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# Sound Stabilizer™ and Speech Intensification System™ (SIS)

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## Introduction

In automatically regulating hearing aids, the amplification characteristics vary as a function of the sound coming to the hearing aid. It is not only the current sound signal which influences the amplification in the hearing aid, the preceding sound sequence also contributes. In fact, the strategy according to which the amplification characteristics are regulated as a function of time is a characteristic of a hearing aid.

SENSO[1] uses a complex algorithm to regulate the amplification level; amplification within the individual bands is regulated on the basis of the currently present sound signals as well as a statistical analysis of the sound sequence within a time frame extending 20-30 seconds back in time. The instantaneous level of amplification in each channel as well as the speed with which the amplification may change is determined by the properties of the input signal. Statistically based regulation is one of the distinctive features of SENSO, since the dominating attack and release times are much longer than in most other hearing aids. This has resulted in minimal temporal and spectral smearing within SENSO. Tests have shown that temporal and spectral smearing only marginally influence speech intelligibility and listening comfort in situations with loud background noise. But the length of the time constants has a major effect on the sound and comfort in moderate or insignificant background noise, and in what is usually called quiet surroundings. Thus, the relatively slow regulation contributes to the clear sound presented by SENSO in situations where the background noise is minimal.

Another of the distinct qualities of SENSO is the noise reduction system. Noise reduction in SENSO is based on detection of speech and noise in each of its three bands. When loud noise is detected in one of the bands, amplification in that band is reduced. When only speech is present, noise reduction is not active. Many users have expressed their satisfaction with this system and have expressed that the noise reduction system makes it possible for them to cope with noisy surroundings for a long time without feeling tired.

These two characteristics, the statistically based regulation and the reduction of noise, are important for the sound representation in SENSO. But while both features have been very well received by the users, they have also resulted in side effects which are present in special listening environments. This article considers these side effects and explains how we have tried to minimise them without reducing the positive effect of the features.

## Sound Stabilizer™

The automatic regulation of amplification in each of the channels in a SENSO hearing aid is based on the statistical characteristics of the input signal during the preceding 20-30 seconds. The duration of the frame analysed has been established on the basis of listening tests. A long analysis frame means that even if SENSO is influenced by a sound varying in time, for instance a speech signal, the amplification of the signal in the three channels will only change minimally as a result of the varying frequency contents of the speech components. Thus, SENSO adapts to the listening environment and not to the individual speech sounds. As mentioned above, this means that SENSO, in a stable listening environment, reacts almost like a linear hearing aid adjusted to exactly that listening environment. If the situation changes, SENSO adapts its amplification characteristics to the new listening environment, after which it again reacts like a linear hearing aid. As also mentioned above, slow regulation has its most distinct advantages when the background noise is modest. This is illustrated in figs. 1-3.

By comparing the output signals for the three hearing aid types, it

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[1] SENSO refers to the original SENSO version, which is often called the SENSO C series.

is evident that with a linear hearing aid the background noise is reproduced at the weakest level. This corresponds well to the subjective impression where the background noise is less annoying. In the hearing aid with a slow AGC, background noise before the speech signal begins is relatively loud, but shortly after speech has begun, the amplification is reduced so that the background noise is reproduced as weakly as in the linear hearing aid. This corresponds to the subjective impression in which the background noise is less annoying. In the hearing aid with a fast AGC, noise is reproduced at a relatively loud level as soon as the speech signal is not dominating, that is, even during short breaks in the speech signal. Subjectively, background noise is more annoying than with linear amplification or slow regulation.

Listening tests within our research laboratory have shown that most hearing aid users prefer linear amplification or a slow regulation speed. This preference is especially clear in situations with moderate background noise. Neumann et al. 1998 have reached a similar conclusion. In this study, 20 persons with a sensorineural hearing loss evaluated the sound quality of a signal consisting of speech and noise. The speech and noise signal was processed in a single-channel wide dynamic range compression (WDRC) hearing aid in which the compression ratio and the release time was varied systematically during the test. It turned out that when the release time was prolonged, clarity, pleasantness and overall impression were rated higher, whereas loudness and the loudness of the background noise were rated lower. This tendency became clearer at higher compression ratios. Thus, when slow regulation is used, the background noise becomes less annoying and the sound becomes clearer and more pleasant.

