Evaluation of the Acoustic Quality of TV-Studio Based on the Impulse Response Measurement

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Abstract – **The evaluation of room acoustic qualities is developing based on the analysis and interconnections of various acoustic quantities. Therefore, besides the reverberation time, quantities like early decay time, definition, clarity etc. are also of great significance. This paper briefly shows the process for determination of acoustic quantities based on the room impulse response. Some TV-studio quantities were practically determined in a few measurement points. Comparison of these quantities and a result analyse was conducted.**

Keywords – **Room impulse response, definition, clarity.**

I. INTRODUCTION

The sounds that are surrounding man can be observed from two aspects: as a physical phenomenon that is perceived as noise, or as a phenomenon that brings information. In the first case, the level of noise depends on its energy content and such phenomenon belongs to a noise protection. However, analysing of the sound that caries a concrete information is much more sensitive because the sound information content may depend on very refined differences for example in voice or music transmission. In that case the room in which the sound is reproduced should be considered as a communication transmission system, and instead of a traditional approach through the energy statistics model, the impulse response represents one of the most important characteristics of a room. Corresponding processing of the response can yield to a various room quantities and measurement parameters.

For a long time, the estimation of room acoustic quality was conducted only based on the reverberation time analysis. Although this quantity is very important for the room acoustic, from acoustic aspect it is not sufficient for a total room characterization [1]. Namely, some rooms have a reverberation time equal to an optimal one but their acoustic quality isn't subjectively equal. This imposed the introduction of new additional quantities that describe the ratio between the direct and reflected sound, in regard to clarity and definition, then energy ratio of sounds arriving from different direction, etc [2]. Utilizing of these quantities in analysis gives a complete sensation about "acoustics" of a room. Determination of above mentioned quantities is based on the impulse response of the room. The great importance of these quantities and their determinations implies the significance of the techniques for room impulse response measurement [3,4].

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The room impulse response has been measured in a various different ways. The simplest way is a direct measurement of the response when the exitation signal is an approximation of Dirac impulse as the gunshot is, or special balloon explosion or emitting of "noisy" impulse. For obtaining the appropriate impulse response it is necessary that source generates a short and simple impulse signal and has repeatable characteristics in time and space [3]. A generated excitation signal should contain sufficiently enough energy in order to produce a sufficiently large signal-to-noise ratio (SNR) within all frequencies of interest. The main drawback of this method directly emanates from the impulse excitation signal.

Nowadays, various method and techniques can be implemented for measurement of room impulse response. One of the techniques for room impulse response measurement showing obvious advantages and yielding the impulse response with high SNR even in noise environment is the Maximum Length Sequence (MLS) technique [2,3]. In this technique, MLS signal represents the excitation signal instead of the impulse. As a consequence, the impulse response is not obtained directly by measurement, but by cross correlation of the excitation signal and measured response.

Corresponding processing of the room impulse response results in number of quantities and parameters of the room and measurement. The integration of such squared impulse response from zero to infinity results in SPL of MLS signal. This enables that measurement of quantity such as sound insulation can be performed by implementation of MLS technique. Namely, SPLs of both source and receiving rooms are obtained from corresponding impulse responses measured by MLS technique.

Determinations of the quantities like a reverberation time (T), early decay time (EDT), definition (D_{50}), clarity (C_{80}), center time (TS) and relative sound level (G) based on the impulse response of the room are given in this paper. Mentioned quantities were determined for TV studio, which is subjectively evaluated as one with a satisfying acoustic quality. Variations of these quantities in a different measurement points are shown and comparison with the recommended values was performed.

II. DETERMINATION OF THE ACOUSTIC QUANTITIES

Impulse response of the room as one of its the most important characteristic, includes almost all important information about the room, so that various acoustic quantities can be determined by its processing. In realistic existing rooms it can be derived by measurements, that is, by simulations for the rooms that are still in the designing phase.

Derived response is subjected to an additional processing that implies filtering, integration and logarithming that leads to the desired acoustic quantities. Ordinarily the entire processing is performed in digital domain. Besides the mentioned quantities, several other acoustic quantities such as the lateral energy or interaural cross-correlation can be determined in the similar way, but their determination demands impulse responses measured by a figure of eight microphone or an artificial head [3]. Therefore, only the quantities obtained from the impulse response measured using an omnidirectional microphone are analyzed. Block diagram of determination of the mentioned acoustic quantities is shown in Fig. 1.

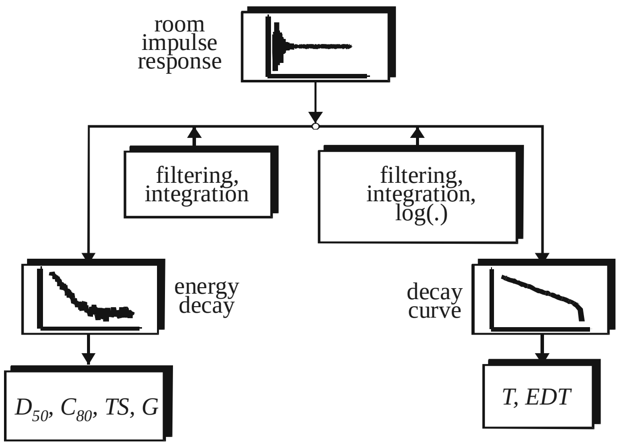

Fig. 1 Determination of acoustic quantities based on the impulse response of the room

Early decay time (*EDT*) is obtained in a similar way as the reverberation time with the exception that in this case the decay range from 0 dB to –10 dB was used. The important influence in its determination has the curvature of the initial part of the decay curve. Namely, this part may be bended besides the fact that it is a curve obtained by the integration of the impulse response [2]. The curvature influence on the deviation of curve from its approximation with straight line is significant particularly at low frequencies.

