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SELECTIVE ACOUSTIC INTENSITY MEASUREMENTS OF THE RADIATION OF SURFACES SUBJECT TO SINGLE OR MULTIPLE EXCITATIONS

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INTRODUCTION

It is becoming standard practice to perform direct measurements of the acoustic intensity for many types of diagnostic work. The principal advantage of measuring acoustic intensity directly is the possibility of estimating the acoustic power radiated by a noise source in situ and of identifying the regions radiating the most noise. It is therefore possible to take more appropriate remedial action to reduce the noise radiated by industrial machinery or other noise sources after thorough investigation using intensity measurements.

The two microphone technique of acoustic intensity measurement increased dramatically in popularity with the advent of the direct cross spectrum formulation first suggested by Fahy [1]. The advantage of this method is that the dual channel analyzer required was already available in most laboratories and any corrections for differences in phase response of the microphones could be easily calculated and applied. Since this date alternative systems permitting a real time analysis have been developed, but the direct cross spectrum method is still sufficient in the majority of cases.

One of the disadvantages of standard acoustic intensity techniques is the inability ot distinguish between the origins of the radiated noise when several sources are in close proximity. This disadvantage is minimised by making the intensity measurements close to the radiating surface to reduce the effects of other parasite sources. In cases where the measured intensity levels are low or where parasite sources have similar intensity levels to the principal source it is desirable to have same means of separating the contributions of each source. The selective intensity technique provides a method of separating the contributions of different sources by using a source reference signal to condition the cross spectrum calculation of acoustic intensity. This paper describes the results obtained and the difficulties encountered in applying this method to separate uncorrelated sources in acoustic transmission measurements.

PRINCIPLES OF THE SELECTIVE TECHNIQUE

The direct cross spectral method permits the calculation of the active acoustic intensity using the very simple relationship

$$I = \frac{I_m\{G_{12}\}}{\rho\ \omega d} \tag{1}$$

where $I_m\{G_{12}\}$ is the imaginary part of the cross spectral density between the two microphone signals, ρ density, ω the angular frequency and d the separation distance of the two microphones. If a single source s is present, the cross spectrum may be calculated in terms of the complex conjugate of the transfer function between the source and the first microphone H^*_{S1} and the cross spectrum between the source and the second microphone G_{S2}

$$G_{12} = H^*_{S1} \cdot G_{S2} \tag{2}$$

This expression conditions the cross spectrum so that the value obtained is uniquely associated with the source by means of the source reference signal. Providing that other noise sources are uncorrelated with this reference signal the cross spectrum calculated in this way will permit the estimation of the acoustic intensity associated with this source.

The cross spectrum any also be calculated using the transfer function between the source and the second microphone H_{S2}, associated with the autospectral density of the source G_{SS}

$$G_{12} = H^*_{S1}.H_{S2}.G_{SS} \tag{3}$$

This expression is particularly useful when dealing with several partially coherent sources because the values of H^*_{S1} and H_{S2} will then have to be calculated using the appropriate partial coherent techniques associated with reference signals of each source. This method has been applied by Bucheger et al. [2] to try and separate partially coherent sources but the risks of errors in the calculation of the phase relationships would seem to limit its practical application.

At Compiegne, only the simplest method for independent sources is being investigated in order to understand the practical problems involved.

EXPERIMENTAL TECHNIQUES

The most recent experiments have been carried out on the outer surfaces of a chip board box 1.60x.80x.70m which was excited by two loudspeakers suspended in opposite corners within the enclosure. Each loudspeaker was fed by an independent white noise generator and power amplifier. In order to obtain independent source reference signals the output signal of each noise generator was used as a reference to calculate the intensity due to each source.

The intensity measurements were made in a direction normal to the outer surface of the box. The enclosure was suspended in an anechoic room to avoid the effects of interference from other sources enabling direct comparisons to be made between the direct cross spectrum method and the selective technique.

