perception of room acoustic quality, and how these aspects can be measured objectively by means of room acoustic parameters.

Although these studies were not extended in studio acoustics the considerations, methods and results can be used for investigations of studios too.

However the perception of sound in studios and generally in rooms has been of interest for many years, the interaction between the objective parameters and subjective sensation is still not well understood.

The investigation of an existing studio can assist to obtain an evaluation of the room acoustic properties of the studio, to derive of certain relationship between the room acoustical parameters and subjective side .

The studio has been investigated was designed by Békésy and it was inaugurated in 1935.

2. The studio

The classical music studio besides recordings is used as a rehearsal room for the Symphony Orchestra of the Hungarian Radio.

The average of studio wall sizes: 19×16.2×7.2 m, area: 300m^2 , volume: 2160 m^3 (Fig. 1).

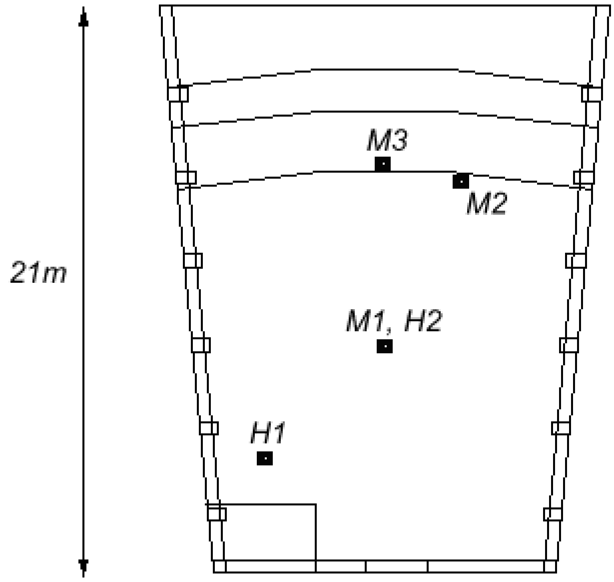

Figure 1. Floor plan of the studio

The aim of the acoustician was to design a room with required subjective quality. To find the objective parameters corresponding to subjective judgement is one of the most difficult part of the work.

Békésy made strenuous efforts to find the optimal value of the reverberation time (RT). At that time the reverberation time was the only one objective parameter which could be calculated and measured. The reverberation time was defined by Sabine [1] as the time for the -60dB attenuation of the received energy.

In his work Békésy changed step by step the reverberation time of the studio and with subjective investigations adjusted the desired time. The subjects participating in the experiments were musicians, teachers of music, experts of Radio and music fans. Békésy first illustrated the reverberant and the very damped condition of the room to observe the phenomenon. Changing the absorbing cover of the walls the listeners had to find the most favourable reverberation time.

The results of his work was published in 1936 [2]. Figure 2. shows the optimal reverberation time adjusted by Békésy.

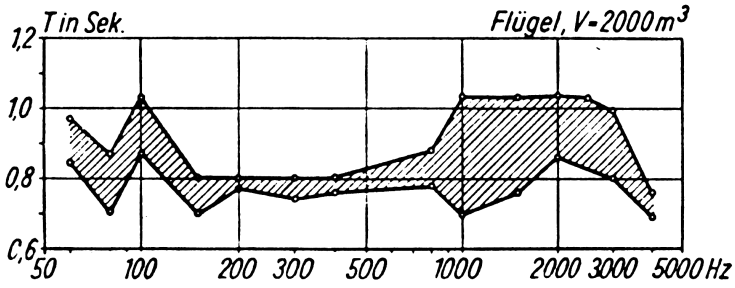

Figure 2. Reverberation time adjusted by Békésy

3. Measured objective parameters

Although the reverberation time is one of most important criterion for designing a room acoustically, more objective parameters are needed to qualify the acoustical space in a room. In the field of concert hall acoustics several new parameters are used to characterise the halls.

These parameters are evaluated on the basis of impulse response measurements. However the optimal value of these parameters are not still well established for the different type of halls and studios, with investigation of them we can assist to obtain the evaluation of the acoustical properties of the studio. By evaluation the results the modelling work can be developed.

The parameters were measured using MLSSA system and all parameters were evaluated on he basis of impulse response measurements. In the formulae $E(t_1,t_2)$ denotes the energy within the time limits t_1 to t_2 of the impulse response p(t), counted from the time of arrival of the direct sound:

$$E(t_1,t_2) = \int_{t_1}^{t_2} p^2(t)dt \tag{1}$$

The objective parameters measured are the followings: Reverberation Time, Early Decay Time, Centre Time, Clarity, Support.

3.1. Reverberation Time, RT

According to Schroeder [3], the reverberation decay R(t) can be calculated from the impulse response. According to the standards the interval in our evaluation is -5dB and -35dB, and the results are averaged for the 5 positions.

The measured values are shown in Fig. 3, and the mean value is $RT_M = 0.93$ sec.

