Measuring Acoustic Parameters with ESS and MLS methods: Effect of Artificially Varying Background Noise

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Summary
Exponential Sine Sweep (ESS) and Maximum Length Sequence (MLS) methods are often being applied for impulse response measurements in the presence of background noise of various types and levels. Scope of this study is the estimation of the effect of background noise on acoustic parameters for ESS and MLS measurements by adding artificial background noise with the use of a sound source. Impulse response measurements were performed in an acoustic space with the use of a dodecahedral loudspeaker for ESS and MLS methods for the same source and microphone positions according to ISO 3382-1:2009. Varying levels of background noise with steps of 2 dB were applied for the measurements with the use of an additional sound source. The different types of background noise that were used were white noise, tonal, narrow band and impulsive. No background noise compensation methods were applied for ESS and MLS. The effect of different levels of background noise for octave band acoustic parameter measurements were estimated for each case by the mean absolute error compared to the measurement without artificial background noise. Results indicate that in the case of white, narrow band and tonal noise, for low background noise levels the mean absolute error for the two methods are similar. However for higher background noise levels there is a greater mean absolute error for the ESS method. In the case of impulsive noise the ESS method seems to outperform the MLS method. Implications of the findings suggest the expected deviation of acoustic parameters in the presence of background noise of various types and levels. In addition the study hints the preferred method for acoustic measurements according to the background noise and levels.

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1. Introduction

The majority of the acoustic parameters characterizing a space can be derived from the impulse response. A dodecahedral speaker is commonly used with excitation signals such as MLS, ESS, Inverse Repeated Sequence (IRS) and Time-stretched pulses for impulse response measurements. However the most prominent and widely used excitation signals are ESS and MLS.
Impulse response measurements using the MLS technique were first proposed by Schroeder [1]

and have been used ever since in the field of room acoustics. The MLS method presents great immunity in distortion [2]. Bleakley and Scaife [3] have shown that the signal-to noise ratio for the MLS sequence increases by 3 dB when the period length of the MLS sequence is doubled. In the presence of a nonwhite stationary noise the MLS technique outperforms the other methods. In a nonrandom noisy environment, where specific source is responsible for the noise, MLS method is considered to provide the best results and to have better reproducibility. Practical aspects of the application of the MLS are discussed by Vanderkooy and Vorlander [4, 5].

Shortly after the publication of MLS technique the IRS method was developed as an alternative theoretical option of the MLS for reducing distortion peaks [6]. The disadvantage of this method is the longer time needed for the calculation of the deconvolution by using high order FFT and IFFT filters [7]. Similar results with the MLS can be obtained with the IRS method, but the MLS is more practical, faster and commonly used.

The Time-stretched pulses were introduced from Aoshima for the measurements of impulse responses [8]. This method aims at increased sound to noise ratio with the purpose of diminishing the peak distortions.

Finally the ESS method was first proposed and developed by Farina [9, 10]. The method intended to overcome most of the limitations encountered in the other measurement techniques. The swept-sine is an optimal excitation signal for the fast measurement of an acoustical impulse response, even without the averaging. It gives a better estimation than other excitation signals in acoustical time-variant environments and slightly nonlinear systems. Also in a noiseless environment the ESS method seems to be the most appropriate. The swept-sine is not considered to be the best choice if the environment generates large levels of background noise. It also gives a bad estimation in a system that has the frequency sensitive automatic gain control or automatic noise suppression. In those cases periodic noise excitation signals as the MLS give a better estimation.

Studies by Farcas [7], Mateljan [11], Guidorzi [12] and Stan [13] present a thorough comparison of the different impulse response measurement techniques.

The aim of our work was to further extend the current knowledge of ESS and MLS measurements by performing the methods in the presence of artificial background noise of various types (white noise, tonal, narrow band and impulsive noise) and levels. Hence the scope of this study was the estimation of the effect of background noise on acoustic parameters by the mean absolute error compared to the measurement without artificial background noise.

These results revealed that in the case of white, narrow band and tonal noise the MLS slightly outperforms the ESS method. In the case of impulsive noise the results indicate that the ESS can provide better results.

Implications of the findings suggest the expected deviation of acoustic parameters in the presence of background noise of various types and levels.

Chapter 2 is concerned with the methodology employed for this study while chapter 3 presents the findings of the research. Discussion section analyses the data gathered and addresses the research questions in turn. Our conclusions are drawn in the final chapter.

