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SYNTACAN: A HIGHLY DIRECTIONAL SYNTHETIC ACOUSTIC ANTENNA FOR INDUSTRIAL NOISE MEASUREMENTS.

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INTRODUCTION

SYNTACAN is a Synthetic Acoustic Antenna that was developed at the Delft University for directional sound measurements on industrial noise sources. During the Internoise-81 Congress, we presented an outline of the theory and instrumentation [1]. Now the system is fully operational and in this paper we will demonstrate the possibilities of SYNTACAN with some practical results. Special attention will be given to the ability of the system to integrate the noise power as a function of the angle of incidence. This feature gives the possibility to measure the total sound immission from an industrial area with exclusion of the contributions from other directions.

THEORETICAL BACKGROUND

The synthetic acoustic antenna is based on the measurement of the spatial cross-correlation function of the incident wave field by means of a microphone array, as described by Nuttall et al. [2]. The spatial cross-correlation function is defined by

$$R(\xi,\tau) = \lim_{T\to\infty} \frac{1}{T} \int_0^T s(x,t)\, s(x+\xi,t+\tau)dt \tag{1}$$

where $s(x,t)$ is the sound pressure along the array axis x.
If we take $s(x,t)$ to be a monochromatic plane wave with an angle of incidence α (see figure 1), the sound pressure is given by

$$s(x,t) = a \cos[2\pi ft - 2\pi(f/c_x)x + \theta] \tag{2}$$

with $c_x=c/\sin\alpha$, where c = sound velocity and c_x = phase velocity along the x-direction. In this case the spatial cross-correlation function can be written as:

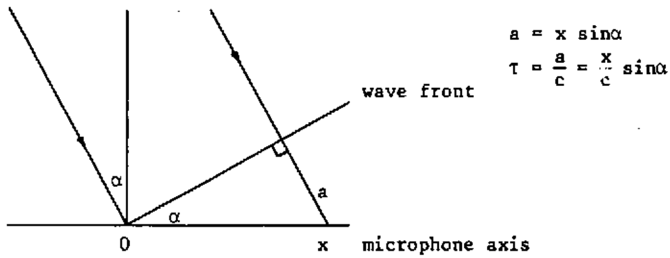

Figure 1: A plane wave, making an angle α with the microphone axis, will have a position-dependent time lag τ.

$$R(\xi,\tau) = \tfrac{1}{2}a^2\cos[2\pi f\tau - 2\pi(f/c_x)\xi]. \quad (3)$$

From eq. (3) it can be seen that $R(\xi,\tau)$ is sinusoidal both in τ and ξ. This means that an arbitrary wave field of uncorrelated noise sources can be decomposed into monochromatic plane waves from different directions by a two-dimensional Fourier transform of the spatial cross-correlation function. The first Fourier transform is from time to frequency and decomposes the total sound field into monochromatic wave patterns, each with a different frequency f. The second Fourier transform measures the spatial frequencies k_x, which are related to the angle of incidence by

$$k_x = \frac{f}{c}\sin\alpha. \quad (4)$$

THE ANTENNA CONSTRUCTION AND THE DATA ANALYSIS SYSTEM

One of the major problems during the development of SYNTACAN was to minimize the total number of microphones and yet be able to analyze a broad frequency range with a high resolving power. To compute the spatial frequencies k_x, the spatial cross-correlation function $R(\xi,\tau)$ must be measured for a contiguous set of ξ values. The increment must be small enough to avoid spatial aliasing at high frequencies and the total antenna length X must be long enough to have sufficient resolution at low frequencies. For this important reason we decided to split the measurements into 4 octave bands from 125 to 1000 Hz. By using a special microphone arrangement, it was possible to have a resolving power of 1.5° over a frequency range from 90 to 1400 Hz with (only!) 32 microphones. The microphone array is shown in figure 2. The distance between the microphones is from 0.15 m at one side, to 9.60 m at the other side of the array, which has a total length of 76.65 m. Because a one-dimensional array cannot distinguish between waves incident from front and rear, we decided to use directional