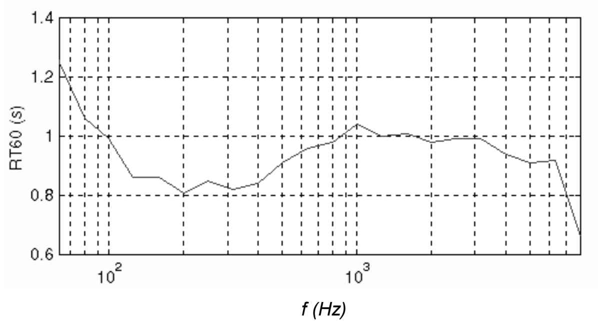

Figure 3. Measured reverberation time of the studio

Comparing the reverberation time measured today with the reverberation time adjusted in 1935, a great correspondence can be found.

3.2. Early Decay Time, EDT

EDT is a newer measure of reverberation time [4], taking into account the subjective importance of the early part of the reverberation process by only looking at the slope of the R(t) curve during the first 10dB interval of the decay.

The measured mean value: EDT=0.82sec

About the optimal value of the EDT can be proved that a high EDT value indicates much reverberance/low clarity and vice versa.

3.3. Centre Time, ts

The ts is the time counted in milliseconds corresponding to the point of gravity of the squared impulse response [5]

$$t_S = 1000 \cdot \frac{\int_0^\infty t \cdot p^2(t)dt}{\int_0^\infty p^2(t)dt} [m\sec] \tag{2}$$

A low value means that most of energy arrives early - whereby it adds to the clarity of the sound - while a high value means that it arrives long after the direct sound - and so provides reverberance. The t_S is very highly correlated with EDT.

3.4 Clarity, C

C is defined as the ratio in dB between the energy of the impulse response before a certain time (i.e. the direct sound plus early reflections) and the energy of the later part after the indicated time.

$$C(t) = 10 \cdot \log \frac{E(0,t_1)}{E(t_1,\infty)} [dB] \tag{3}$$

For concert halls the usual time interval is 80 ms. In smaller rooms the appropriate time-interval could be smaller. Evaluating the results in this study the C was calculated for t_l=80ms and 40ms.

3.4. Support, ST1, ST2

In concert halls ST_1 and ST_2 are used as platform parameter. ST describes the ratio between the early reflection energy sent back to the platform and the energy of the direct sound in dB.

$$ST1 = 10 \cdot \log \frac{E(20,100ms)}{E(0,10ms)} [dB] \tag{4}$$

$$ST2 = 10 \cdot \log \frac{E(20,200ms)}{E(0,10ms)} [dB] \tag{5}$$

ST_1 is suggested for measurement of musicians' possibility to hear each other on the orchestra platform.

ST_2 has been found to correlate well with musicians' general judgement on acoustic quality and feeling of support, i.e. the degree to which the reflections from the room assist the sound created by the musicians own instrument.

For both parameters high values indicate good conditions with much reflected sound.

4. Evaluation of the measured results

In the different position measured results for t_s, C, ST_1 and ST_2 are given in Table 1. (h1,m1)… (h2,m2) are the different measurement positions, indicated in Fig.1.

	t_s	C_{40}	C_{80}	ST1	ST2
h1,m1	33,8	5.7	8.88	-2.54	-1.31
h1,m2	42.1	7.6	10.52	2.01	3.1
h1,m3	64.6	3.46	6.57	3.6	5.06
h2,m3	34.9	7.5	10.4	2.29	3.34
h2,m2	48.4	5.6	8.83	3.54	4.75

Table 1: Measured objective parameters

Emphasising the fact that the objective parameters listed above were measured and calculated in different works only for concert halls, it is not surprising that these values show deviation from the excepted results.

To find the optimal values of the new objective parameters for different type of studios several subjective tests have to be carried out.

5. Conclusions

By introducing new objective parameters to qualify the acoustical parameters of a room more possibilities are given to predict the acoustical behaviour of the studios.
To find the optimal values of the objective parameters extensive research work is needed.

References

[1] W.C. Sabine, “Architectural Acoustics”, Eng. Rec., 38:520-522 (1898)

[2] G. v. Békésy, “Sur La Reverberation Optimum des Petites Salles”, Revue D’Acoustique , Vol.V. , 145-182 (1936)

[3] M.R. Schroeder, “New method of measuring reverberation time”, L.Acoust. Soc. Am. Vol.37., p. 409 (1965)

[4] M. Barron, L. Lee, “Energy Relations in Concert Auditoriums” J. Acoust. Soc, Am, V. 84 , p. 618 (1988)

[5] A.C. Gade , “Acoustical Survey of Eleven European Concert Halls” TUD Report. No.44. (1989)

[6] É. Arató-Borsi, T. Póth, A.T. Fürjes: “Room Acoustic Evaluation of Small Rooms” 16th ICA , Seattle USA (1998)

[7] A.T Fürjes, É. Arató-Borsi: :”Methods for Designing Room Acoustics in the Past and in the Future” International Békésy Centenary Conference on Hearing and Related Sciences, Budapest (1999)