

## Reflection loss measurements on flat and non flat samples using MLS method with signal subtraction

P. Cobo <sup>(1)</sup>, M. Garai <sup>(2)</sup>, and J.S. Santiago <sup>(1)</sup>

(1) Instituto de Acústica. CSIC. Serrano 144, 28006, Madrid. Spain.

(2) Department of Energetic, Nuclear and Environmental Control Engineering. University of Bologna. Viale Risorgimento 2, 40136 Bologna, Italy.

### Summary

1. This paper reports on the sound reflection measurements done at the Department of Energetic, Nuclear and Environmental Control Engineering (DIENCA), University of Bologna, Italy. Angle-averaged 1/3 octave Reflection Loss spectra were obtained, using the facilities provided by DIENCA, on flat and non-flat samples of materials, Rockfon and Beton Bois, respectively.

### Introduction

MLS are sequences of binary integers generated recursively by N-stage shift registers which have the following properties (Garai, 1993):

- (1) have a flat frequency spectrum, like an ideal impulse;
- (2) are exactly repeatable;
- (3) have low crest factor, providing high signal-to-noise ratios;
- (4) are immune to background noise.

Excitation of a system with a MLS signal permits to recover the system impulse response in a repeatable way, even in presence of a high background noise (Garai, 1993). These properties make the MLS a suitable method to measure acoustic characteristics of materials in situ. In order to enlarge the low frequency contents of the measurements, the MLS method with the signal subtraction technique (Mommertz, 1995) was implemented using commercially available components and devices.

### The MLS method with signal subtraction technique

The MLS method with the signal subtraction technique to measure angle-averaged 1/3 octave band spectra is sketched in Figure 1.

Reflection Loss spectra are calculated from measurements by

$$\langle \text{RL}(\omega) \rangle = - \frac{\int |\xi [d_r(t) p_m(t) w_r(t)]|^2}{\int |\xi [d_o(t) p_o(t) w_o(t)]|} \quad (1)$$

where  $\xi$  stands for Fourier transform,  $p_o(t)$  is the reference signal,  $p_m(t)$  is the reflected signal at angle  $\theta_n$ ,  $w_r(t)$  is the window for the reflected signal,  $w_o(t)$  is the window for the reference signal, and  $d_r(t)$  and  $d_o(t)$  are the gain functions to correct the reflected and reference signals for spherical divergence. Both  $w_r(t)$  and  $w_o(t)$  are flat in its central part, with flanks smoothed according to a Blackman-Harris shape. Direct and reflected signals received at the microphone can be separated using the subtraction technique. This requires:

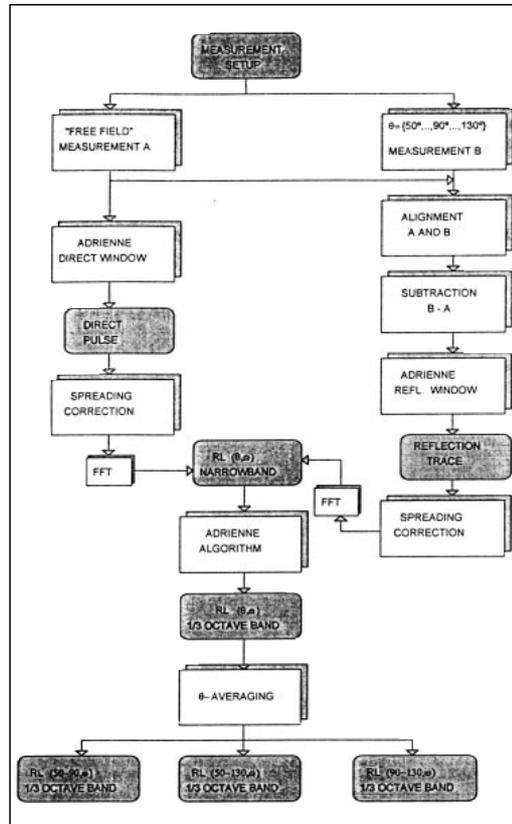


Figure 1. The MLS method with signal subtraction technique

- Measuring a reference signal without echoes within the sample reflection region (A).
- Measuring the reflected signal with the loudspeaker/microphone system over the sample (B)
- Alignment of both A and B signals.
- Subtraction of B minus A.
- Windowing of A, that affords the direct signal.
- Windowing of B, that provides the reflection signal.

A spherical-wave model has been assumed. Wave amplitude of spherical waves decay as  $(1/r)$ . Therefore, a gain function,  $d(t) = r = c t$ , is used to restore the true amplitude of the late arrivals in the reflected trace. However, while weak reflections are brought up in strength, noise components in the data also can be boosted (Yilmaz, 1987). This is one undesirable aspect of this spreading correction. Finally, averaged Reflection Loss spectra are calculated.

