A PU sound probe for high sound levels

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Introduction

For several high noise level applications, e.g. jet engines, the standard particle velocity (u) and sound pressure (p) probes can not be used.

In order to meet these challenging acoustic requirements, both the particle velocity and the sound pressure transducers have been optimized.

The novel design will be explained and its acoustic performance will be discussed. Attention will be paid to the calibration of such a probe.

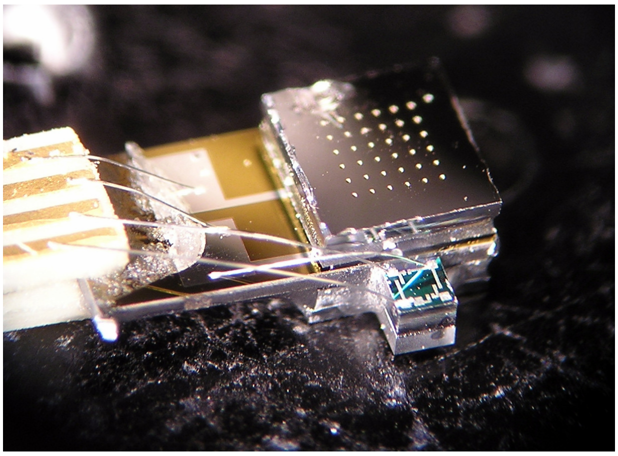

Figure 1: A high level PU probe.

High sound level particle velocity sensor

A regular Microflown [1] is linear up to 135dB, the selfnoise of such sensor is 0dB in 1Hz bandwidth at 1kHz.

A simple modification that reduces the particle velocity level at the sensor is used to increase the upper limit. On two sides of the Microflown sensor a stiff cap is constructed that has a few very small holes in it. The version that is shown in Figure 1 has a damping of approximately 35dB, the upper limit is now proven to rise to 170dB and the selfnoise is also rising 35dB. Due to the use of the damping cap the dynamic range of the Microflown is unchanged.

High level calibration of particle velocity

The calibration of the particle velocity is not trivial at all because standard calibration techniques make use of a known acoustic impedance [3]. At higher sound levels (135dB) the sound pressure and particle velocity are not linear anymore and the acoustic impedance can not be used for calibration.

In [1] the calibration of particle velocity sensors at high sound levels is explained. The basis of the method is the use of two monopole sound sources. If first only one is switched on, the particle velocity at the exit can be calculated by a measurement of the sound pressure at a certain distance.

At high sound levels the monopole creates apart from the high sound levels also a lot of wind, see further [1]. If a second monopole is put close and driven in anti phase a sound field is created in between the monopoles that consists of particle velocity only. This has two advantages: the emitted sound level is low so that one can use it without hearing protection and the wind has vanished.

With this set up the measurements of the following paragraph are done.

The **Sensitivity** of the particle velocity sensor is given below. It shows that the damping cap is not altering the frequency response; it is only damping 35dB.

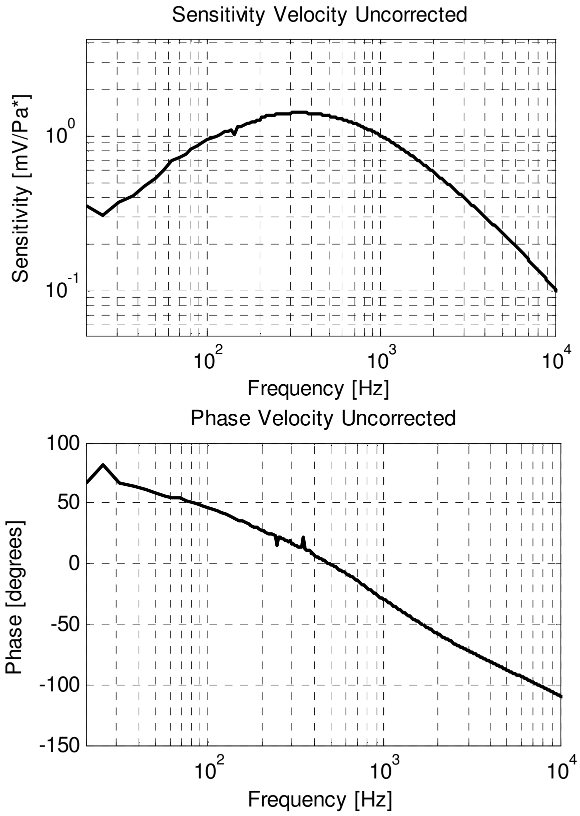

Figure 2: Amplitude (upper) and phase response (lower) of the high dB particle velocity sensor.

The maximum level of the probe is measured with a pure tone. The level is increased until higher harmonics are found 20dB lower that the base harmonic.

With a sound pressure microphone at a certain distance the linearity of the loudspeaker was checked.

As can be seen in Figure 3, for frequencies below 2kHz the sensor is linear up to 170dB. One measurement at 6kHz shows a lower maximum level. It is unclear if this a wrong measurement or another effect.

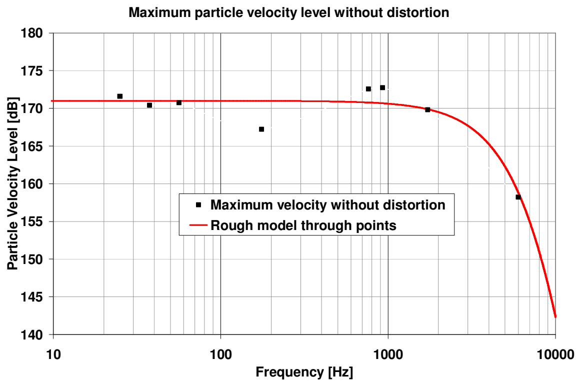

Figure 3: Maximum level without distortion of the particle velocity sensor.