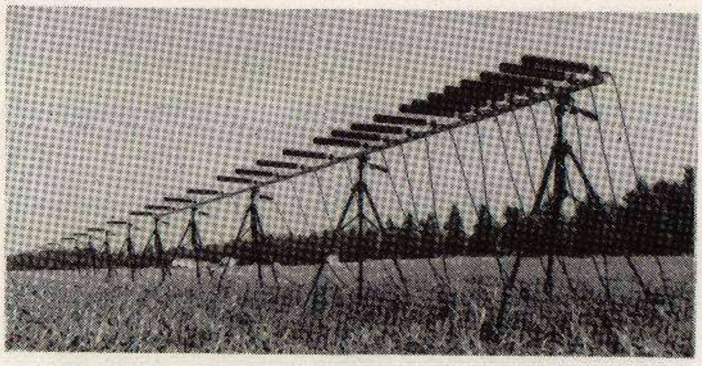

Figure 2: The antenna consists of 32 directional microphones that make up an array of ca. 75 m.

microphones with a good front/back ratio. The microphone signals are fed to an on-line data analysis system that is housed in a motorvan (figure 3). The cross-correlations are computed on-line as 1/12-octave cross-spectra which are stored in a background memory for later retrieval and post processing. This post processing comprises of: averaging over a number of measurements (also possible during acquisition); focussing on any distance; plotting of polar octave diagrams; plotting of the 1/12- octave spectra with integration over an arbitrary angular range; printing of these spectra with linear- or A-weighting and summed over 1/3- and full octave bands.

APPLICATIONS

The main application of SYNTACAN is the measurement of the sound immission from large industrial areas, where directional information is necessary. Important examples in practice are: 1) if the position of the noise sources is unknown; 2) if the acoustic powers cannot be calculated from emission measurements; 3) if the sound transmission is too complicated for reliable calculations; 4) if there is too much background noise for normal immission measurements. For the application of SYNTACAN the same meteorological conditions must be fulfilled as for conventional measurements. Furthermore sufficient space has to be available at the measurement site for installing the antenna. Now, we will demonstrate the usefulness of SYNTACAN with the results that were obtained from measurements near a petro-chemical factory. All

Figure 3: The data analysis system in the motorvan.

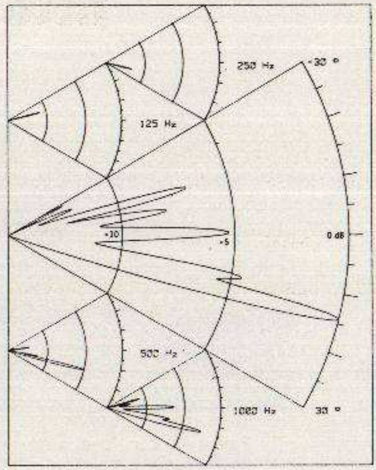

Figure 4: The polar diagram of a measurement.

relevant sound sources were situated on a distance between 1000 to 1500 m. Figure 4 shows the A-weighted sound pressure levels as a function of the angle of incidence for the octave bands from 125 to 1000 Hz and summed over these bands. We calculated the A-weighted immission levels for several angular ranges, as shown in this table:

Angular range	Immission level (90 - 1400 Hz)
-17.5° to 12.0°	41.3 dB(A)
12.0° to 17.0°	39.7 dB(A)
-17.5° to 17.0°	43.5 dB(A)

From these results it can be predicted that elimination of the source at 14° will reduce the total immission level of the area with 2.2 dB(A) over the frequency range from 90 to 1400 Hz.

REFERENCES

1. M.M. Boone and A.J. Berkhout, "Industrial Noise Source Identification with a Sparsed Microphone Array", Proceedings of Internoise 81, Amsterdam (1981).
2. A.H. Nuttall, G.C. Carter, and E.M. Montavon, "Estimation of the two-dimensional spectrum of the space-time noise field for a sparse line array", J. Acoust. Soc. Am., 55, 1034 (1974).