Unidirectional Silicon Microphones: Testing And Basic Modelling

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Introduction

Communication microphones in car cabins are roughly classified in two categories:
1.: near-field transducers (handsets & gooseneck types)
2.: free-field transducers (handsfree microphones).
While the latter are almost not affected by noise and the acoustic environment, the last have to achieve acceptable results by design and proper placement.
Security considerations have lead to legal restrictions so the driver in control has to apply the handsfree mode in order to minimize any interference with his dedication to the traffic requirements. Free field capture of speech signals means a loss of S/N-ratio of 20 to 30 dB due to the increased source distance, but a typical car cabin should not be considered as an anechoic chamber.
Silicon microphones offer many advantages in terms of electrical and vibrational immunity, combined with easier handling during the final assembly. However, for a successful automotive application, some additional requirements have to be met.

The acoustic Environment

It is a common experience that upholstered seats and surfaces provide plenty of absorption to any sound signal, so in combination with the small volume there is almost no reverberation. Plenty of glass panels, however, result in a variety of so called „early reflections“ . These result in a typical „ringing“ distortion affecting speech intelligibility and adding unwanted coloration to the speaker's voice. In building acoustics, especially in the design of conference halls and studios, much care is taken to avoid direct reflections during the first 10 msec, the so-called „initial time gap“. Later reflections and an optimized amount of reverberation can even enhance speech intelligibility [1].
To visualize the effect of a bad design, a TDS measurement of a small loudspeaker was recorded using The TEF analyzer [2]:

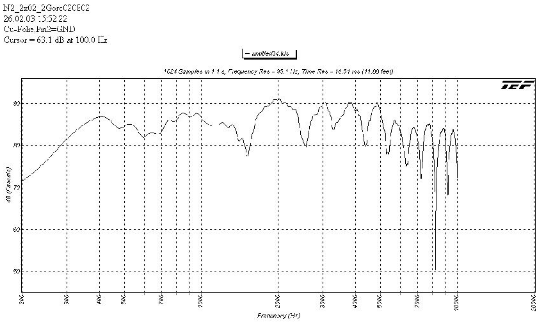

Figure 1: **Frequency response of a 2” loudspeaker in front of a reflecting surface at a distance of 36 cm, with the microphone centered at 18 cm distance**

The “ringing” effect is clearly visible. Rather than keeping all reflective surfaces more than 3.4 meters away from the microphone, which would create the desired “initial time gap”, a more practical solution is applied by using a “PZM“ arrangement (**P**ressure **Z**one **M**icrophone [3]). Placing the transducer near to or inside a boundary area will almost double th sound pressure in the regarded frequency range, depending on the surface matarial.

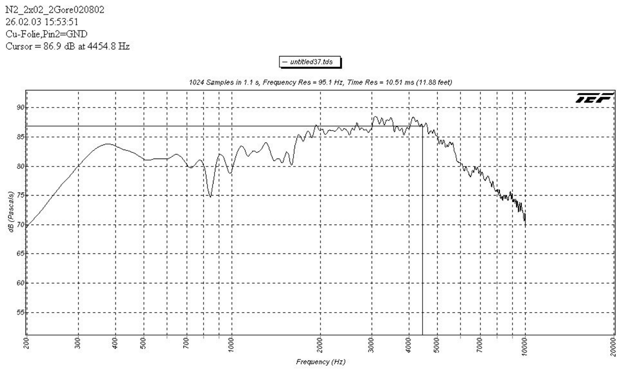

Figure 2: **Frequency response as Fig 1, reflective area in a 5 mm distance to the microphone.**

The curve shows almost no time delay distortion. As there are more than one reflective planes, favourite installation locations can usually be found near corners, as shown in the following example:

Figure 3: **Typical installation of a handsfree microphone**

Requirements

To comply with this type of installation, a silicon microphone should have the following additional features:
1: unidirectional polar sensitivity (cardioide pattern)
2: small outline package
3: high immunity to vibrational noise
4: integrated preamplifier with a 2-wire interface

Common unidirectional microphones use the “pressure gradient” principle by coupling the diaphragm's surfaces through different mechanical networks (front and rear) to the

sound field. As the rear coupling performs a second order low pass filter, the phase corrected subtraction of both input sources at the location of the diaphragm leads to a resulting high pass characteristic.
Ever smaller case outlines require exact matching of these network elements, so the application of simulation tools is a good help for the prediction of the product performance, once the basic model is defined and approved. The complete derivation of the exact model is explained in [4]. With a simplified network, a spice prediction is shown for two different resistive elements in the rear side low pass:

