

# IN SITU MEASUREMENT OF THE SURFACE IMPEDANCE OF FOAM AT OBLIQUE INCIDENCE USING PSEUDO-RANDOM SEQUENCES AND A SINGLE MICROPHONE

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## Introduction

The surface impedance of materials can be determined experimentally in the free field or in rooms (*in situ*) from the technique of two- or single-microphone transfer functions. The purpose of this article is to extend the use of the pseudo-random sequence and a single microphone to *in situ* impedance measurement of materials at oblique incidence. First an experimental technique for measuring the acoustical impedances of materials is described. Then spherical-wave surface impedance of materials are estimated using the relationship between pressures at two field positions. Finally the experimental results are presented.

## Experimental techniques

A sketch of the experimental set-up is shown in Fig. 1. The acoustical impedance at midpoint  $M$  is expressed by two transfer functions  $H_1$  and  $H_2$  measured sequentially at  $M_1$  and  $M_2$  (time dependent factor  $e^{-i\omega t}$  is used here):

$$\tilde{Z}_M = \frac{p}{u} = \frac{i\omega\rho a}{2} \frac{\bar{H}_1 + \bar{H}_2}{\bar{H}_1 - \bar{H}_2}, \quad (1)$$

where  $\rho$  is the air density,  $\omega$  is the angular frequency,  $\bar{H}_{1,2} = (1/N) \sum_{n=1}^N H_{1,2n}$ . A digital pseudo-random signal called a Maximum Length Sequence (MLS) is used in the measurements. The measurement system was validated using the measured residual pressure-intensity index

## Experimental Procedure, data acquisition and processing

The sound source was a loudspeaker in a wooden box enclosure driven by the pseudo-random sequence generator of the MLSSA system. The loudspeaker was supported by a stand which allowed the angle of incidence  $\theta_0$ , and the distance from the source to the surface of the material  $r_0$ , to be varied. A microphone was mounted on a support allowing the position relative to the surface of the test sample to be adjusted with a precision of 0.025 cm. The test material was an industrial CONAFLEX foam ( $1.2 \times 1.2 \times 5 \text{ m}^3$ ). The test sheet was backed by an acoustically hard plane boundary. The measurements were made for different angles of incidence in a semi-reverberant room and in an anechoic chamber. Surface impedances  $Z_s$  and reflection coefficients  $R(\theta)$  were calculated from  $\tilde{Z}_M$  using the following relationships,

$$Z_s = \frac{\rho c}{\cos \theta_0} \frac{1 + R(\theta_0)}{1 - R(\theta_0)} \frac{1}{1 + i/kr_0}, \quad (2a)$$

$$R(\theta_0) = \frac{-i\omega\rho a/2 + B\tilde{Z}_M}{C\tilde{Z}_M + i\omega\rho aD/2}, \quad (2b)$$

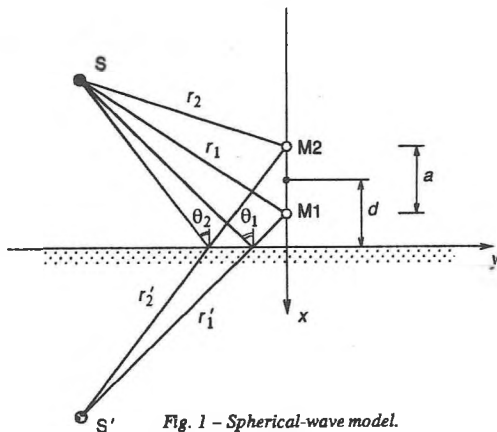


Fig. 1 - Spherical-wave model.

where  $A = T_1 + T_2$ ,  $B = T_1 - T_2$ ,  $C = T_2' - T_1'$  and  $D = T_1' + T_2'$  with  $T_1 = e^{ikr_1}/r_1$ ,  $T_1' = e^{ikr_1'}/r_1'$  for example.

## Experimental results and analysis

Fig. 2 shows the absorption coefficients  $(1 - |R|^2)$  at  $\theta = 0^\circ$  measured in the semi-reverberant room and those measured in an anechoic room. It is noted that the values measured in the two environments have good agreement in the frequency range 300 Hz to 7000 Hz. However there are big discrepancies at low frequencies below 300 Hz because of systematic errors. Fig. 3 shows the measured surface impedance  $Z_s/\rho c$  versus angle of incidence at given frequencies with  $r_0 = 31 \text{ cm}$ . It is shown that the surface impedance of foam is a function of the angle of incidence.

## Conclusion

Measurements were carried out on a CONAFLEX foam at oblique incidence. The variations of the surface impedance with the angle of incidence demonstrate that the foam is of local reaction at the test frequencies. The comparison of results of experiments in a semi-reverberant room and in an anechoic room shows that the acoustical properties of materials can be measured in an arbitrary room using a pseudo-random sequence and a single microphone.

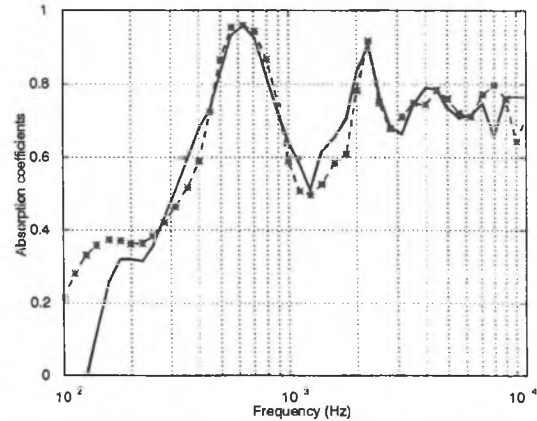


Fig. 2 Surface absorption coefficient of foam measured in an anechoic room (—) and in a non-anechoic room (\* \* \* \*).

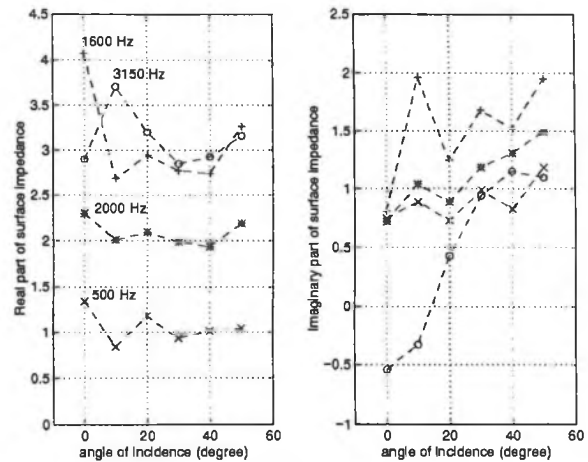


Fig. 3 - Surface impedance  $Z_s/\rho c$  of CONAFLEX foam with a thickness of 5 cm at oblique incidence.