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THE USE OF CHEAP MICROPHONES IN EXTENSIVE OUTDOOR NOISE MONITORING NETWORKS

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1 INTRODUCTION

Nowadays, microphones appear a lot in consumer electronics (like mobile phones, laptops, portable digital music players, etc.) and hearing aids. Due to mass production, such devices come at a (very) low price. The main application of such microphones is speech. Just like high-quality (type 0 and I) measurement microphones, these are mainly electrets microphones. MEMS microphones, where the membrane is placed on the chip itself, can be found as well.

The price difference with dedicated measurement microphones is huge (up to a factor 10^2-10^3). In this study, it is investigated to what extent such cheap microphones can be used for environmental noise monitoring.

The characteristics of a noise-measurement chain are not only determined by the microphone itself, but also by amplifiers, power supplies, and loggers. Besides high-quality but very expensive dedicated hardware, PC-based measurements are increasingly becoming popular. Software like e.g. Euterpe[1] is then needed to do the processing.

This research is part of the IDEA project (Intelligent, Distributed, Environmental assessment). IDEA aims at developing an extensive noise and air pollution measurement network. For such a network to be applicable, low-cost sensors are essential. Each node in the network will need some processing power. Therefore, Single Board Computers will be used. These are stripped-down CPUs with limited computing power but equipped with a network and audio card.

Similar research project with an interest in noise are e.g. DREAMSys[2] and MESSAGE[3].

2 SELECTION OF MICROPHONES

Eight on-shelf and off-shelf microphones were tested, including two high-quality (reference) microphones, a type II microphone and a MEMS microphone. The prices ranged from a few Euros for the cheapest ones, to 2000 Euro for the high-quality measurement microphones. The type II and high-quality microphones need pre-amplification. To make the cheap microphones operational, a RC-circuit was included. In this way, the output voltage of the sound card of the SBC could be used. As the sensitivity of these microphones differs, an adequate amplification factor for the sound card of the SBCs was set to avoid range-problems. The prices given in Table 1 include preamplifiers where needed.

3 INDOOR MICROPHONE TESTING

The indoor testing was performed in an anechoic chamber. All microphones were tested connected to SBCs. In a pre-test, two identical high-quality measurement microphones were put directly besides each other, one connected to a high-quality dedicated logger system (Pulse system from B&K) and the other one to a SBC. This test showed that the SBC with audio card is well suited to do the logging. Only a very small increase of 2 dB in noise floor was observed at very low levels (at 10 dB for a 1 kHz pure tone) by the SBC, making them very suited to do the measurements.

Table 1. Overview of properties and results of the microphones considered

ID	Type	Membrane diameter	Cost (including preamplifier where needed)	Measured noise floor at 1 kHz (*indoor test*)	Average difference with REF1 for hourly L_{eq} levels (February 2010) (*outdoor test*)
ELECTRET1	Electret	< 1/8"	3 €	35 dB	0.9 dBA
ELECTRET2	Electret	< 1/8"	3 €	41 dB	*failed*
ELECTRET3	Electret	< 1/8"	30 €	32 dB	*failed*
ELECTRET4	Electret	< 1/8"	50 €	36 dB	0.6 dBA
MEMS1	MEMS	< 1/8"	30 €	23 dB	1.5 dBA
TYPEII	Electret	1/4"	300 €	15 dB	0.7 dBA
REF1	Electret	1/2"	2,000 €	15 dB	0 dBA
REF2	Electret	1/2"	2,000 €	13 dB	0.2 dBA

Three microphone characteristics were tested: noise floor, saturation at 100 dB, and linearity and flatness of the frequency response. A reference microphone was connected to a high-quality dedicated hardware. The tested microphones were connected to SBCs and both were put in front of a loudspeaker. Pink noise and a 1 kHz tone were emitted with various intensities.

Saturation at 100 dB was not observed at any microphone. The noise floor differs significantly among the tested devices. For a 1 kHz pure tone, the noise floors ranged from 13 dB to 41 dB, as shown in Table 1.

The frequency response relative to the reference noise measurement (at a total level of 70 dBA) is shown in Fig. 1. For each response, the deviation at 1 kHz is set to zero. The reference microphones have a flat frequency response over the full audible region. Some microphones are sufficiently flat up to a few kHz, while others deviate largely from an equal sensitivity at different frequencies. Linearity is most often observed – the same deviations from the flat response are found at various level. This means that easy compensation is possible.

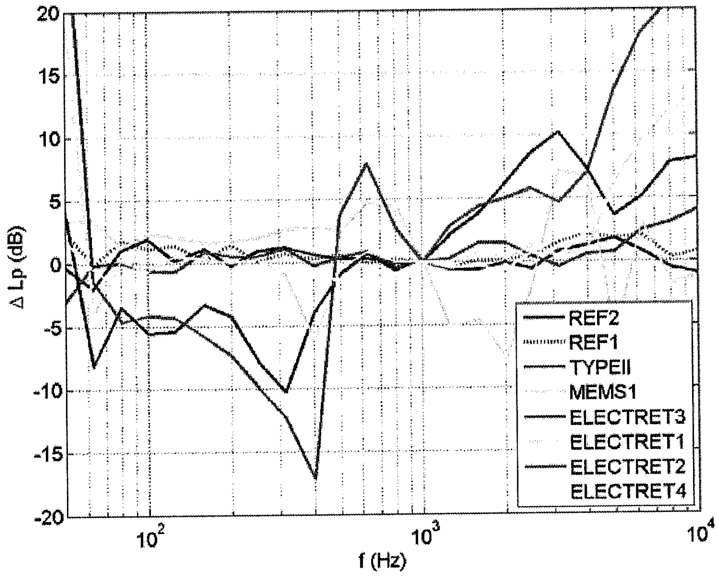

Figure 1. Frequency response of the tested microphones (for pink noise at 70 dBA).

