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THE MEASUREMENT OF THE ACOUSTIC TRANSMISSION CHARACTERISTICS OF WOOD FRAME WALLS USING SELECTIVE INTENSITY TECHNIQUES

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INTRODUCTION

As part of a programme to develop a method of on site measurement of acoustic transmission characteristics in wood frame constructions, a new technique of intensity measurement has been developed which permits the effects of parasite sources of noise to be eliminated. The technique is more onerous than standard two microphone methods and requires more care to obtain an accurate result, but enables measurements of low levels of intensity to be made in a noisy environment. This can be important when a detailed diagnosis of transmission characteristics is required while the building is still under construction. Measurements have been carried out on a reduced size model of a room whilst awaiting construction of a full size two room model. It was the noisiness of the only site available for the full scale model that led to the examination of the methods that could be applied to eliminate such effects from the intensity measurements.

PROBLEMS OF ON SITE TRANSMISSION LOSS MEASUREMENTS

The standard transmission suite consisting of two reverberation rooms separated by the panel under test enables measurements to be made in a truly diffuse field. The incident and transmitted intensity can then be calculated using the standard relationships

$$< I > = P^2_{r.m.s.} A/4 \rho C \qquad (1)$$

where $A = 0.16\ V/T$

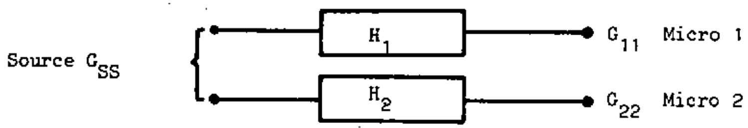
$< I >$ is the time average intensity, P the sound pressure, ρ the density , C the speed of sound, A the room absorption, V the room volume and T the reverberation time. The transmission loss may then be calculated using the expression ;

$$T.L. = 10 \log_{10} < I_i > / < I_t > \qquad (2)$$

where $< I_i >$ is the time averaged incident intensity calculated for the source room and $< I_t >$ the transmitted intensity for the reception room. Crocker [1] eliminated the need for the reception room by using an intensity meter to measure the transmitted intensity. Villot [2] - Fahy [3] and Cops [4] have extended these measurements to individual room surfaces by averaging the intensity measured over many points of the surface to calculate the contributions of each wall. For on site measurements the intensity method eliminates the requirement for a diffuse field in the reception room but still requires a diffuse field in the source room in order to ensure that all possible modes are excited. The failure to attain this condition leads to transmission loss values higher than those measured with a transmission suite and this is difficult to achieve at low frequencies particularly in small rooms of regular shape. In a situation where the two rooms are not identical it is common sense to choose the largest most irregular and reverberant room for the source. Experimental dispositions of diffusers to obtain the most uniform field possible should be checked by narrow band analysis for several microphone positions. In the small scale model used for the measurements presented below, space was too restricted to optimise the characteristics of the sound field, but noticeable improvements were obtained with only two flat diffuser panels. Calculation of the transmission loss by narrow band analysis with subsequent conversion to third octave representation would seem to be the best way of processing the data. The results presented indicate the resonant phenomena at high frequency far better than a third octave analysis.

THEORY OF THE SELECTIVE INTENSITY METHOD

Fahy 5 introduced the use of the cross spectral formula to calculate the acoustic intensity using the signals of two microphones placed in the sound field. The selective method [6] simply calculates this cross spectral intensity using a reference signal coherent with the source. The signal from the source reaches the two microphones via two single input single output linear systems with frequency responses functions H_1 and H_2 respectively



For such a system

$$H_1 = G_{S1}/G_{SS} \quad ; \quad H_2 = G_{S2}/G_{SS} \qquad (3)$$

Where G_{SS} is the autospectral density of the source and G_{S1} is the cross spectral density source/micro 1, G_{S2} is the cross spectral density source/micro 2. It can then be shown that the cross spectral density between the two microphone signals is given by :

$$G_{12} = H_1^* \cdot H_2 \cdot G_{SS} \qquad (4)$$

where H_1^* represents the complex conjugate of H_1. The use of the transfert functions H_1 and H_2 selects only that part of the signal coherent with the reference signal. The intensity may then be calculated using the standard formula :

