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THE EFFECTS OF INTERMICROPHONE INTERFERENCE IN ACOUSTIC INTENSITY MEASUREMENTS

P.R. Wagstaff, R. Pech, J.C. Henrio

Universite de Technologie de Compiegne - France

INTRODUCTION

Most methods of measuring acoustic intensity rely on the use of the signals captured by two closely spaced microphones in the near field of the source. The acoustic power can be measured in situ and the areas radiating the most sound energy may be identified directly. The acoustic intensity is most easily calculated using the cross spectrum between the two microphone signals [1], but whichever method is used, the pressure and phase relationships between the microphones must be measured with a high degree of precision to obtain an accurate result. Phase matched microphones and amplifiers or appropriate correction techniques must be used [2]. One of the errors that cannot be corrected for in this way is the effect of the presence of the microphones on the sound field and the interference effects between the two microphones. Measurements of these effects for the side-by-side microphone arrangement have given results that were inferior to the face-to face arrangement. In each case these effects have been measured by generating a plane wave in a anechoic room and measuring the phase difference between the two microphones. The differences noted when comparing the theoretical phase difference between the microphone positions and those actually measured were then presumed to be due to the interference effects [3,4] In fact the errors measured are due to the totality of the effects of interference between the microphones and the support and it is not possible to assess the effects of the microphones alone. The differences noted between the performance of different microphone arrangements could then be due to the differences between the supports in each case and not to the inherent nature of the microphone disposition.
The method introduced here permits the interference effects of the microphones to be directly measured, not only in an anechoic room, but also in a normal industrial environnement and in the far or near field of any source.

PRINCIPLES OF THE METHOD

The acoustic intensity may be calculated from the cross spectrum between the two microphone signals using the following relationship

$$I = \frac{Im\{G_{12}\}}{\rho\omega d} \quad (1)$$

where I, the intensity, is calculated from the imaginary part of the cross spectral density $Im\{G_{12}\}$, divided by the density ρ, the frequency in rad.s^{-1} ω, and the distance between the microphones d.

As shown in a previous papers [5,6] it is possible to obtain a selective measure of the acoustic intensity by calculating the cross spectrum indirectly using a reference signal which conditions each microphone signal using only that part of the signal coherent with the source reference signal.

$$G_{12} = H^*_{S1} \cdot G_{S2} = H^*_{S1} \cdot H_{S2} \cdot G_{SS} \quad (2)$$

where G_{12} is the cross spectrum between the two microphone signals, H^*_{S1} is the complex conjugate of the transfer function between the source reference signal and the first microphone G_{S2} and H_{S2} are the cross spectrum and transfer function between the source reference and the second microphone respectively and G_{SS} is the autospectrum of the source reference signal.

If the quantities H_{S1} and G_{S2} are calculated in successive acquisitions the value of H^*_{S1} may be measured in the presence of or in absence of the second microphone. Similarly the value of G_{S2} may be calculated with or without the first microphone. The necessary conditions for this technique to be applied are that the source must be stationary and the milieu stationary. The comparison of the intensity contaminated by interference effects I_c, an the intensity with the interference effects removed I_r, gives a direct measurement of these effects and their importance in different source environments. Because of the sequential nature of the acquisitions the measurements are subject to increased statistical errors in comparison with simultaneous acquisition of all three signals or direct acquisition of the cross spectrum. The effects of interference are still visible as a modification of the mean value of intensity over a certain frequency range or deterministic variations around the mean value of a different nature to the statistical variations.

MEASUREMENT PROCEDURE

A first set of measurements was made in an anechoic room using a loudspeaker as a source at 1.5m from the intensity measurement probe using a side-by-side arrangement. A white noise generator drove the loudspeaker through a power amplifier and the output of the noise generator was used as a reference signal. The signal processing was carried out using a Nicolet 660A dual channel analyser coupled to a PDP 11/23 computer. An initial acquisition was performed with one microphone only in position. The second and third acquisitions were made with both microphones in position and the fourth acquisition was performed after the first microphone had been removed. This ensured that the position of the microphones was the same for the conditions with and without the other microphone in place. The stand supporting the microphone mounting blocks was also extremely heavy and rigid to ensure that the position of the microphones was not changed during the operations of replacing and removing the microphones. Two standard $\frac{1}{2}$" microphones (B & K type 4133) were used, mounted on their pre amplifiers (type 2619) which were clamped in two unsymmetrical support blocks measuring approximately 25x35x20mm with a distance of 52mm between the mounting blocks and the microphone grid. The nominal separation distance between the microphones was 20mm. The intensity was measured using the technique indicated above in the axis of the source and then at an angle of 45°. The $\frac{1}{2}$"microphones were replaced by $\frac{1}{4}$"microphones (B &.K type 4135) using suitable adapters to the pre amplifiers which displaced the microphones grids to a height of 121mm above the mounting blocks but preserved the same spacing between the two microphones. The intensity was measured using the same technique as before.

INITIAL RESULTS

The results using these measurement conditions are reported in reference [7]. Figure 1a shows the intensity measured with both $\frac{1}{2}$ "microphones in place in the source axis and 1b when only one microphone was in position for each acquisition. Figure 2 shows the ratio of these results. It can be seen that apart from the statistical variations there is no discernable difference between the two measurements indicating that the interference effects between the microphones are negligeable for the frequency range examined. When the measurements were performed at 45° the only difference apparent in the intensity ratio (Figure 3) is an increased statistical variation between the measurements, but again no discernable trend due to interference effects can be observed.

