The effects of SNR driven amplitude compression in hearing aids on output SNR and signal envelope distortion

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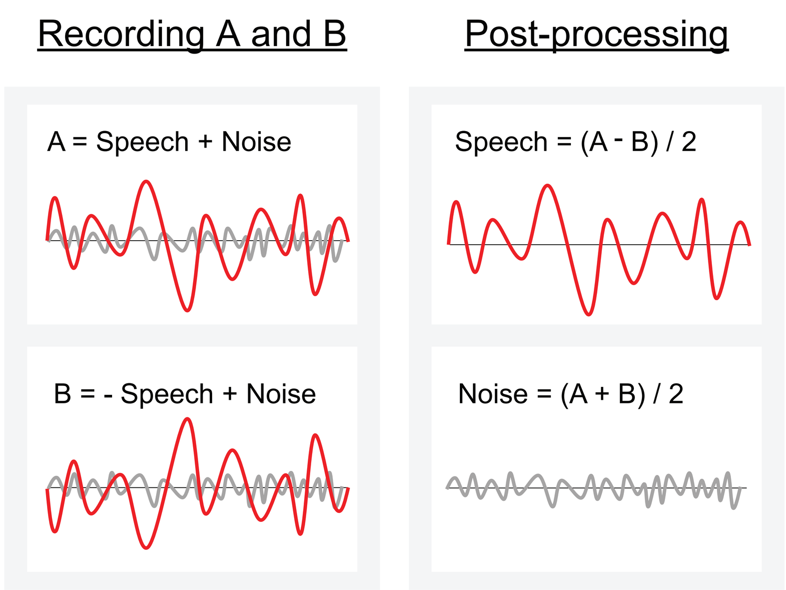
Amplitude compression has two faces

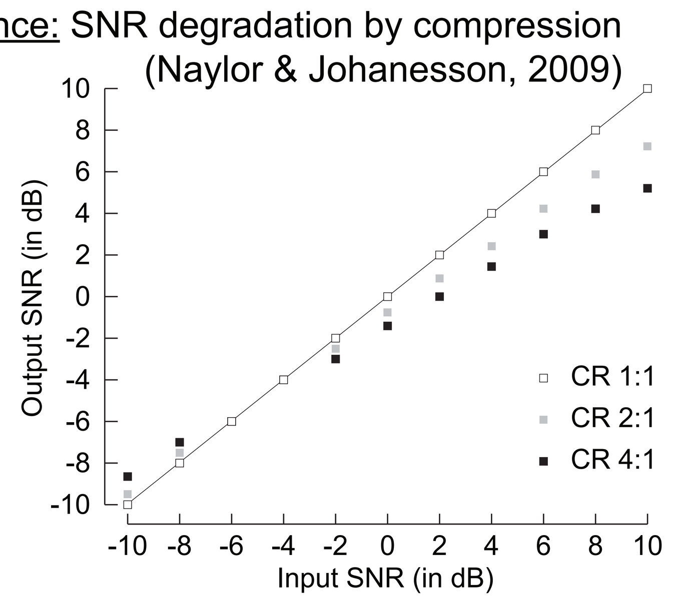
Compressing the amplitude of the incoming signal is a standard application of hearing aid amplification. The amount of compression is initially defined by the selected fitting rationale that indicates how much gain should be applied to a speech signal at different input levels. The results from speech intelligibility tests, in controlled environments, indicate that compression can compensate for the loss of audibility for soft speech in quiet (Davies-Venn et al., 2009).

Difficulties appear when noise degrades the speech signal. In this case, the compressor still applies gain based on the input level without distinguishing the signal type. Over-amplification of noise by compressive amplification was found to result in degradation of the output SNR (Naylor & Johannesson, 2009) and speech envelope flattening (Souza et al., 2006). Using a SNR driven amplitude compression, that applies gain based on the signal type, should reduce this negative effect.

Hearing aid output SNR

Measuring the hearing aid output SNR is possible by separating the signal from the noise in recordings of the hearing aid output using the inversion technique described by Hagermann & Olofsson (2004). This method was successfully used to evaluate the effect of wide dynamic range compression (Naylor & Johannesson, 2009), noise reduction (Hagerman & Olofsson, 2004), directionality, and a combination of these features (Wu & Stangl, 2013).



