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A COMPARISON OF SOUND INSULATION MEASUREMENTS USING FFT SYNTHESISED AND ANALOGUE 1/3 OCTAVE FILTERS

G. Rock

Somerset Scientific Services, Somerset County Council
County Hall, Taunton, TA1 4DY

1 INTRODUCTION

Using the most basic noise measuring equipment, a sound level meter and 1/3 octave filter set, sound insulation measurements are tedious and very time consuming. Determination of the impact and airborne insulation of a floor can require 768 measurements and take up to one and a half days.

With the recent increase in interest in building sound insulation a growing demand for insulation measurements, especially in local authority properties, was anticipated but not to a level that would justify obtaining a building acoustics analyser. A test method was sought that would be easy, relatively quick, involve minimum extra expenditure and would conform as closely as possible to the requirements of BS 2750 [1]. This Standard specifies that the discriminating characteristics of the filters used should be in accordance with IEC 225 [2]. The department's portable FFT analyser, a Hakuto AD 3522, has a 1/3 octave synthesis facility and test measurements were made to compare results using the analyser with those obtained using analogue filters.

2 ANALOGUE FILTERS and FFT SYNTHESIS

The fundamental principles of filters and FFT analysis are well explained elsewhere [3,4]. Analogue (and digital) filters produce a time signal at the output which is a convolution of the input signal and the filter impulse response. FFT analysers compute a discrete frequency spectrum from a discrete time signal sampled over a short period. The constant bandwidth bands can be converted to constant percentage bands but adjacent bands will be computed from different numbers of spectral lines. This can give rise to detrimental effects described below.

The AD 3522 can synthesise 1/3 octaves in two ranges of 29 bands. The high range produces bands with centre frequencies from 20 Hz to 12.5 KHz which means the required test range of 100 Hz to 3,150 Hz is covered in one spectrum. The spectrum is computed from three linear spectra with ranges 200 Hz, 2 KHz and 20 KHz. The time for the production of a spectrum is about 4 seconds. The synthesised filter characteristics are within the specifications of ANSI class III Standard and thus within IEC 225.

Analysis and 1/3 octave synthesis by FFT gives rise to the following effects:

a) *The analysis is not in real-time. Each spectrum is produced from short 'snap shots' of the time signal.*

b) *The Fourier transform of the time window produces sidelobes or 'leakage' that reduce the selectivity and effective dynamic range.*

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c) *Errors in level linearity can accumulate in those bands composed of a large number of spectral lines of low level.*

d) *A higher electronic noise floor exists in those bands composed of a higher number of spectral lines.*

e) *Where the 1/3 octave spectrum is composed from two or more linear spectra the steepness of the filter flanks can differ. At the boundary between two successive decades the steepness ratio will be 10:1 even though both may fall within the tolerances specified for the filter class [3].*

3 TEST MEASUREMENTS

Test measurements of two floors were conducted. These were both simple wood joist floors in a two storey school classroom block. The rooms were square with floor dimensions of 7x7 metres. Airborne sound insulation was measured in the downward direction. The measurement procedure followed was that specified by BRE [5]. For the analogue method the 16 band levels were measured as Leq (5s) and recorded manually at each of the six microphone locations. (This procedure is required 7 times; for source room levels, for receiving room background and airborne levels and 4 times for impact sound levels.)

The test procedure was repeated using the FFT analyser and the output from the B & K 2231 SLM. Averages of 16 spectra were recorded at each microphone location. The analysis was paused and the microphone moved. The averaging was then continued so that after the sixth location a single spectrum level listing was obtained from the analyser's printer. The procedure took less than 10 minutes for the airborne sound and about 30 minutes for the impact sound levels.

The impact noise and the low frequency end of the airborne noise spectrum produce time signals with rapid fluctuations. Experiments with the FFT analyser showed little change (0.1 dB) in the 1/3 octave band levels after the sequential averaging of 8 spectra. It was expected that for a random noise signal the averaging procedure would compensate for a) above, the non real-time analysis.

Effects b) and e) above might be expected to be detrimental in the measurement of spectra with steep slopes. In these tests the maximum slopes (occurring at 800 Hz) were about 80 and 70 dB/decade for the receiving room airborne and impact noise spectra. With a Hanning time window the sidelobe fall-off rate is 60 dB/decade so some detrimental effect in the bands around 800 Hz was expected.

Effect d) above, the instrument noise, was most critical in the 1.6 KHz band. It did not interfere with the airborne sound level measurements but the high overall level of impact noise meant a sufficient dynamic range could not

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be achieved. By switching in the 'A' weighting network of the SLM a reduction of 10 dB was obtained allowing the measured spectrum to be 'lifted' clear of the noise floor. Levels in the 5 highest bands were then obtained by correcting for the 'A' weighting applied. This necessitated repeating the procedure for the impact noise spectrum but by averaging only 8 spectra at each microphone location the extra time needed was reduced to about 15 minutes.