The result with the $\frac{1}{4}$"microphones placed in the source axis again produces a similar result to these indicated above (Figure 4).

It may be concluded that in the cases examined previously by standard techniques the variations observed in the phase difference between the microphone signals were essentially due to the effects of the support.

INVESTIGATION AT HIGHER FREQUENCY

The original mounting blocks did not permit the microphones to be placed closer together and a new series of measurements was undertaken with a support permitting a choice of microphone spacings of 21mm and 13mm for the $\frac{1}{2}$"microphones.

The measurements were repeated for a spacing of 21mm for the lower frequency range and a this time as small but well defined difference was noted between the measurements with and without the second microphone. Here the comparison is made by calculating $\frac{I_r - I_c}{I_r}$ where I_r is the intensity with the second microphone removed and I_c the intensity with both microphones in place (Figure 5). The effect of measuring with both microphones in place is to increase the intensity slightly over the whole frequency range, but with a maximum difference of the order of 10%. This result is perhaps due to a secondary interaction of the support with the microphones. In this case the support was no larger than before but was symmetrical about the line joining the centres of the two microphones and was in the form of a plate rather than a block.

At a spacing of 13mm the results were similar if more pronounced in the lower frequency range and in the higher frequency range the measurements with both microphones in place gave a lower result for the measured intensity (Figure 6). The maximum difference between the mean levels was of the order of 30% in this case. At an angle of 45° to the source the differences were only noted in the low frequency range with a maximum difference of the order of 15% - 20% (Figure 7).

The source was then moved to a laboratory with relatively reflective horizontal and vertical surfaces. The intensity was measured using the $\frac{1}{2}$"microphones with a spacing of 13mm and at a distance of 1m from the source. The intensity spectrum was modified by the reflections from the floor and other surfaces (Figure 8) but the differences between the measurements with both microphones in place and these with only one microphone (Figure 9) were almost identical to the results found in the anechoic room (Figure 6).

Lastly a face-to face arrangement was tested back in the anechoic room using a Brüel and Kjaer type 3519 probe with a spacing of 12mm. In order to try and correct for the absence of the spacer which normally blocks the direct entry of sound waves in the axis of the microphone the grid was covered with plastic tape during the measurements with only one microphone. The results were disappointing (Figure 10) because the differences between the measured values of intensity were extremely large, of the order of 120%. This is certainly due to the effects of the tape rather than interference effects because the probe as a whole has much lower errors than this. The measurements will be repeated using different means of blocking the direct incidence.

CONCLUSIONS

The results show that under most conditions the effects of intermicrophone interference are either negligeable or relatively small as measured by this new technique. The test conditions have been limited to a few simple cases, but the method can be applied to any situation for the side-by-side arrangement. For the face-to face arrangement the problem of obtaining exactly the same conditions of measurement for the single microphone and two microphone cases reeds to be resolved before applying the technique to more complex sound fields. Further work needs to be carried out to evaluate the secondary effects of the microphone support.

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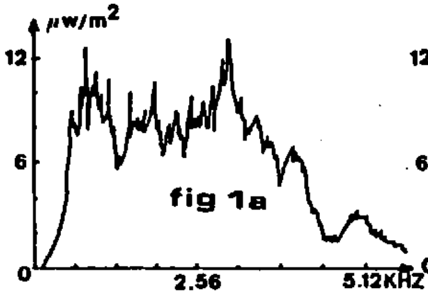

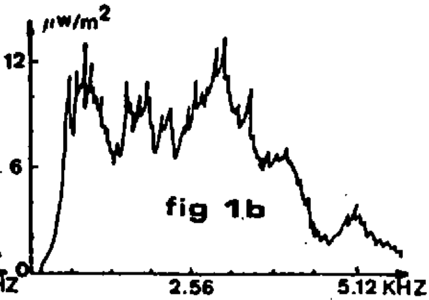

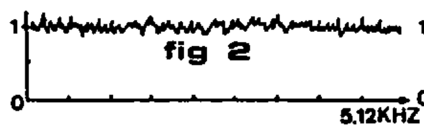

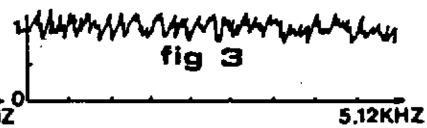

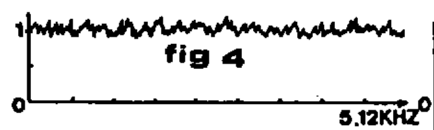

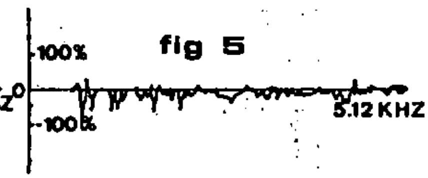

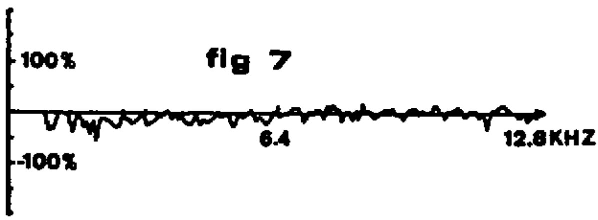

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