Previous investigations have already noted the disadvantages of using the loudspeaker input as a reference signal [3], but in the dual source situation it is essential to avoid any kind of mutual interaction between the source reference signals which can occur with microphone singals. The most important parameters determining the quality of the measurements in this case are the time taken for all the multiple reflections of the output signal to finally radiate to the outside, the coherence between the signals and the frequency resolution. Most of these problems can be resolved by the use of long transform lengths to calculate the spectral quantities required. In this case,use was made of the 'zoom' transform to increase the resolution and transform time and the frequency range was covered by shifting the zoom centre frequency the appropriate amount each time. It is normally preferable to make the acquisitions of all the signals required at the same time, but here the acquisitions were made sequentially two at a time using a dual channel analyzer. The spectra were then transferred automatically to a mini-computer for the subsequent calculation of the acoustic intensities. This method was chosen because of limitations imposed on the length of data records that could be acquired directly on the computer via the multi-channel ADC.

Initial measurements indicated that the coherence between the input and output signals was relatively low and therefore the number of averages required to obtain good estimates of the spectral quantities involved was relatively high. It was also noted that the selective method was much more affected by the distance between the microphones than the direct technique. In fact the higher level of errors involved in the selective techniques makes it much more important to optimize the distance between the microphones to have the maximum phase difference for a given frequency range. The results presented here were obtained using a distance of 20mm between the microphones but other measurements have shown that the low frequency accuracy is improved by increasing the distance.

RESULTS

The most significant difference between the selective technique and the direct cross spectrum calculation is the problem caused by the low coherence between the signals that is encountered with the selective technique. For the frequency band between 1280Hz and 2920Hz it can be seem that the coherence between the two microphones is close to unity over the whole range (Figure 1), whilst for the selective technique the coherence between the input reference signal and the first microphone is much lower (Figure 2). These results were obtained with only one source in action. When the second independent internal source is switched on, the coherence between the two microphones is not affected to any great extent, if anything there is an improvement (Figure 3), but the coherence between the first source and the first microphone is reduced (Figure 4). The errors are therefore increased and it is important to average a sufficient number of spectra to obtain the required accuracy. In this case the results are the sum of 64 averages whereas the direct technique would normally require far less than this to minimize the errors.

In Figures 5 and 6 the spectrum of the intensity measured over the frequency range from 1280Hz to 2920Hz is presented using first the selective and then the direct cross spectrum technique for a point situated close to the outer surface. It can be seen that they are extremely close, bearing in mind the fact that the measurements were not carried out at the same time and that the scales are linear. This measurement was carried out with excitation of the first source only. In Figures 7 and 8 the measurement is performed using the same level of excitation for the first source but with the addition of the second source. It can be seem that the effect on the results obtained using the selective method (Figure 7) is negligeable, the spectrum is very close to the results calculated previously for the single source. For the direct cross spectral method however,the effects of the second source have completely changed the characteristics of the measured intensity spectrum (Figure 8).

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The results discussed above cover a limited range of frequencies. It was therefore necessary to repeat the analysis over the higher and lower frequency bands using the zoom transform. In each case it was found that the results were slightly less satisfactory due to an increase in the errors in the selective technique. These errors were not linked to the presence of the second source because the levels of intensity measured by the selective technique were comparable in each case. The principle reason seems to be the problems involved in obtaining the ideal conditions of analysis for a selective measurement. The intensity measured using the selective technique is always lower than the direct measurement. These errors hawever are relatively small in most cases and can be reduced by optimizing the intermicrophone distance to obtain the maximum phase difference for the frequency range being measured. Figures 9 and 10 show the measured intensity with the single source using the selective then the direct technique. Figures 11 and 12 show the same measurements with the second source in action. It can be seen that the selective technique in Figure 11 is unaffected by the second source. Similar results ware obtained for the high frequency range. For the complete range from 180Hz to 4190Hz the intensity calculated using the selective technique is given in Figure 13.