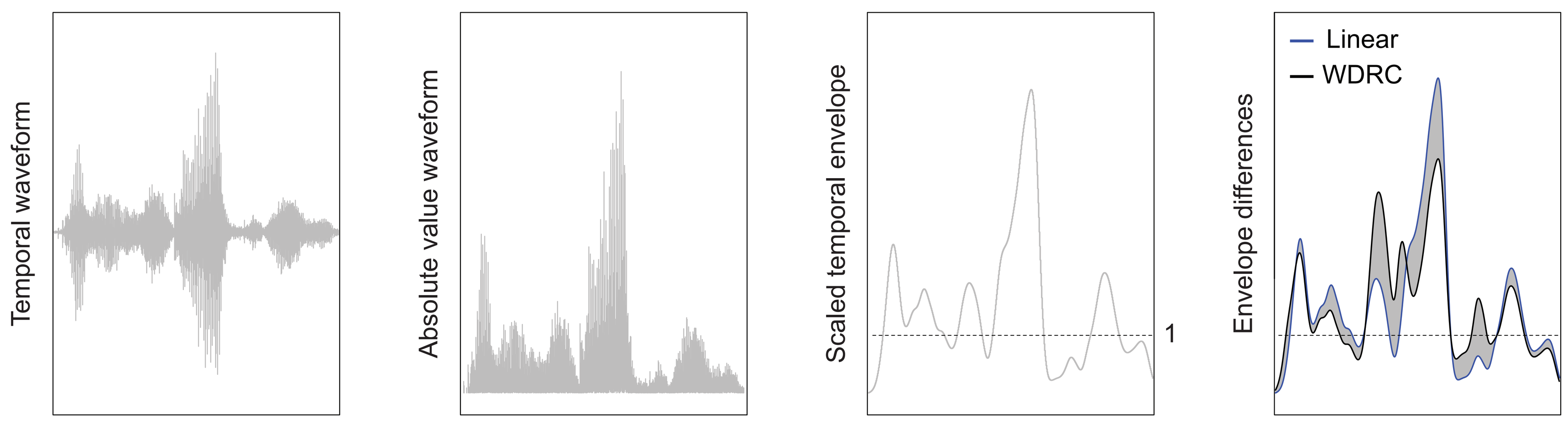


The relationship between differences in output SNR and speech perception in noise has been evaluated by Miller et al. (2017), Gustafson et al. (2014), and Wu & Stangl (2013) using different measurements tools. These studies show that a change in output SNR cannot be systematically predicted and measured with speech intelligibility tests like speech reception thresholds or phoneme recognition. They suggest that a change in output SNR might affect other aspects of speech perception like acceptable noise levels or listening effort measured with response time.

Envelope difference index

Fast compression is designed with the main aim to improve the audibility of soft phonemes. However, while it makes soft speech more intelligible, it will also induce envelope distortions. This side effect might be challenging, as some hearing impaired listeners might primarily rely on envelope cues to recognize some specific phonemes. For speech in steady noise, especially at positive input SNRs, the envelope will also be flattened by reducing the "distance" between speech and noise.

The idea of quantifying the temporal contrast of the speech envelope with the envelope difference index (EDI) was suggested by Fortune et al. (1994). This technique is based the temporal envelope subtraction and generates an index quantifying the difference between two temporal envelopes of the speech signal (e.g. without and with compression). This index has a value between 0 for identical signals and 1 for entirely unrelated signals.



Envelope distortion induced by dynamic compression might affect phoneme recognition in quiet Jenstad & Souza (2007). However, this effect is reduced for speech in background noise (Souza et al., 2006), i.e. valleys from the original signal are filled by noise. The envelope fidelity can be restored to some extent with signal processing algorithms like noise reduction (Arehart et al., 2015).

