COMPARISON OF ROOM IMPULSE RESPONSE MEASUREMENT METHODS

S.Norcross
Audio Research Group, University of Waterloo, Waterloo, Ontario, N2L 3G1.
J.S. Bradley
Institute for Research in Construction, National Research Council, Ottawa, Ontario, K1A 0R6.

INTRODUCTION

One of the most important measures of a system such as a room is is impulse response. Almost all characteristics of that system can be calculated directly from the impulse response, i.e. in room acoustics numerous objective parameters such as reverberation time, early/late ratios and RASTI can all be obtained from it. In room acoustics, due to large reverberation times, longer impulse responses are needed and a large dynamic is desired.

The impulse response of a system is defined as the output when a perfect pulse, or delta function, is applied to it. Hence, the simplest of all techniques is just to apply a short duration pulse to the room and then measure its response. Other broadband signals can be used, with various processing, to calculate the impulse response. One example is the use of a chirp, a short duration sine sweep. This approach has more energy output than a pulse, but requires post-processing. If one stretches out the chirp so that it is a continuous repeating sweep, even more energy is output, and this requires similar post-processing. Finally, a pseudorandom noise, or a maximum-length sequence signal, with a Fast Hadamard transform can be used, to calculate the impulse response. For all of these techniques to be valid, the system under study must be linear and time invariant (except with the pulse method where time invariancy is not a problem.)

This paper will compare each of these approaches, and describe the strengths and weaknesses of them when applied to room acoustics.

THEORY

As mentioned above, the simplest approach is to excite the room with a short pulse and then measure the response. This approach does not produce much energy in the room. Therefore, to achieve an adequate signal-to-noise ratio, numerous averages have to be made. This requires more time and is not always practical.

A chirp, which is generated simply by creating a sine wave that changes frequency in time, can have a duration of about 10-100 ms and can be repeated every 2 to 3 seconds. One measures the response of the room due to that chirp and later calculates the impulse response. The processing is a correlation of the input and output to obtain the impulse response. This can be accomplished by using FFTs, dividing the complex spectra of the source and received signals followed by an inverse FFT to get the impulse response. One problem is that the correlation with FFTs is actually a circular one and a wrap-around effect is present. This can easily be fixed by padding with zeros or subtracting the length of the chirp from the end of the calculated impulse response[1]. Due to the chirp frequency being dependent on time, one can contour the frequency spectrum of the chirp by varying the amplitude of individual frequencies. Thus, one can produce a white spectrum, or taper the frequencies to what is desired.

A sine sweep is similar to a chirp but it is continuously repeated so that there are no gaps in the signal. The processing is similar, but since the signal is continuous and is periodic one does not have to worry about the circular correlation problem. Therefore, to obtain the impulse response, simple FFT methods can be used. The one advantage over the chirp is the amount of energy that is output with the continuous sweep is greater.

Finally, a maximum-length-sequence signal and a Fast Hadamard transform can be used to calculate the impulse response[2,3]. The basic idea here is to excite the system with the MLS, acquire the response of the room, then cross-correlate that response with the MLS source signal. The result is the system impulse response.

EXPERIMENTAL PROCEDURE AND DATA

Each of the above mentioned techniques was implemented using a PC and a 16-bit A/D board, and data was sampled at 12780 Hz. For the pulse method, the pulse width was 0.23 ms and the peak was approximately 4.5 volts. The chirp duration was about 40 ms, while the sweep and MLS signal were about 2.5 seconds in duration.

Figures 1 through 4 show the first 60 points of the impulse response of a low-pass filter with a cutoff frequency of 5.22 KHz cutoff. Figure 1, the pulse method, shows little energy output, while Figures 2 and 3 (chirp and sweep) show about the same energy output. This is due to correlation process normalizing the impulse response with the source signal. The most energy output is by the MLS. All the impulse responses look very similar and further tests in rooms will show how the strengths of each method when dealing with longer impulse response and background noise.

CONCLUSIONS

In a simple test, each of the methods produced similar results, except for the pulse with little energy which was expected. Therefore, tests in rooms need to be performed to further investigate the four methods.