CONCLUSIONS

Although the selective intensity technique is relatively difficult to apply, it seems to offer certain advantages over the direct method for multiple source situations. The results indicate the need to optimize the transform lengths and the intermicrophone distance to obtain the least degree of error in the measurements. The work is continuing on methods of improving the quality of the results in more realistic conditions.

REFERENCES

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[3] P.R. Wagstaff et al. "The Measurement of the Acoustic Transmission characteristics of wood frame walls using selective intensity techniques"
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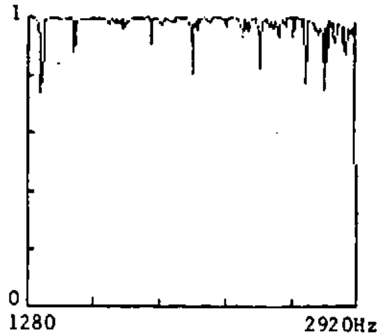

Fig. 1-Coherence between microphones single source

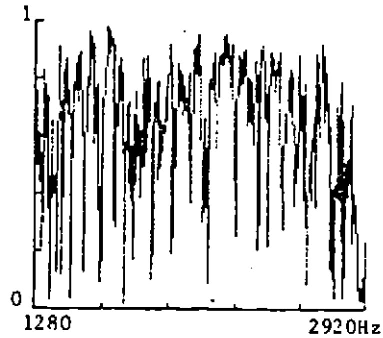

Fig. 2 - Coherence between single source and first microphone

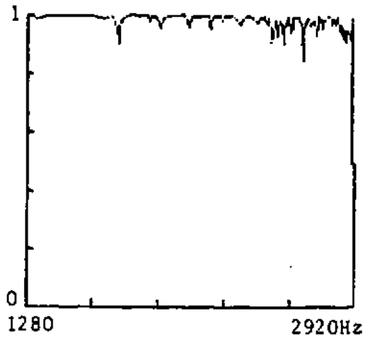

Fig. 3- Coherence between microphones two sources

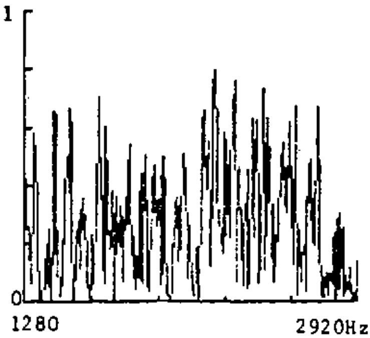

Fig. 4 - Coherence between first source and first microphone, two sources in action