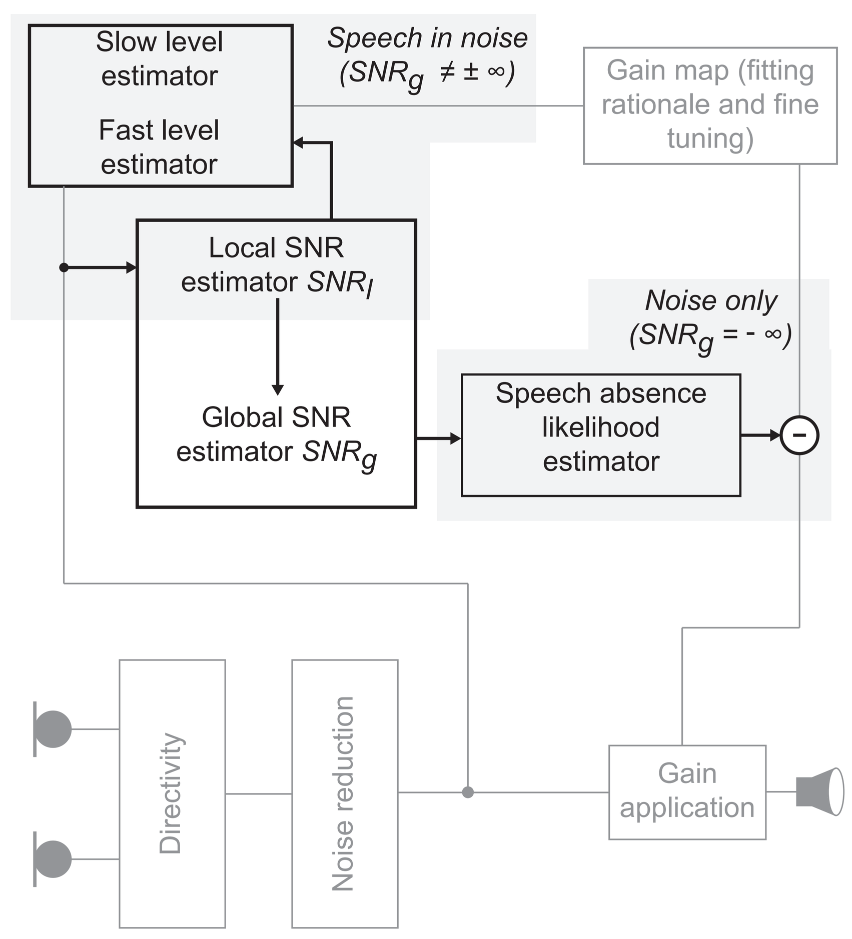
SNR driven amplitude compression

A decision block, using SNR estimation with phonemic resolution at the compressor's input, was designed to reduce the re-amplification of noise after its initial removal by directivity and noise reduction. SNR driven amplitude compression controls the amount of amplification depending on how much the signal is corrupted by noise - the effective compression or gain will be released when the SNR decreases. This qualification is not restricted by pre-defined rules for listening environment detection so that it can measure small and fast changes in daily situations.

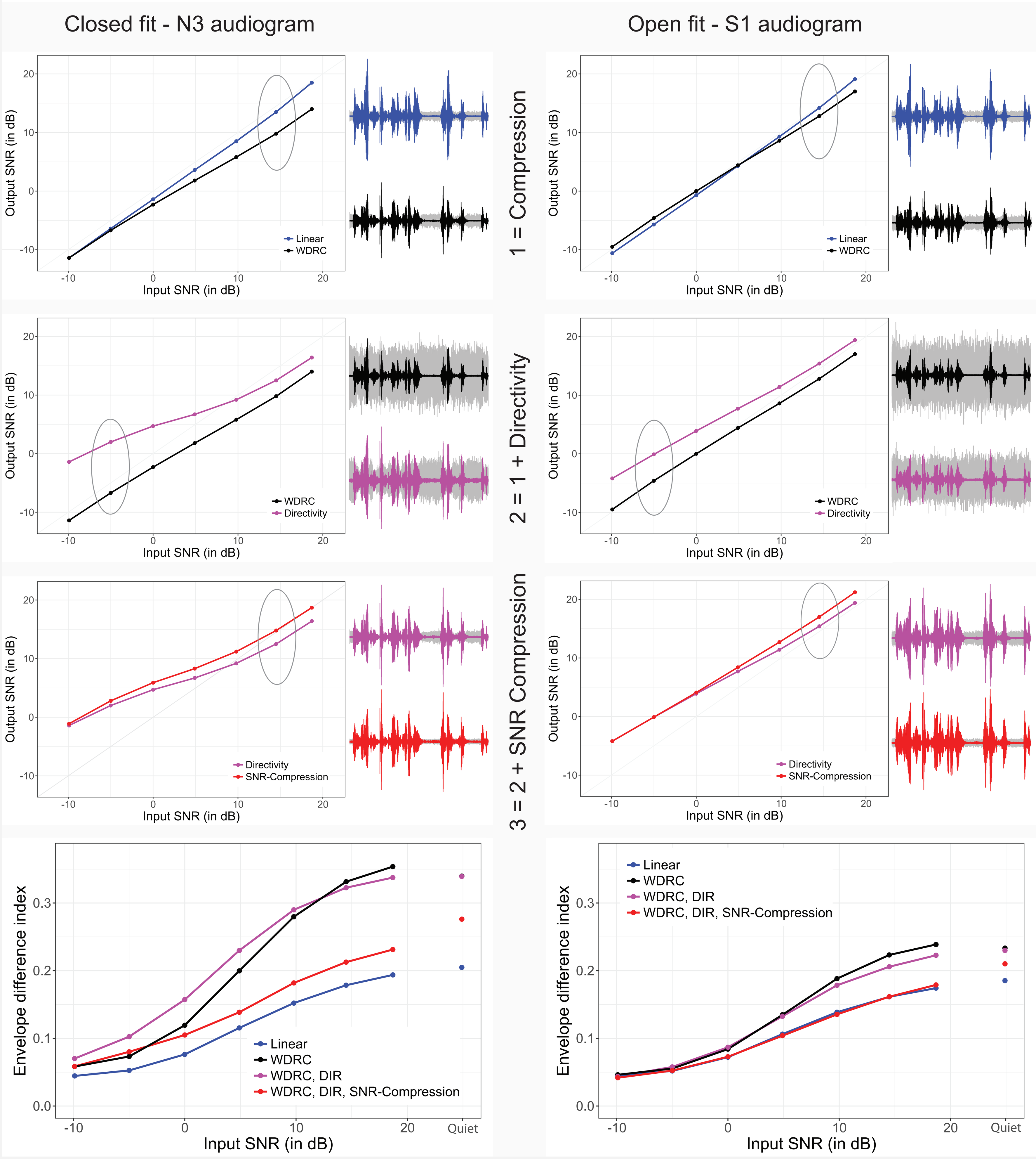
Speech in quiet:
- with clean speech signals (i.e. global input SNR is very high), SNR driven amplitude compression must provide the gain defined by the fitting rationale and the fine tuning corrections.