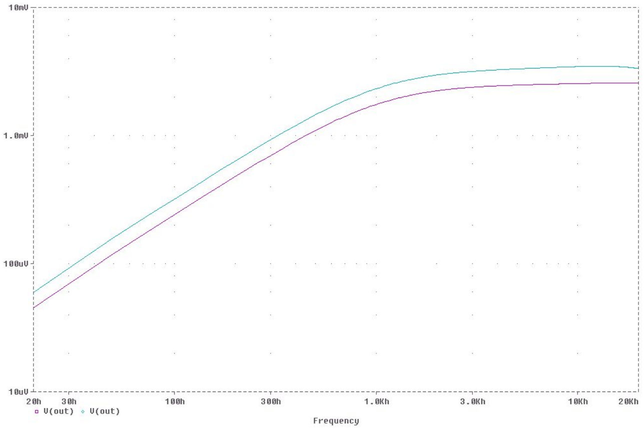

Figure 4: **Predicted frequency response in 0°/180° direction for high resistive damping**

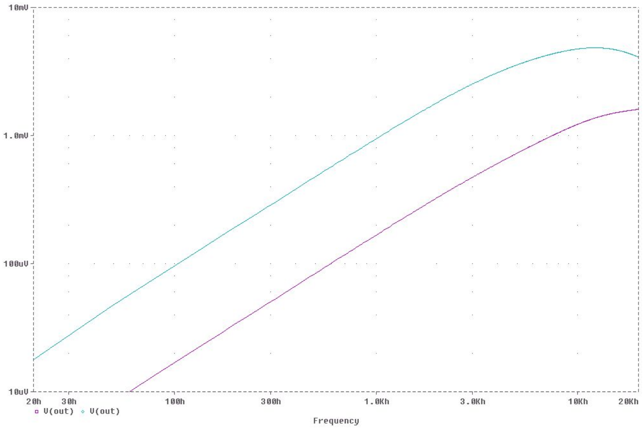

Figure 5: **Predicted frequency response in 0°/180° direction for less resistive damping**

These different results were obtained by the variation of just one resistor in the model by a factor of 5. The effect on the performance is quite evident.
The resulting high pass filter is generally an intended feature to suppress vibrational noise, but the slope must be matched to individual needs which requires addditional filtering in the amplifier circuit.

Results

To approve the desired performance of the final product, first samples were tested using the TDS measurement in a typical PZM arrangement:

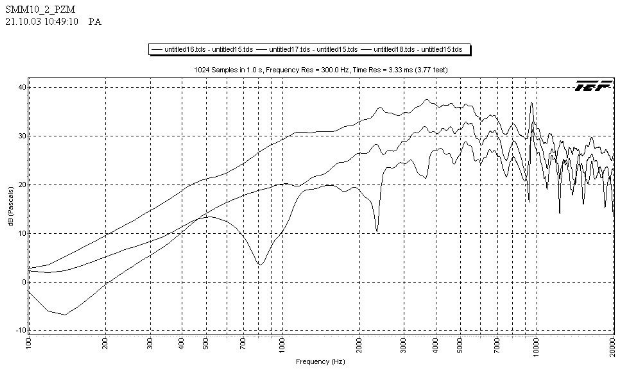

Figure 6: **PZM frequency response in 0°/90°and 180° angles. of a silicon microphone sample with integrated preamplifier**

TDS measurement provides the opportunity to visualize the polar directivity versus frequency in a single 3D diagram. If normalized to the 0° response, the resulting horizontal graph looks like this:

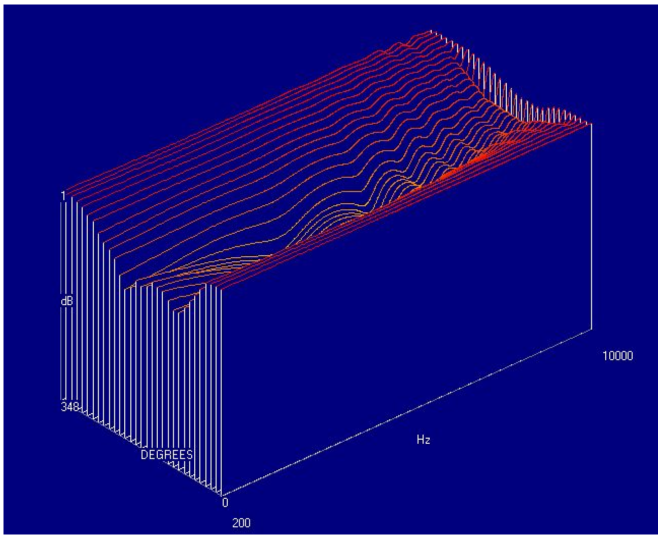

Figure 7: **Horizontal directivity vs. frequency in 32 angles**

As a result it can be seen that a good directivity pattern, combined with a matched frequency response, can be designed with the application of modelling techniques that help understanding and predicting the resulting performance.

References

[1] Peutz, V.M.A.; Designing sound systems for speech intelligibility, 48th Aud.Eng.Soc.Conv, Los Angeles 1974
[2] Don and Carolyn Davis; Sound System Engineering; Indianapolis, Indiana; Howard W. Sams, 1989
[3] URL: www.uneeda-audio.com/pzm
[4] Marc Füldner, Alfons Dehé; Development of directional silicon microphones; CFA/DAGA '04, Strasbourg, France