$$I = I_m\,(G_{12})/\rho\,\omega\,r \qquad (5)$$

where I_m denotes the imaginary part of the cross spectral density, ρ the density, ω the angular frequency and r the distance between the microphones. This procedure may be implented on any dual channel FFT analyzer, providing it has facilities to store and perform arithmetic operations on spectra. In this case the acquisitions were made on a NICOLET 660 A dual channel analyzer which was coupled to a PDP 11/23 computer which performed the arithmetic operations and displayed the results. This required the transfer functions to be calculated during two separate acquisitions thus limiting the statistical accuracy of the results. Work is under way to perform the acquisition of the reference and microphone signals simultaneously. In order to evaluate the improvement in accuracy obtainable.

RESULTS

Tests were carried out using a pointsource in an anechoic room. The object was to show that the measured intensity remained unaffected by the presence of a strong parasite source adjacent to the primary source. Figure 1 shows the spectrum of intensity calculated by the selective method compared with the results obtained using the standard technique with and without the parasite source B. The results are plotted on a linear scale to emphasize the errors. These tests showed that the accuracy of the result depended on the length of the sound path, the resolution of the analysis and the length of the acquisition. It is clear that there is almost total rejection of the parasite source and an estimate of intensity in good agreement with the standard method.
Subsequent tests were carried out on a small scale model room of dimensions 1.05 m x 0.65 m x 0.55 m constructed of 22 mm chipboard. The transmitted intensity was measured on several faces using the standard technique and then the selective technique with different types of reference signal. Because of the imperfect quality of the sound field and the small dimensions of the model there are several resonant peaks in the intensity spectrum, those in the 2 KHz range corresponding to the critical frequency for the chipboard.
Figure 2 compares the results obtained using the standard method with those obtained using different reference signal:(A) generator input to loud speaker (B) sound pressure measured close to the lound speaker (C) an accelerometer placed on the radiating surface. In every case the generator input gave lower intensity levels than the standard technique or other reference signals. For certain measurements the acceleration reference gave a lower value. Use of a larger bandwidth and hence a reduced resolution resulted in a diminution of the level, particularly with the generator as reference best results were obtained with a bandwidth of 2.5 KHz and a resolution of 5 Hz, where the agreement is almost perfect. Increasing the resolution to 12.5 Hz (bandwidth 6.5 KHz) introduced errors up to 5 and 20 per cent for the pressure and accelerometer signals and 70 per cent for the generator. Increasing the resolution using the zoom transform reduced the errors noticeably (figure 3) but the source reference under estimates the level at the highest peak by 10 per cent. This may be partly due to the sequential acquisition procedure.

CONCLUSION

A selective intensity method has been presented which gives good results for wooden structures proving sufficient care is taken in choosing the reference signal and resolution. This will be implemented on a full size model now under construction to measure flanking transmission characteristics.
The reference signal required is best provided by the pressure signal in the source room but work is being carried out to improve the quality of results using the source generator to improve noise rejection characteristics.

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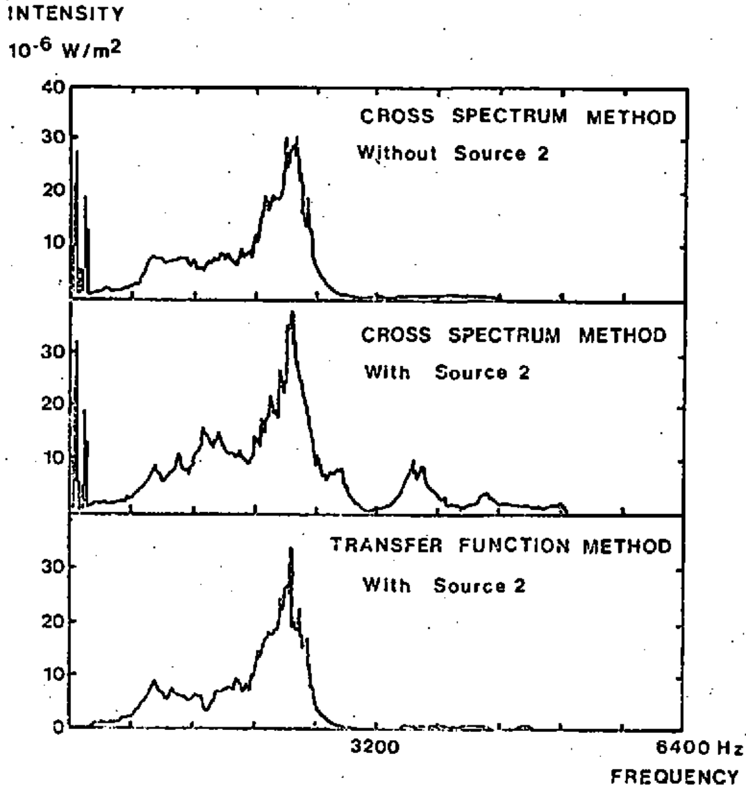
FIGURE 1