Speech in noise:
- with noisy speech signals (i.e. global input SNR is slightly higher or lower than zero), SNR driven amplitude compression reduces the undesired noise amplification that could potentially occur on short segments where the local SNR is negative.

Noise only:
- with pure noise signals (i.e. global input SNR is very low), SNR driven amplitude compression decreases the overall gain allocated by the gain map that is initially defined for a speech signal.

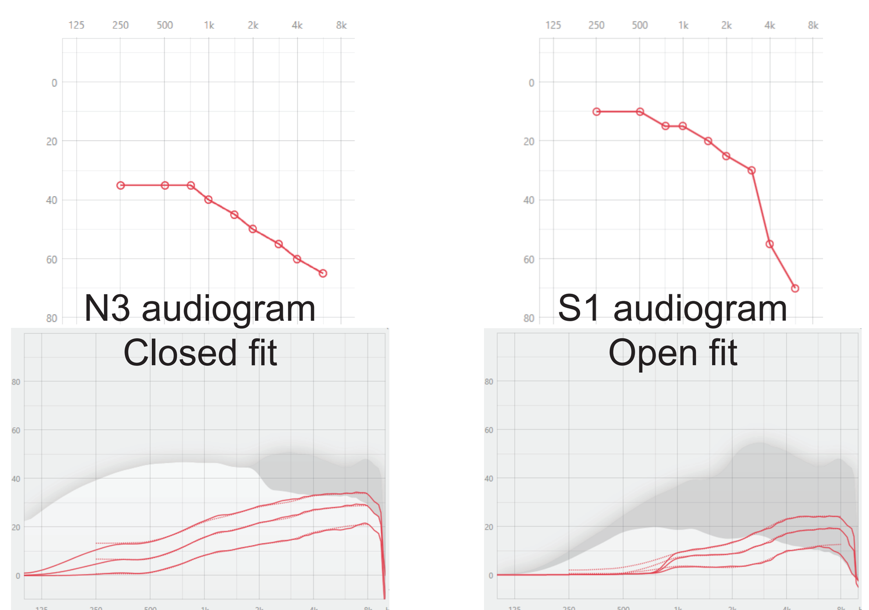


Measurements results



Test setup

- Bernafon Zerena 9 hearing aid placed on KEMAR and fitted with NAL-NL2
- ISTS speech from 0° and spectrally matched noise from 135° (Holube et al., 2010). Constant 65 dB SPL overall level. SNR range from -10 to +20 dB SNR and one condition in quiet for the EDI
- Test conditions: linear on 65 dB input target, (1) compression, (2) = (1) and directivity, and (3) = (2) and SNR driven compression



Discussion

- Effect of signal processing: output SNR degradation and envelope distortion are found when compression is activated. Directivity partially improves the output SNR but cannot avoid the SNR degradation and envelope distortion caused by compression at positive input SNRs. With SNR driven amplitude compression, envelope distortion is partially compensated for and SNR degradation is avoided in all the tested conditions.
- Effect of test conditions: acoustical options and gain play a major role when evaluating signal processing algorithms. Open acoustical options might reduce the SNR degradation and envelope distortion caused by compression. However, they will also reduce the benefit given by algorithms such as directivity or SNR driven amplitude compression.

References

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SNR driven amplitude compression is commercially available under the name Dynamic Amplification Control™

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