Definition and clarity are similar quantities that can be obtained using the initial and corresponding energy ratio. Furthermore, D_{50} is important for speech intelligibility while C_{80} is important for music [5,6]. Definition is response energy in first 50 ms and total energy ratio:

$$D_{50}[\%] = 100 \int_0^{0.050} h^2(t)dt \Big/ \int_0^{\infty} h^2(t)dt \,, \qquad (1)$$

where h(t) represents the room impulse response. Clarity is ratio between arrival energy in first 80 ms and energy that arrives in remaining time from 80 ms to infinity:

$$C_{80}[\mathrm{dB}] = 10\log\left(\int_0^{0.080} h^2(t)dt \Big/ \int_{0.080}^{\infty} h^2(t)dt \right). \qquad (2)$$

This quantity is related to subjective judgments of clarity or balance between clarity and reverberation.

Another quantity related to subjectively judgment of clarity is center time (*TS*) that represents the center of gravity of the impulse response or time of energy response first moment defined as:

$$TS[s] = \int_0^{\infty} t h^2(t)dt \Big/ \int_0^{\infty} h^2(t)dt \,. \qquad (3)$$

The relative sound level (*G*) is a quantity that represents a measure of the amplification of sound level at particular location in room in reference to the sound level in free fild. The bigger this quantity the louder the sound in that location. The relative sound level is calculated from corresponding energy response measured in the analyzed room and total energy response measured in a free field at the 10 m distance:

$$G_{t_1}^{t_2}[\mathrm{dB}] = 10\log\left(\int_{t_1}^{t_2} h^2(t)dt \Big/ \int_0^{\infty} h_A^2(t)dt \right). \qquad (4)$$

The mentioned corresponding energy refers to the total energy of room response when the integration range is from 0 to ∞ resulting in total relative sound level, or to early and late energy when the integration range is from 0 to 80 ms, that is, from 80 ms to ∞, respectively.

III. ACOUSTIC QUANTITIES OF STUDIO

In order to obtain acoustic quantities of TV studio, measurement of impulse response in three points (A, B and C) was conducted using the developed measurement system based on PC and applying MLS technique. Four measurements in each point were carried out using MLS signal of order of 18, which led to a relatively big decay ranges of over 45 dB.

The studio aqoustic quality was subjectively evaluated as good. Dimensions of this studio are about 6×5×3 m. The walls are acousticly treated with the appropriate absorbers and the ceiling contains the electric lighting devices. Objective quantities were obtained based on the measurements of impulse response that were performed in three points A, B and C. The points A and C were in the center of the studio and point B is near the one wall. The point A is located at the place where the microphone for a speaker commonly is. During the measurement, MLS signal was emitted from the PC through the external amplifier (SONY TA–FE 510R) and isotropic sound source. The response signal was recorded using condenser microphone (B&K Type 4144), microphone preamplifier (B&K Type 2619) and microphone power supply (B&K Type 2807).

Obtained characteristics of reverberation time and early decay time are shown in Fig. 2. The average values for *T* and *EDT* are about 0.4 s. It is noticeable that the variations between times obtained in a different measurement points are significantly greater at low frequencies. These variations are greater for *EDT* (about 0.3 s) than those for *T* (below 0.2 s). This can be the result of bigger curvature of the initial part of decay curves and smaller decay range used for determination of *EDT*. Mutual differences of *T* and *EDT* obtained at the same measurement point are also greater at the low frequencies (up to about 0.3 s). There are similar differences at all three measurement points.