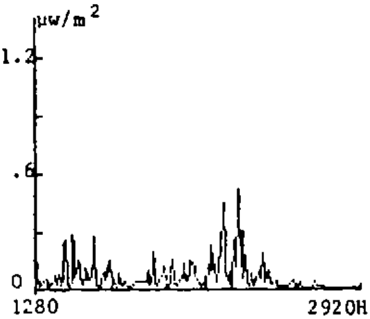

Fig. 5 - Selective intensity single source

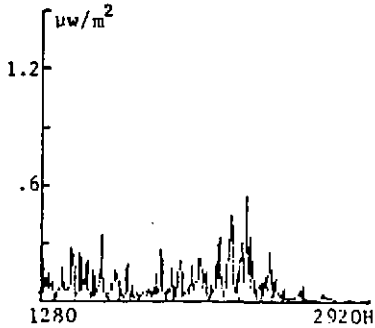

Fig. 6 - Direct intensity single source

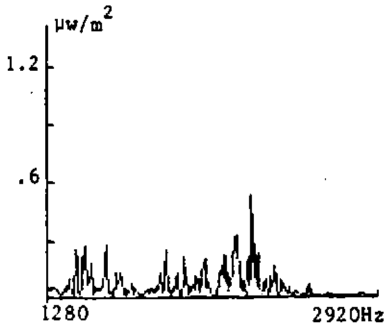

Fig. 7 - Selective intensity with both sources in action

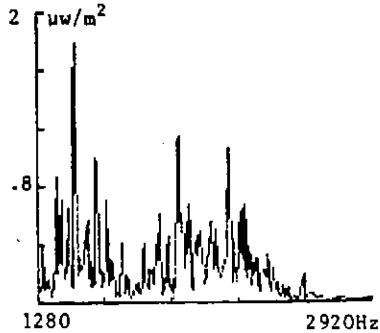

Fig. 8 - Direct intensity with both sources in action

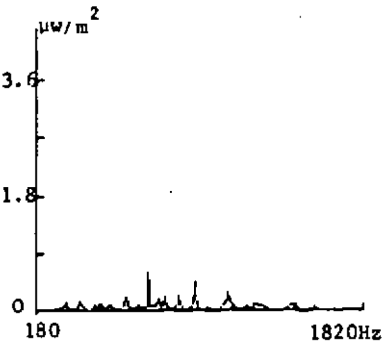

Fig. 9 - Selective intensity single source

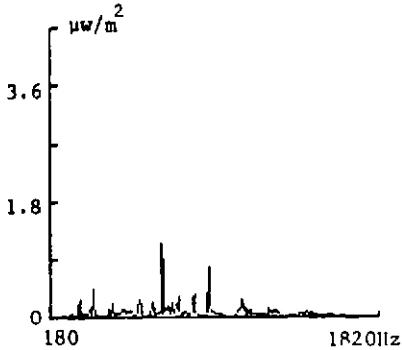

Fig. 10 - Direct intensity single source

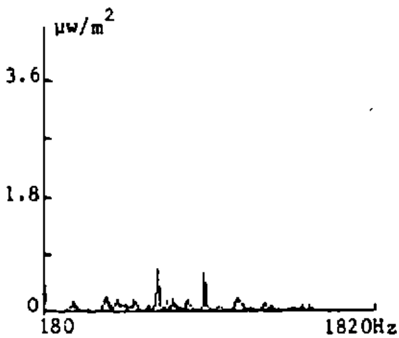

Fig. 11 - Selective intensitive with both sources in action

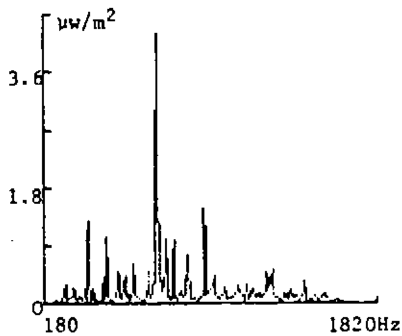

Fig. 12 - Direct intensity with both sources in action

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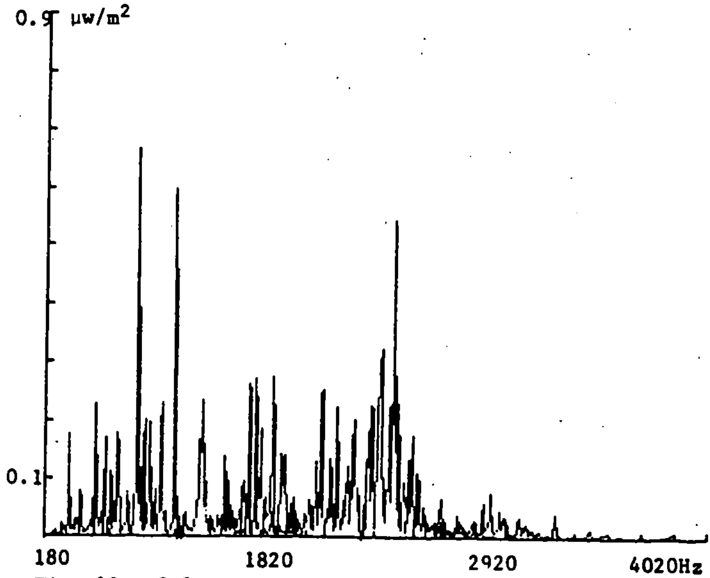

Fig. 13 - Selective intensity over whole frequency range both sources in action