2. Methodology

Impulse response measurements were performed in an amphitheater of the Technical Educational Institute of Crete, Department of Music Technology and Acoustics, Greece with a volume of 1088 m^3.

Impulse responses were measured with the use of a dodecahedral loudspeaker for ESS and MLS methods for the same source and microphone positions according to ISO 3382-1:2009 [14]. Two different microphone positions were used. No background noise compensation methods were applied for ESS and MLS. In order to perform an objective comparison of the impulse response qualities, the sound levels of the ESS and MLS signals in the measurement positions were set to 84 dB for both methods. This level was preferred because it corresponds to the mean value between the optimum levels for the MLS (75.5 dB) and ESS (92.5 dB) signals as proposed by Stan [13]. Precautions were taken in order the background sound level would be approximately the same for every measurement.

The sampling frequency of the impulse response measurements was 44.1 kHz. An appropriate sequence length and time constant for the ESS and MLS signal was chosen according to the expected

Reverberation Time (RT). A single iteration was performed for each of the measurement points for each method. An omniderctional microphone (Type 4190, Earthworks) was used for each of the measurements. The dodecahedral loudspeaker (Type DO12, 01 dB-Stell) was placed in the center of the stage of the amphitheater.

Varying levels of background noise with steps of 2 dB were applied for the measurements with the use of an additional sound source. The sound source was directed to the wall in order to achieve maximum diffusion of the artificial background noise. Level measurements were made at the microphone position with a sound level meter (01dB-Steel SdB02). The maximum acceptable deviation from the expected sound level was 0.1 dB.

The different types of background noise that were used were white noise, tonal, narrow band and impulsive noise.

The acoustic parameters that were calculated from the impulse responses are RT, Early Decay Time (E.D.T.), Clarity (C80) and Definition (D50). The effect of different levels of background noise for octave band acoustic parameter measurements were estimated for each case by the mean absolute error compared to the measurement without artificial background noise.

3. Results

Results are presented in four figures according to the type of the background sound (Fig.1 white noise, Fig.2 narrow band noise, Fig. 3 tonal noise, Fig 4. impulse noise). For each figure the mean absolute error for the four acoustic parameters (RT, E.D.T., C80 and D50) and for the ESS and MLS method is presented.

In the case of white noise and narrow band noise as background noises the results suggest that for higher levels of background noise the ESS method has a greater mean absolute error for every acoustic parameter. The same can be noted for the tonal noise but in a lesser extent. In the case of impulse noise it is clear that the ESS method outperforms the MLS method and it has smaller mean absolute error for every acoustic parameter. For low levels of background noise in the case of white noise, narrow band and tonal noise as background noises, the results suggest that the ESS has a slightly lower mean absolute error.

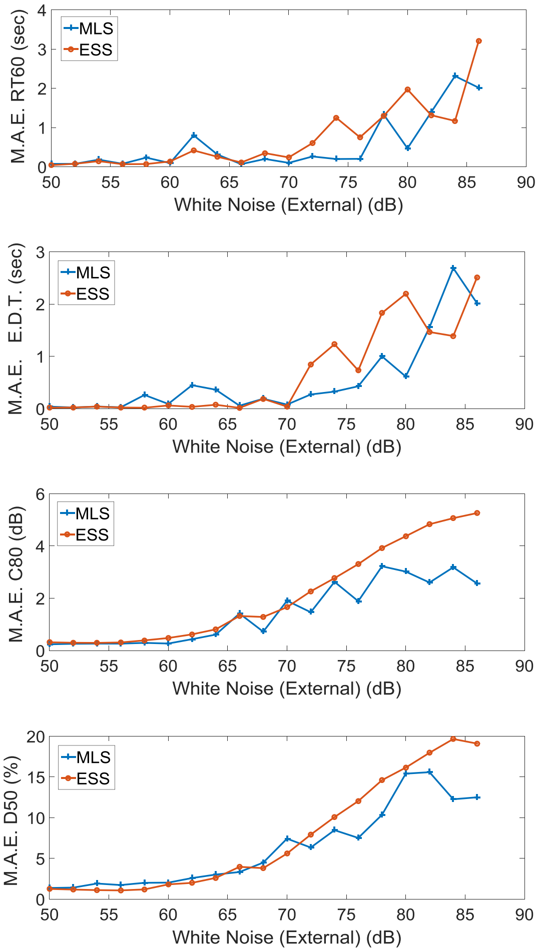

Figure 1 Mean Absolute Error in the case of White Noise as background noise for RT60, E.D.T., C80 and D50

4. Discussion

The overall direction of results shows that in the cases of white, narrow band noise and tonal noise the MLS method performs better than the ESS. On the contrary for impulsive noise, the ESS outperforms the MLS method.