The directivity of the high dB level Microflown is as expected a figure of eight as can be seen in Figure 4.

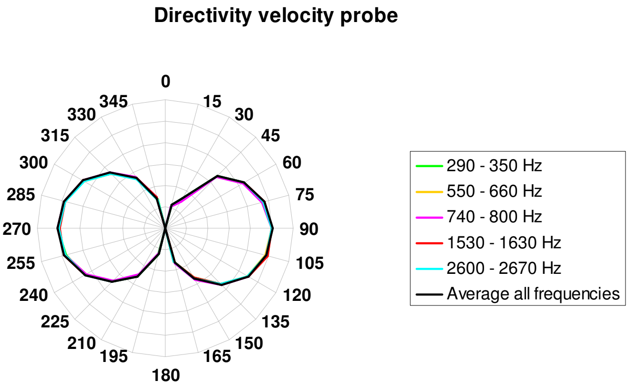

Figure 4: The high level Microflown has a figure of eight angular sensitivity.

The selfnoise is the amount of signal without any acoustic signal. It is given in a sound level per square root of Hertz. The selfnoise is similar to a regular Microflown except that it is 35dB higher, see Figure 5. This is caused by the 35dB reduced sensitivity.

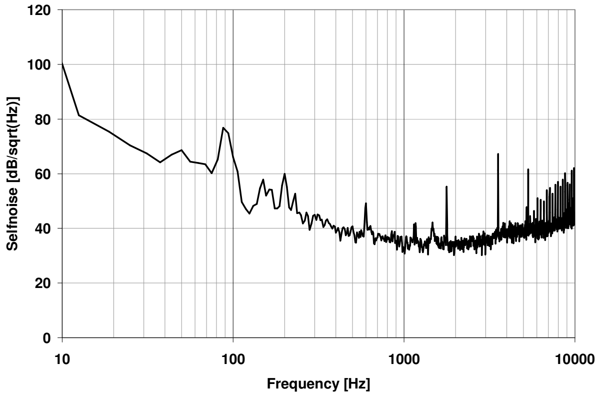

Figure 5: The selfnoise of the high level Microflown is 35dB higher as a regular Microflown.

High sound level sound pressure sensor

The small element that is seen in Figure 1 below the particle velocity sensor is a sound pressure element. The element is a micromachined, piezoresistive pressure sensing chip. The upper specified pressure level is 190dB.

The sensitivity is relatively simple to measure by comparing its output to a reference microphone in a small pressure chamber.

The sensor is linear up to approximately 3kHz as can be seen in Figure 6. It is not clear if the sensor breaks up or that the calibration method fails at these high frequencies.

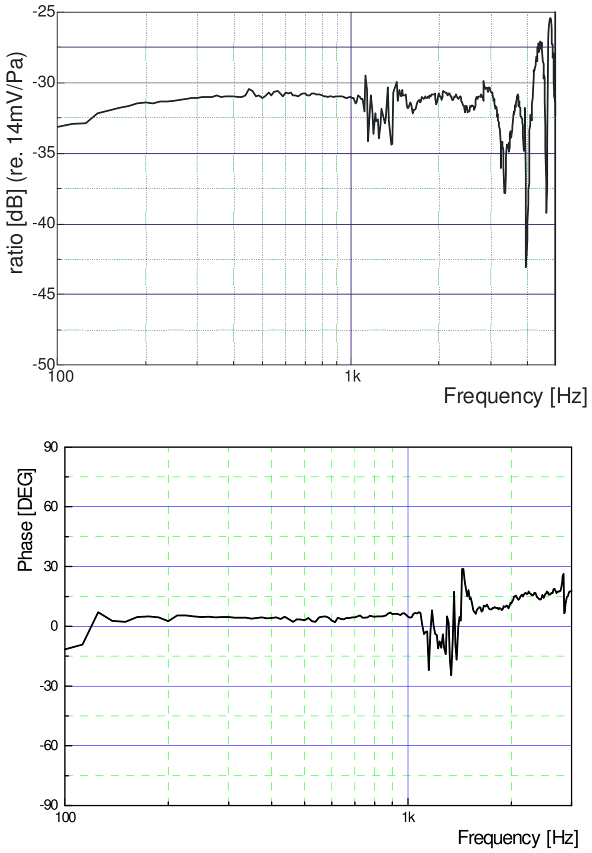

Figure 6: The sensitivity of the high level sound pressure element. Upper graph: amplitude response, lower graph phase response.

Conclusion

A pu sound probe capable of measuring sound pressure and particle velocity up to 170dB was constructed and calibrated. The upper limit of the sound pressure element is 190dB according specification. For sound levels higher than 130dB the sound pressure and the particle velocity become non linear. The pu sound probe can now measure both quantities at higher sound levels opening the way for studying non linear phenomena.

References

[1] H-E. de Bree et al, The Microflown; a novel device measuring acoustical flows, Sensors and Actuators: A, Physical, volume SNA054/1-3, pp 552-557, 1996

[2] Emiel Tijs, Hans-Elias de Bree , Calibration of a particle velocity sensor for high noise levels, DAGA 2008

[3] Tom Basten and Hans-Elias de Bree, A full bandwidth calibration procedure for acoustic probes containing a pressure and particle velocity sensor, submitted to JASA 2009.