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EXPERIMENTAL VALIDATION AND OPTIMISATION OF PARAMETERS FOR AN INVERSE METHOD OF IDENTIFYING SOURCES

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1. INTRODUCTION

The identification of the strengths and spatial positions of acoustic sources is an essential task in order to enable noise to be reduced. Direct identification of contributions to the output may be possible from spectral data for partially coherent inputs, but the power of the inputs is unavailable. Indirect or inverse measurement techniques may, however, be used to obtain this information from the output response but only if the frequency response functions between the sources and the output points can be measured. The identification is possible even when the sources are partially or fully coherent. Experiments applying this technique have been carried out on a small burner of a wall mounted domestic central heating boiler in order to find a suitable source model representing the flame noise. Reciprocal measurements of the frequency response functions of the source transmission paths were used. In this application direct measurements are impossible because the sources are situated in a small combustion chamber and subject to high temperatures. Some preliminary results of the identification of a source distribution equivalent to the flame noise were presented in INTER-NOISE 95 [1].

This paper presents and analyses the results of a number of laboratory experiments that were performed in order to validate and optimise the method using controllable and verifiable artificial sources (two small loudspeakers) in an enclosure. The enclosures tested were the combustion chamber of the burner and the boiler itself.

Singular value decomposition was used to calculate the pseudo-inverse of the frequency response matrix needed for the calculation of source strengths as well as to optimise the experimental techniques.

2. PRINCIPLES OF THE INVERSE TECHNIQUE

The principles of applying the inverse technique have already been given in publications by several authors and also the paper presented in INTER-NOISE 95 [1]. For a linear Multiple Input Multiple Output system the relationship between the matrix [Gmm] representing the response output spectra and [Gss] which is the matrix representing the equivalent sources is given by :

$$[G_{ss}]=[H_{sm}]^{H+}[G_{mm}][H_{sm}]^{+} \quad (1) \text{ and its inverse } [G_{ss}]=[H_{sm}]^{H+}[G_{mm}][H_{sm}]^{+} \quad (2)$$

where $[H_{sm}]$ is the matrix of the frequency response function relating the different sources to the pressure at each output point. $[Hsm]^{H}$ represents the hermitian transpose of $[H_{sm}]$ and "+" the pseudo inverse operation.

The required response functions are measured reciprocally. A monopole source is placed at each output point and the frequency response functions are measured between this source and each pressure transducer at the chosen source (speaker).positions to obtain the frequency response function matrix.

The measurement of the response spectral matrix at the output points together with the inverse operation on the previously measured frequency response function matrix enables the equivalent source strengths to be calculated

3. EXPERIMENTAL IMPLEMENTATION

The two speakers produced a sound power level of approximately 80 dB each using broadband noise. The identification of the number of independent sources was studied whilst varying several parameters such as the type of enclosure, the relative power level of the sources, the correlation between sources and spatial separation and numbers of output response locations.

The two sources to be modelled were tested in 3 different configurations, with no enclosure, in the combustion chamber of a burner and in the boiler itself.

A microphone representing the source position was placed above each of the two speakers. Four to seven response microphones were placed in appropriate positions around the sources after measuring frequency response function matrix.

4. RESULTS

The number of independent sources was identified from the singular values. The level of the speaker S1 was kept constant whilst varying the level of S2. The two sources were placed in the chamber and four response microphones were used. The independence of the two speakers is indicated by the close spacing of the singular values of the response spectral matrix in figure 1.

The spectra representing the singular values show that there are only two independent sources. The two first spectra are close and much higher than the others. When the level of speaker S2 drops to tenth of its previous value there is no change in the first singular value but the second drops in proportion to amplitude as shown in figure 2.

When the speakers were supplied with an identical white noise signal the inputs were fully correlated.and the first singular value dominated similarly to the case in figure 2.