A comparison of the effects of a parasite noise source of the measured intensity using the standard and selective techniques

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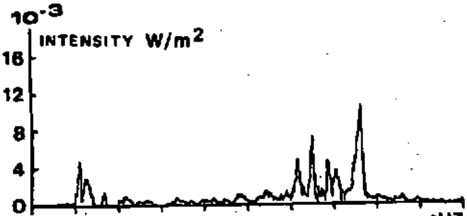
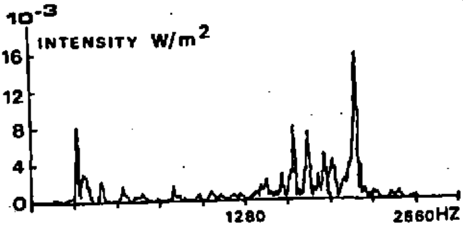
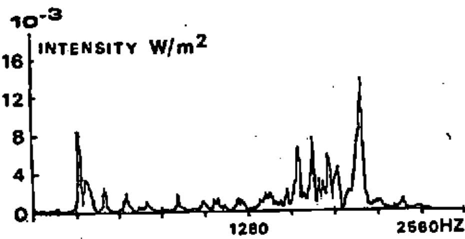
FIGURE 2



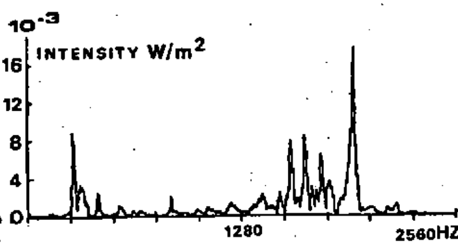
A selective (reference source)



B Selective (reference micro)



C Selective (reference accelerometer



D Standard cross spectral method

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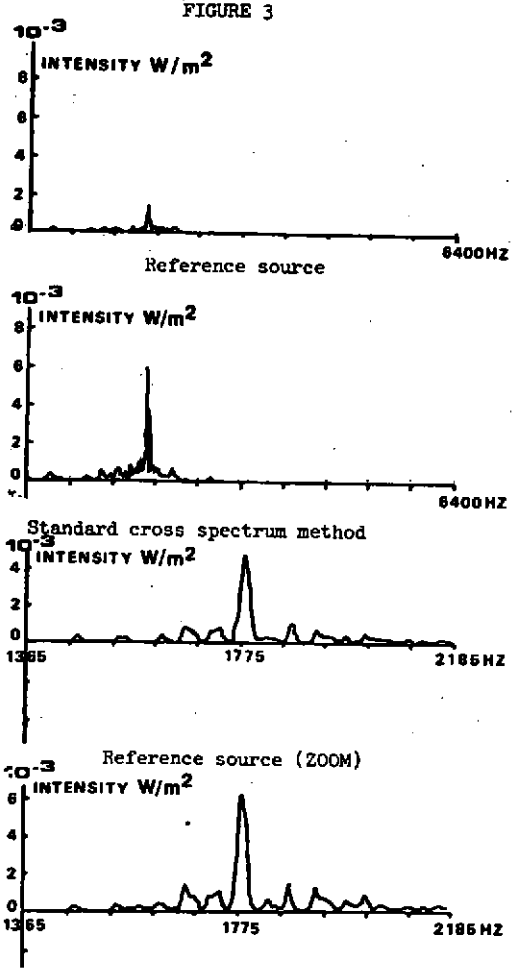
FIGURE 3



Standard cross spectrum method (ZOOM)

Intensity spectrum with and without zoom transform