Our findings are continent with the expected results in the cases of white, narrow band and tonal background noise. Stan [13] states that in a (nonrandom) noisy environment the MLS (or IRS) method is subject to giving better results than the other methods (ESS). Contrary to expectations in the case of impulsive noise the results favored the ESS method.

The present study has only investigated the performance of ESS and MLS signal qualities in the case of the same excitation level from the signals in the measurement position.

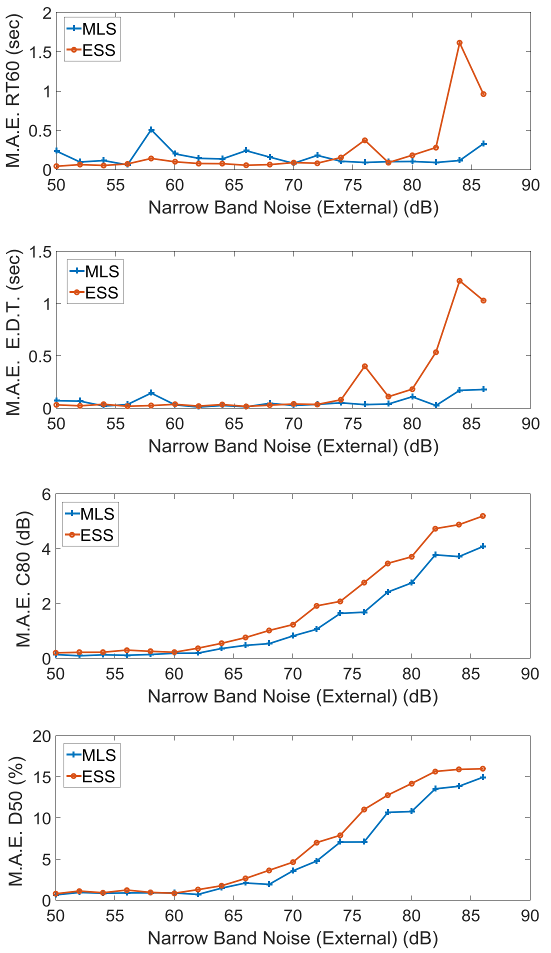

Figure 2 Mean Absolute Error in the case of Narrow Band Noise as background noise for RT60, E.D.T., C80 and D50

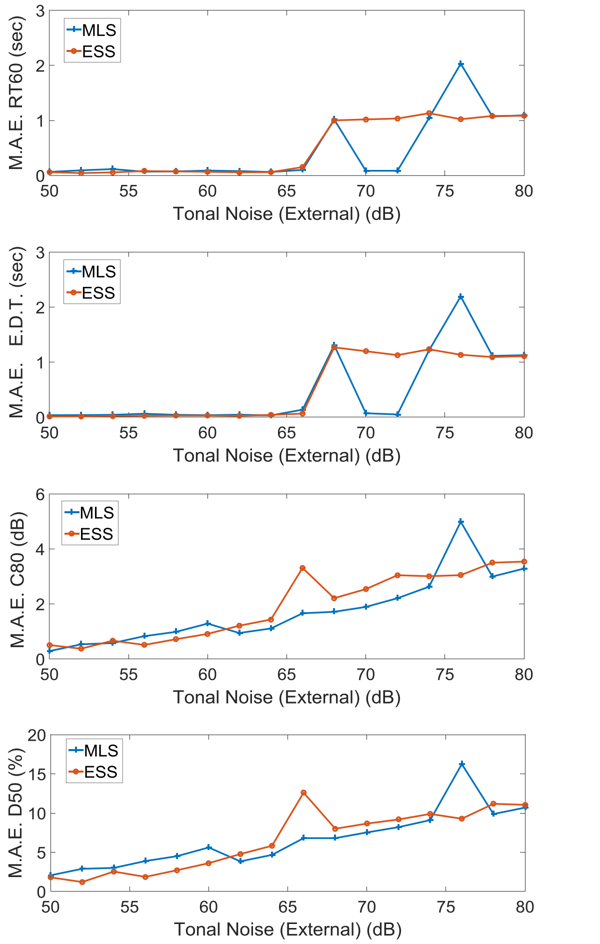

Figure 3 Mean Absolute Error in the case of Tonal Noise as background noise for RT60, E.D.T., C80 and D50

However optimum signal levels have been proposed for the ESS and MLS [13] which are different for each method. Despite this we believe our work could be a starting point for similar studies that explore the performance of the ESS and MLS under different conditions.