4 OUTDOOR MICROPHONE TESTING

Indoors, weather resistance and wearing, and wind-induced microphone noise could not be tested. Therefore, a long-term outdoor test was set up. All microphones were attached next to each other on a horizontal bar on the roof of a building, with direct view towards a busy viaduct. On-site meteorological observations were made. If not available by the manufacturer, self-fabricated rain and wind protection was provided. The experiment started at December, 20 (2009). Measurements up to the end of February 2010 are included. This period was characterized by long periods of freezing temperatures, high relative humidity, and some periods with snow and intense rainfall. The basic logging consisted of 1-s equivalent sound pressure levels, expressed in 1/3 octave bands. The clocks of the SBCs were synchronized by a ntp-server. An outdoor loudspeaker was placed in front of the microphones to emit test signals over the full audible region, since the spectral range by traffic is rather constant.

In Fig. 2, the hourly linear correlation coefficient (R^2) is shown between each microphone and one of the reference microphones (REF1). The basic data was aggregated to 1-minute equivalent levels. Note that this linear correlation is a sensitive indicator: even the comparison between both reference microphones leads to values of 0.8 at some hours. These graphs give a good overview of the variability of the microphone behavior over time. In Table 1, the 1-month (February 2010) average deviations, relative to the reference microphone for hourly aggregated equivalent levels, are shown. Two microphones of less than 50 € were identified to give errors of less than 1 dBA. Especially the 50 € microphone (ELECTRET4) has a reasonable constant behavior over time. Note that the minimum difference that could be achieved is 0.2 dBA (which is the difference between the two reference microphones REF1 and REF2 on the test bar). The MEMS1 microphone has a bigger deviation of near 1.5 dBA. Although such microphones have a low noise floor at a reasonable cost; reliability outdoors in winter (see Fig. 2) seems to be a problem. ELECTRET2 and ELECTRET3 failed during the test. This is clear from Fig. 2: the minute-based levels are not correlated anymore with the reference microphone in February. Therefore, no average hourly deviations were presented in Table 1.

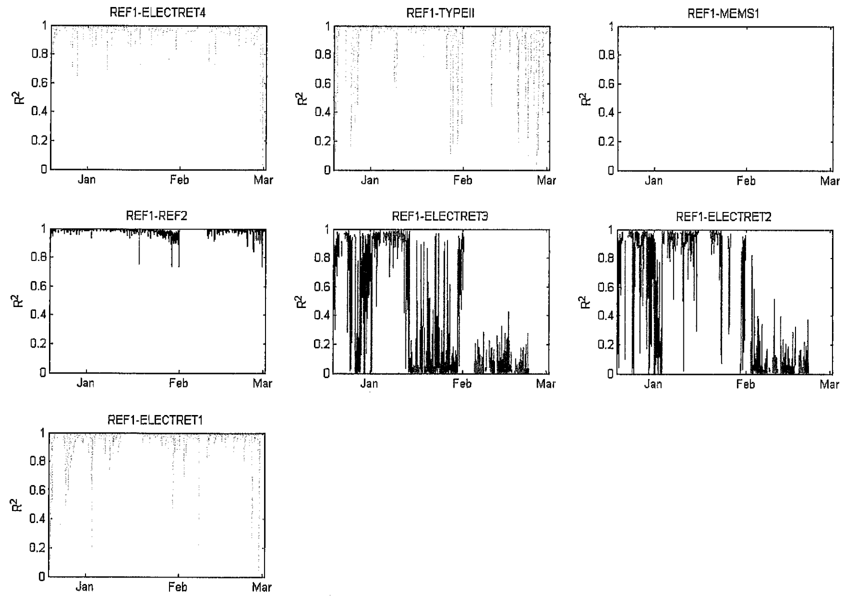

Figure 2. Linear, hourly correlation coefficient between each microphone and the reference microphone in the outdoor test.

5 CONCLUSIONS

Based on detailed indoor and outdoor microphone testing, low-cost microphones were identified that can accurately measure environmental noise. ELECTRET4 is of special interest. The minute-by-minute correlation analysis during 2.5 months shows that it is reliable outdoors in winter. For hourly integrated levels, a small error is observed of only 0.6 dBA, comparable to the more expensive TYPEII microphone in the test. Furthermore, it has a reasonable flat frequency response up to 4 kHz. The noise floor, on the other hand, is significantly higher than at the more expensive microphones.

The outdoor test is still active, and the microphone behavior will be evaluated during a summer period as well.

6 REFERENCES

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