Reverberation times were calculated from decay curves recorded on a level recorder.

4 RESULTS

Figures 1 and 2 show the standardized level difference and standardized impact sound pressure level curves for the two methods and the two floors. The level difference curves show close agreement in most bands and although discrepancies of up to 5 dB appeared, the single number values of DnT,w were the same for one floor and differed by 1 for the other. The impact sound level curves also show close agreement except in the 4 highest bands. The single number values L'nT,w were the same in each case. These values were governed by adverse deviations in the region below 500 Hz where agreement was good. The poor results at the high end of the spectrum did not influence the L'nT,w values. These poor agreements may have resulted from the limited dynamic range and the subsequent 'A' weighting applied. Better results might have been obtained if a high pass filter had been available.

5 FURTHER TIME SAVINGS

Reverberation times were calculated from decay curves recorded using a B & K type 4224 sound source and type 2306 level recorder. The modular type 2231 SLM has now been equipped with a reverberation processor module. The processor generates tone bursts through the sound source and computes the reverberation time by a reverse integrated impulse response method. This system is semi-automated and affords a useful saving in time. The operation requires only the transfer of the microphone to the next position and a visual check that the processor has not reported any measurement error. Sets of results are retained in the memory until the end of the operation when they are transferred to an Epson PX-4 portable computer. The Epson is also used to compute the values DnT,w and L'nT,w according to BS 5821 using programs written in BASIC [6]. Final results can therefore quickly be obtained on site.

6 CONCLUSION

Despite the fundamental differences in frequency analysis by filters and FFT the comparison of sound insulation measurements gave encouraging results. The whole test can be carried out by one operator in about 2.5 hours which *means the use of hired equipment such as the tapping machine can be optimised. The additional equipment required cost much less than a building acoustics analyser. In cases where full compliance with BS 2750 is not essential this FFT procedure is regarded as a useful 'quick' method. For example, it has been used to determine whether the benefits of remedial insulation works are sufficient to justify the cost.*

The procedure could be further automated by controlling the analyser and the B & K 2231 from a computer which would also calculate the results, including graphs, in-situ.

REFERENCES

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Part 4: Field measurement of airborne sound insulation between rooms.
Part 7: Field measurement of impact sound insulation of floors.
(Equivalent to ISO 140/IV and 140/VII - 1978)

[2] BS 2475:1964 Specification for octave and one-third octave band-pass filters (equivalent to IEC 225:1966) British Standards Institution

[3] Randall R B & Upton R Digital filters and FFT technique in real-time analysis. Bruel & Kjaer Technical Review No. 1 - 1978

[4] Thrane N The discrete fourier transform and FFT analysers. Bruel & Kjaer Technical Review No. 1 - 1979

[5] Fothergill L C Recommendations for the measurement of sound insulation between dwellings. Applied Acoustics 13 (1980) 171-187

[6] BS 5821:1984 Rating the sound insulation in buildings and of building elements.
Part 1: Method for rating the airborne sound insulation in buildings and of interior building elements.
Part 2: Method for rating the impact sound insulation.

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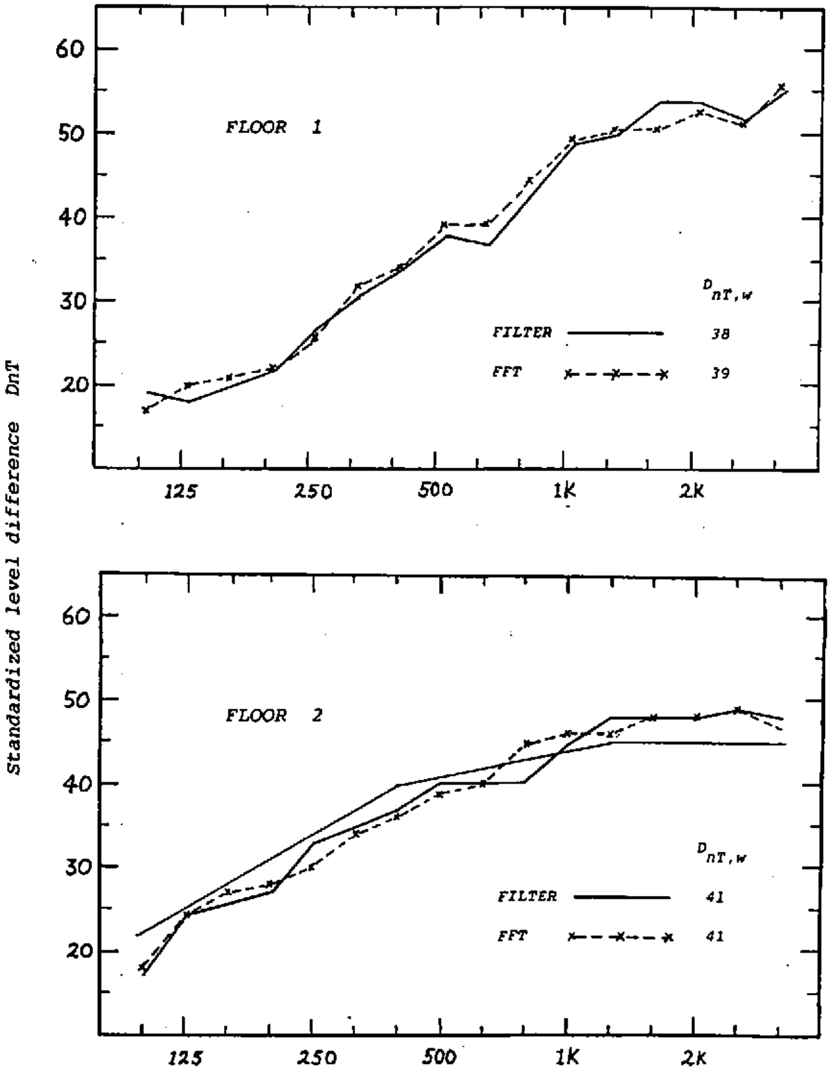