REFERENCES

1. Otnes, R.K. and Enochson L., "Digital Time Series Analysis", John Wiley and Sons, pp. 244-249 (1972).
2. Borish, J. and Angell, J.B., "An Efficient Algorithm for Measuring the Impulse Response Using Pseudorandom Noise", Journal of the Audio Engineering Society, Vol. 31, No., pp. 478-487 (1983).
3. Rife, D.R. and Vanderkooy, J., "Transfer-Function Measurements with Maximum-Length Sequences", Journal of the Audio Engineering Society, Vol. 37, No., pp. 419-487 (1989).

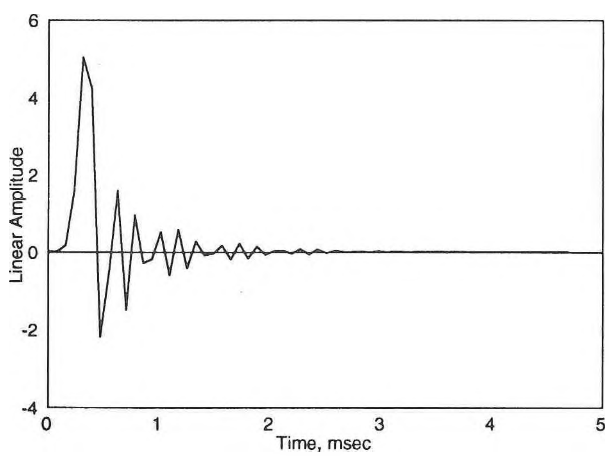

Figure 1. Impulse response from pulse method.

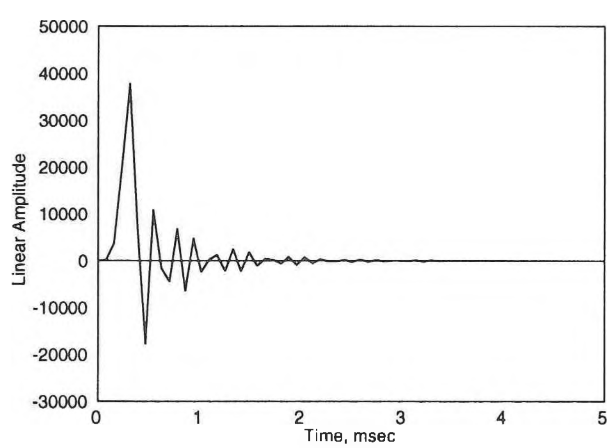

Figure 2. Impulse response from chirp method.

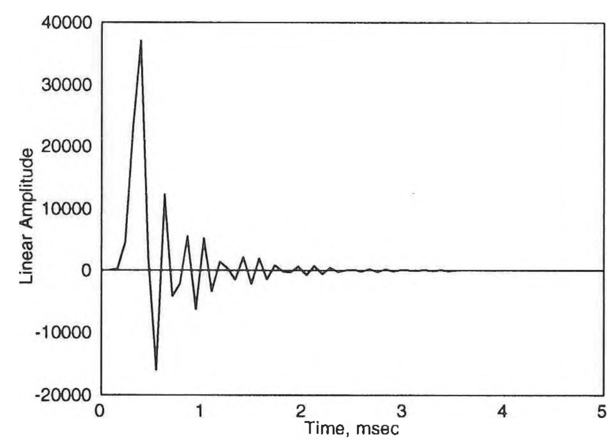

Figure 3. Impulse response from sweep method.

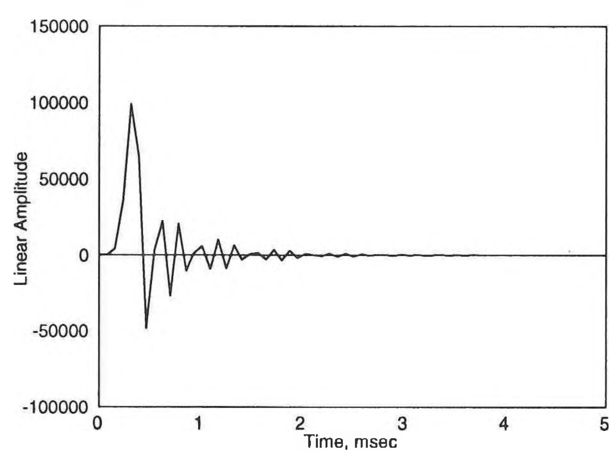

Figure 4. Impulse response from MLF signal methd.