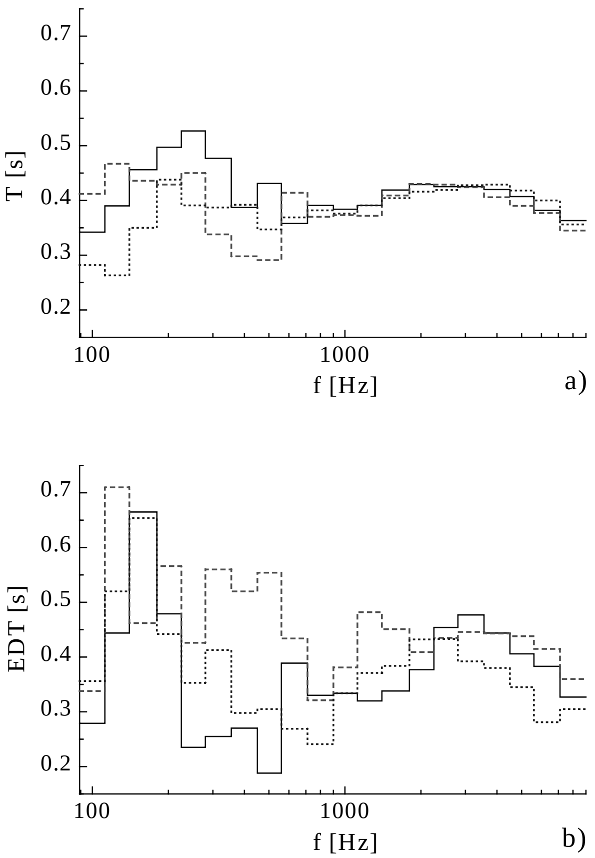

Fig. 2. Studio reverberation time a) and early reverberation time b) in three measurement points: A (—), B (---) and C (···)

The quantities obtained from the energy decay using the correction of filtered response delays [4] are shown in Fig. 3. One can also notice the significant variations of the corresponding quantities obtained at the different measurement points. For example, variations for D_{50} are smaller between the points A and C, while they are greater between the values from these points and those obtained at the point B (about 30 %).

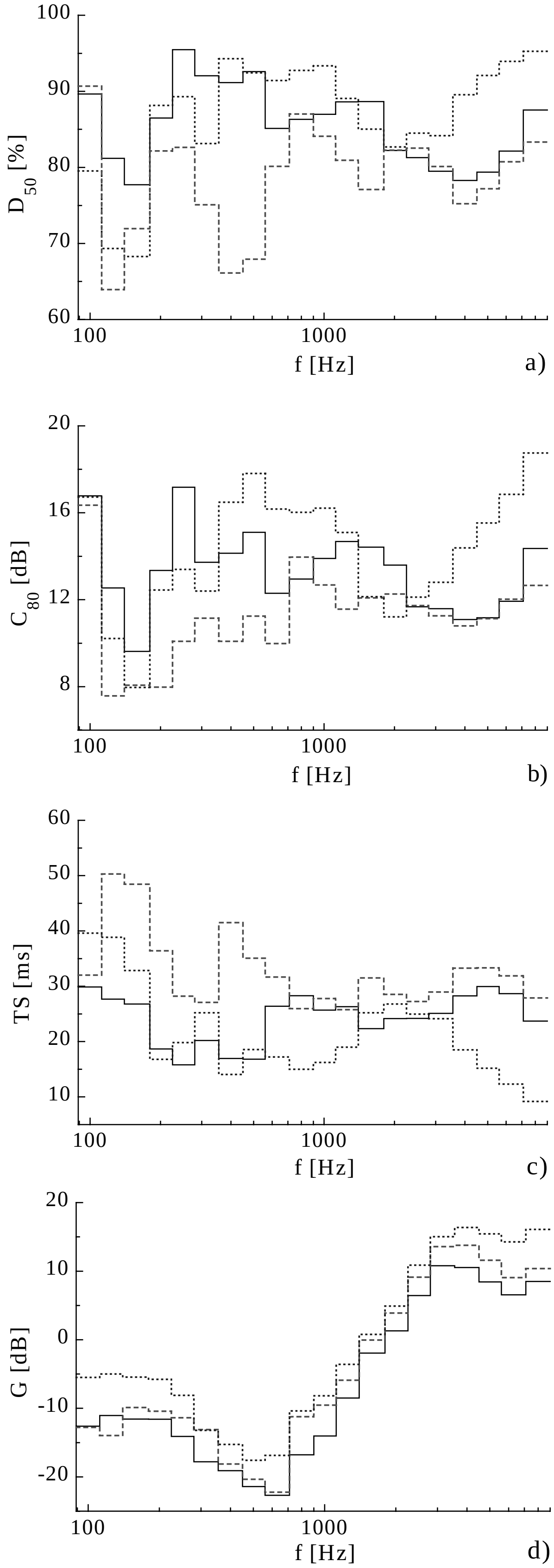

Fig. 3. Acoustic quantities definition a), clarity b), time center c) and relative sound level d) at three measurement points: A (—), B (---) and C (···)

IV. CONCLUSION

The average values for T and EDT of this studio are about 0.4 s so the studio is subjectively estimated as one with a good acoustic quality. However, one can notice very big variations of EDT at low frequencies depending on frequency and measurement location. Values for D_{50} and C_{80} are relatively big. Good correlations exist between early-to-late ratios and speech intelligibility. However, music clarity can not be so clearly defined as a function of frequency as speech because of the vastly greater number of variables in music.

In the available literature it is suggested that D_{50} should be greater than 50 %, and C_{80} greater than 0 dB [6,7]. However, this values shouldn't be too large but for all three measurement locations D>70 % and C>8 dB in entire frequency range. It shows that the influence of the direct sound is significantly greater that a reverberation influence. However, this is desirable characteristic for a speech studio, which is mostly the main purpose of this one. Above mentioned confirms the value of TS that is about 30 ms. Generally, it can be concluded that there is a correlation between EDT and T with the quantities D_{50} and C_{80} and TS.

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