Figure 1 AIRBORNE SOUND INSULATION

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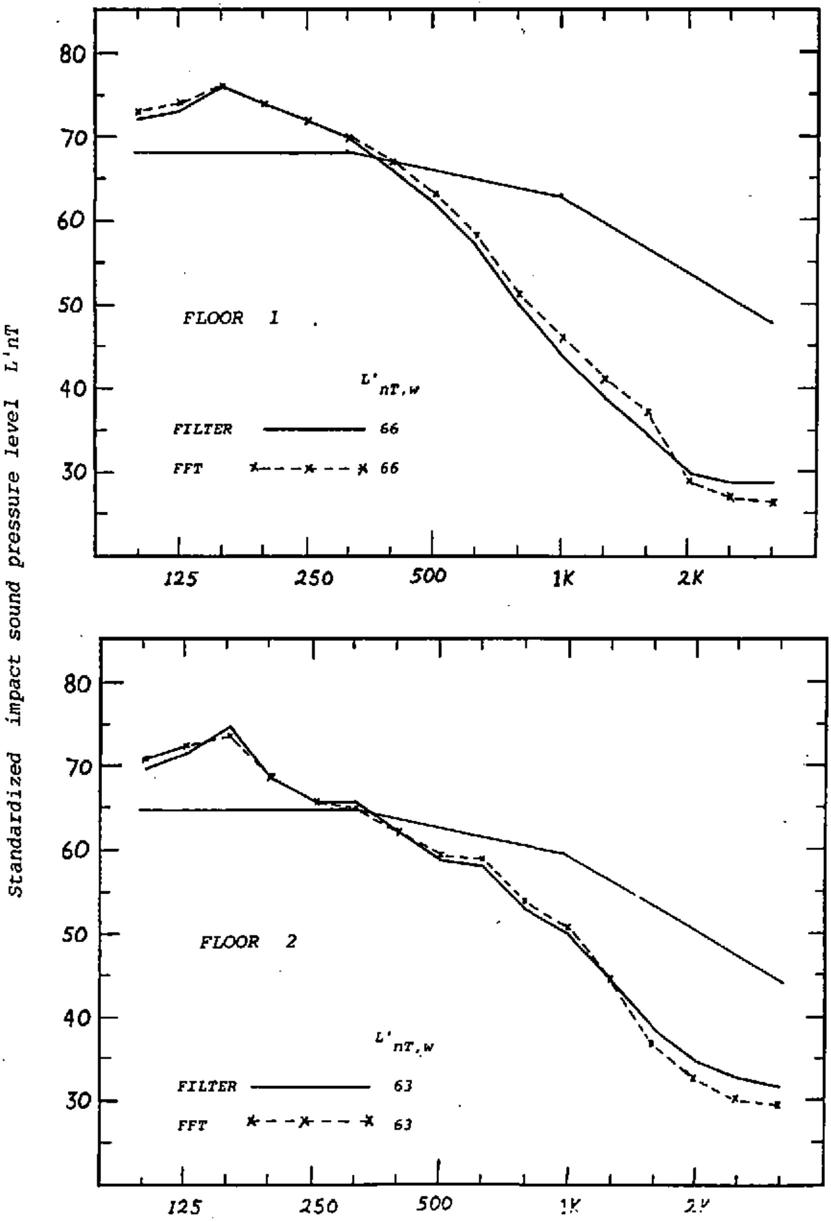

Figure 2 IMPACT SOUND INSULATION