## Results

The measurements were done indoors, in the DIENCA Laboratory. The sample was laid down on the floor and the loudspeaker/microphone system was suspended over it. The geometrical arrangement was as follows: loudspeaker-microphone distance: 1.25 m; microphone-sample distance: 0.25 m; sample area: 4x4 m<sup>2</sup>; angles: 50°, 60°, 70°, 80°, 90°, 100°, 110°, 120°, and 130°. A signal free of echoes within the processing window is measured by pointing the loudspeaker/microphone system towards the wall opposite to the user's desk.

Averaged RL curves on 50°-90°, 90°-130°, and 50°-130° for Rockfon (50 mm thick) and Beton Bois (wood-cement tiles) samples are presented in Figures 2 and 3, respectively.

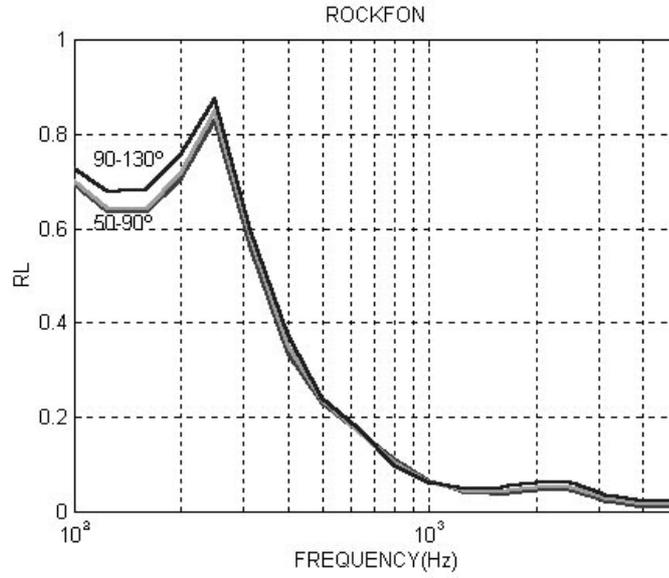


Figure 2. Averaged Reflection Loss curves on Rockfon for 50°-90°, 90°-130°, and 50°-130°

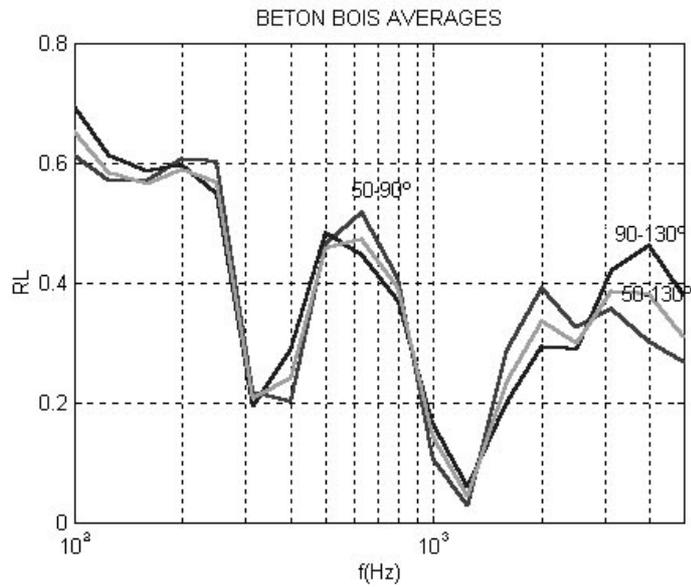


Figure 3. Averaged Reflection Loss curves on Beton Bois for 50°-90°, 90°-130°, and 50°-130°.

### Conclusión

Some properties (repeatability, background noise immunity) make the MLS method with the signal subtraction technique appropriated to characterize flat and non-flat acoustical materials in situ.

### Acknowledgement

Financial support from the SMT Programme of the UE (Project MAT1-CT94049 "ADRIENNE") is duly recognized.

### References

- Garai, M., 1993. "Measurement of the sound-absorption coefficient in situ: The reflection method using periodic pseudorandom sequences of maximum length". *Applied Acoustics*, 39, 119-139.
- Mommertz, E., 1995. "Angle-dependent in-situ measurement of reflection coefficient using subtraction technique". *Applied Acoustics*, 46, 251-263.
- Yilmaz, O., 1987. *Seismic Data Processing*. Society of Exploration Geophysicists, Tulsa, OK.