Implications of the findings suggest the expected deviation of acoustic parameters in the presence of background noise of various types and levels. Also the results point to the preferred method for acoustic measurements according to the background noise and levels.

This study is a first step way towards enhancing our understanding of the specific effect of the measurement method in the acoustic parameters that define a space. These observations have several implications for research into other aspects of impulse response measurements.

We are currently in the process of investigating the effect of background noise in the measurement of acoustic parameters with ESS and MLS signals with optimum sound levels for each method. To further our research we are planning to account for the effect of averaging for both methods over a number of iterations.

Future work will also concentrate on the effect of adding background noise compensation methods for ESS and MLS in order to estimate which method is most favorable according to the optimum measurement condition and setup and what is the effect on the acoustic parameters and the impulse responses. We believe that the proposed studies may improve knowledge about the preferred method for acoustic measurements according to the background noise and levels.

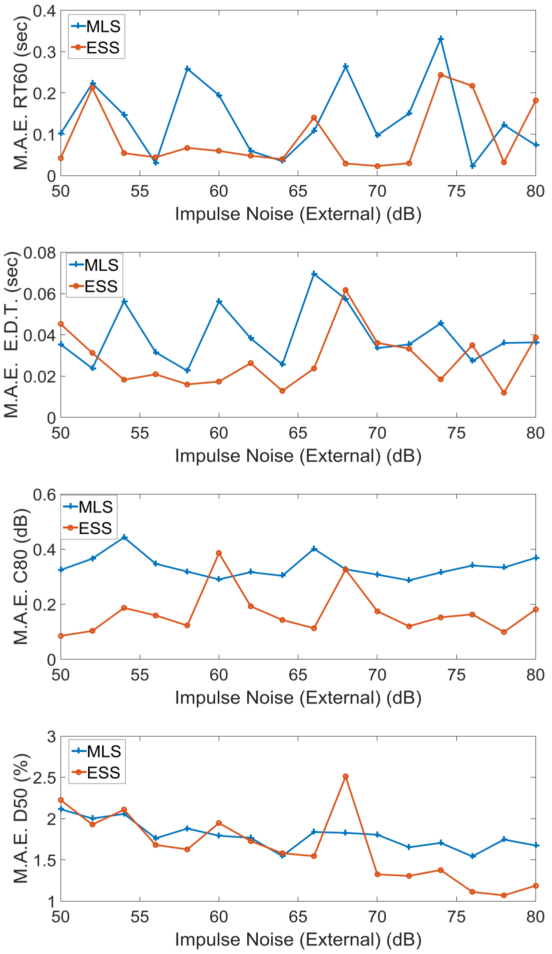

Figure 4 Mean Absolute Error in the case of Impulse Noise as background noise for RT60, E.D.T., C80 and D50

5. Conclusions

We assessed the effect of background noise on acoustic parameters for ESS and MLS measurements by adding artificial background noise with the use of a sound source. The effect of different levels of background noise for octave band acoustic parameter measurements were estimated for each case by the mean absolute error compared to the measurement without artificial background noise.

The evidence from this study points towards the idea that the MLS methods for white, narrow band and tonal background noise can provide better results especially for higher background noise levels. However in the case of impulsive noise the ESS method seems to outperform the MLS method.

This study has provided further evidence on the suitability of the MLS in the presence of background noise. The importance of our work lies in the data about the expected deviation of acoustic parameters in the presence of background noise of various types and levels. In addition the study points to the preferred method for acoustic measurements according to the background noise and levels.

The present study has only investigated the case of the same excitation sound level for the ESS and MLS signals. Consequently additional measurements are needed for the case of optimum signal levels for both methods. To further our research we are planning to account for the effect of averaging for both methods over a number of iterations. Future work will also concentrate on the effect of adding background noise compensation methods for ESS and MLS in order to estimate the best method according to the optimum measurement conditions and setup.

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