SPEECH INTELLIGIBILITY IN NOISE:
About STI, MTF and noise suppression

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1. INTRODUCTION

The STI (Speech Transmission Index) is a tool for predicting or measuring the quality of speech transmission, for instance in auditoria. It is based on the concept of the MTF (the Modulation Transfer Function), thus accounting for the effects of interfering noise and reverberation on speech intelligibility (Houtgast and Steeneken, 1985). Recently, we have performed a series of experiments to study in detail the effect of additive noise on speech intelligibility. We could distinguish three separate detrimental effects of the noise, of which only one is accounted for by the MTF. I will discuss the consequences of this finding, also in the light of the possible benefits of noise suppression algorithms.

2. EFFECTS OF NOISE

I will report about a study on how exactly the intelligibility of speech is affected by the addition of noise. At first sight, this may seem a rather trivial question: In terms of Modulation-Transfer, the additive noise causes a reduction of the original modulations in speech, thus reducing speech intelligibility. Still, the exact nature of the underlying process is not obvious, and deserves some further attention.

In our study we considered continuous thermal noise, with a spectral shape equal to the long-term speech spectrum. We studied the effect of noise by comparing, for a given ¼ octave band, the output of that band for the original speech and for the speech-plus-noise. When doing so, we can observe three separate effects. (a) *Average envelope-modulation reduction*: when considering the intensity-envelope, the original envelope is, on average, simply raised by the mean noise intensity, implying a reduction of the original modulation index. (b) *Random instantaneous envelope fluctuations*: on an instantaneous basis, the speech-plus-noise envelope shows random variations, caused by the instantaneous fluctuations in the noise intensity, and by the instantaneous changes in the phase relation between the speech and the noise. (c) *Perturbations of the carrier phase*: in the ¼ octave band carrier signal the addition of the noise causes a random phase shift, when compared to the instantaneous phase for the original speech.

By applying signal processing techniques, we were able to either include or exclude each of these three effects separately. Thus, for a given speech-to-noise ratio, we produced all possible eight combinations, including as limit cases no effect at all (original speech) and all three effects together (the 'normal' speech-plus-noise condition). All eight combinations were subjected to intelligibility measurements. The results indicate the following order of the detrimental effect on the scores: (1) the average envelope-modulation reduction, (2) the perturbation of the carrier phase, and (3) the random envelope fluctuations. Although the envelope modulation reduction appears to play a key role in the masking effect of noise (and is the only one accounted for in the STI concept!), the other two effects do play a role as well. This will be discussed in the light of modeling speech reception in noise, and the possible benefits of noise suppression.

3. CONCLUSIONS

Besides the well known effect of additive noise (the average envelope-modulation reduction), two additional stochastic effects on the instantaneous intensity and phase of the speech signal should be considered as well. These latter two effects underlie the limited benefit of noise suppression schemes.

Houtgast, T. and Steeneken, H.J.M. (1985). *A review of the MTF-concept in room acoustics*, J. Acoust. Soc. Am. 77, 1069 – 1077.