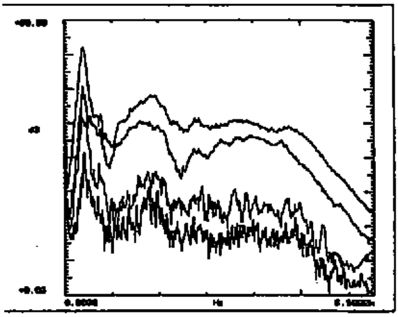

Figure 1 : Drop of the second singular value withthe drop of the level of speaker

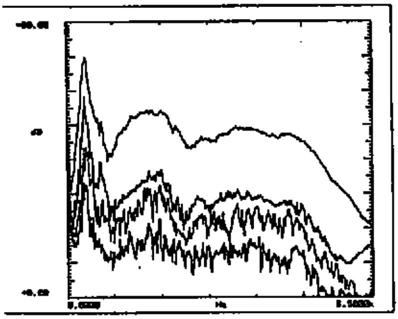

Figure 2: Response singular values S1>>S2

Identification of source strength

The identification of source strength was made with both sources operating in the combustion chamber and compared with those obtained in freefield conditions.

Figure 3 shows the result obtained for S2 when the source strength is a) four times greater than S1 and b) equal to S1. The reduction of S2 with reduced power input is exactly as expected and corresponds well with freefield results. the enclosures used.

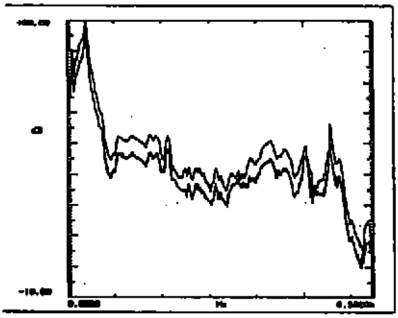

Figure 3: S2 identified at different levels

Location of an extra source

Locating the position of an extra source is possible if the frequency response functions are measured correctly. An additional smaller point source was placed in the centre point of the speaker S2. The spectrum representing the source strength of S1 was unaffected, but S2 increased in the frequency range corresponding to the parasite source as shown in figure 4.

The frequency response functions had to be measured with the parasite source in place to obtain this result.

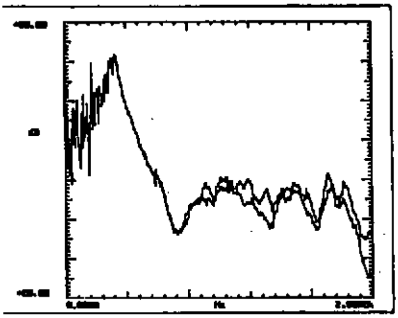

Figure 4. Identified source with parasite

As the source was moved from the centre of S2 the result changed markedly and the energy was spread over the two identified source reference points in a random fashion. It is necessary to have accurate frequency response functions to obtain satisfactory results and even small changes close to the sources affect results.

5. CONCLUSIONS

The experiments carried out on this system with two speakers showed that the determination of the number of independent sources is valid using the singular value decomposition of the output response data. Equivalent source strengths were found to be close to real ones when using the inverse technique and output response matrix associated with a previous reciprocal measurement of the frequency response functions. Even when the sources are fully correlated a model of equivalent sources can be found. This is only possible if the spatial information is sufficient to overcome the lack of information in the source signals. The validity of the spatial data can be checked by determining the singular values of the frequency response function matrix which determines the limits of resolution for both the output and input or equivalent source positions.
The change in the environment around the sources did not appear to modify the calculated source strengths except for the effects of resonances of the enclosures which existed in certain configurations.
The possibility of locating a third parasite source was demonstrated providing the frequency response function was valid. Since significant changes in these functions occur for small modifications to the environment the process of reciprocal measurements had to be repeated to obtain good results.

6. REFERENCES

[1] : "Characterisation of flame noise in the burner of a domestic central heating system by inverse techniques and singular value decomposition", G. Schubert, Q. Luo, P. R. Wagstaff, J. C. Henrio, A. Guedel, *INTER-NOISE 95 PROCEEDINGS*, p. 1195, (1995)