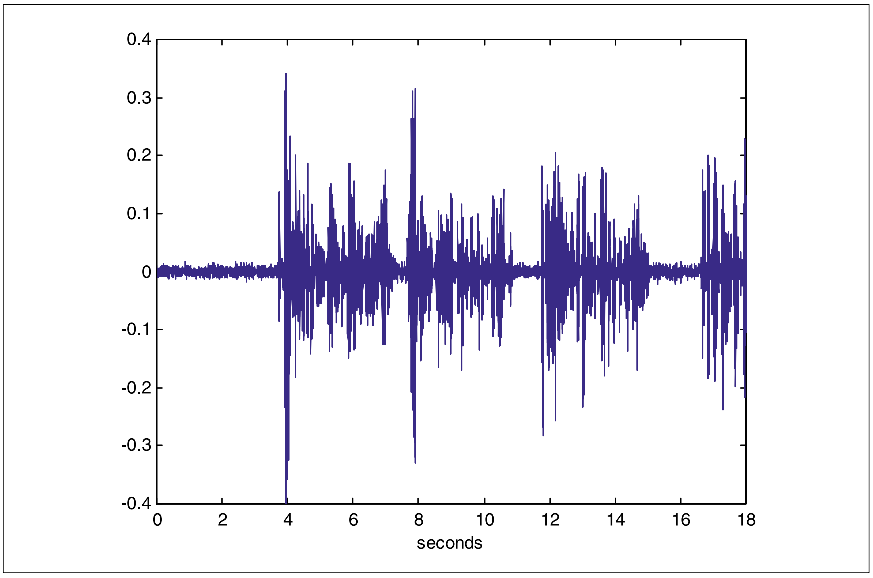


*Fig. 1. Linear reproduction of speech in weak background noise. SNR = 20 dB.*

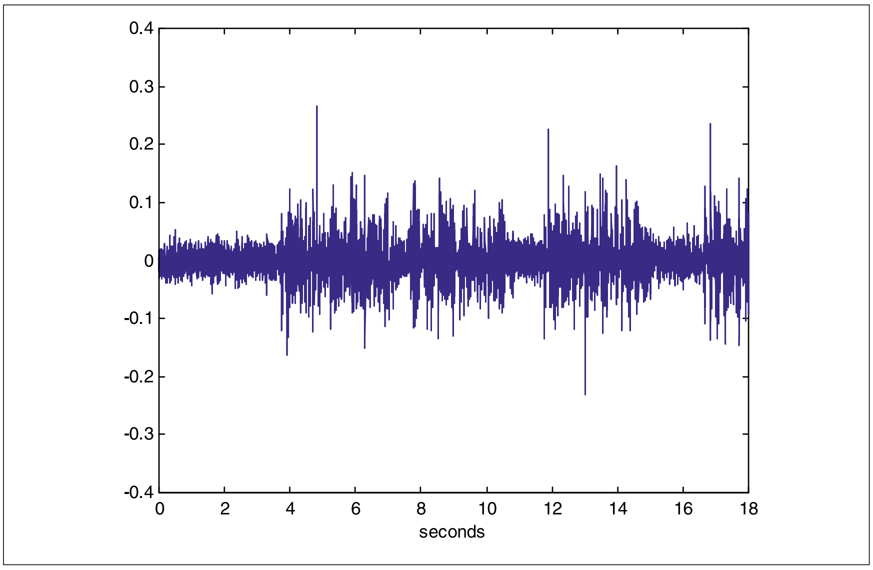


*Fig. 2. Speech in weak background noise (as fig. 1) through a 3-channel WDRC hearing aid with a release time of 200 ms. CR = 1:2.5 in all channels. (CR = compression ratio).*

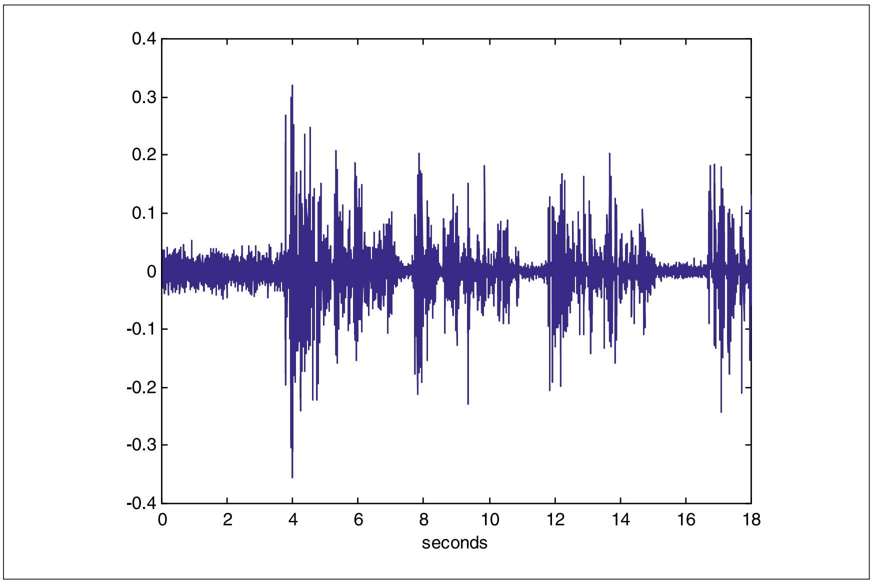


*Fig. 3. Speech in weak background noise (as fig. 1) through a 3-channel WDRC hearing aid with a release time of 10 seconds. CR = 1:2.5 in all channels.*

## Side effects using a slow regulation speed

The slow regulation speed does, however, also have some adverse side effects[2] which may, in certain situations, be inconvenient for the user. Such a situation may arise when the listening environment suddenly changes. A few seconds pass before the hearing aid fully adapts to the new listening environment. The SENSO user will only experience this as problematic if the sound level in the two listening environments differ substantially, and only if the user goes from a high sound level to a very low sound level. The opposite situation, in which the SENSO user goes from a low into a high sound level, very seldom creates problems. A problem may arise for a lecturer who has to hear a question from the audience, or for a hearing aid user who is in a room with a high noise level which suddenly stops. One example of such a situation is shown in figs. 4-6 demonstrating the sound signal from three different hearing aids when the sound suddenly changes from loud party noise into soft speech without background noise. The linear hearing aid shown in fig. 4 does not compensate for the change in input level. If the user of the linear hearing aid wants to understand the soft speech, she/he must use the volume control.

In fig. 5 you can see how a 3-channel hearing aid with a release time of 10 seconds reproduces the sound. As you can see, it takes 5-10 seconds for the amplification within the hearing aid to adapt to the new situation. In certain situations this may be critical.

Such a problem is easily solved by increasing the regulation speed. But this solution is not optimal because of the many negative effects of a fast regulation speed. In order to solve the problem, we have tried to predict when the regulation speed can be increased without

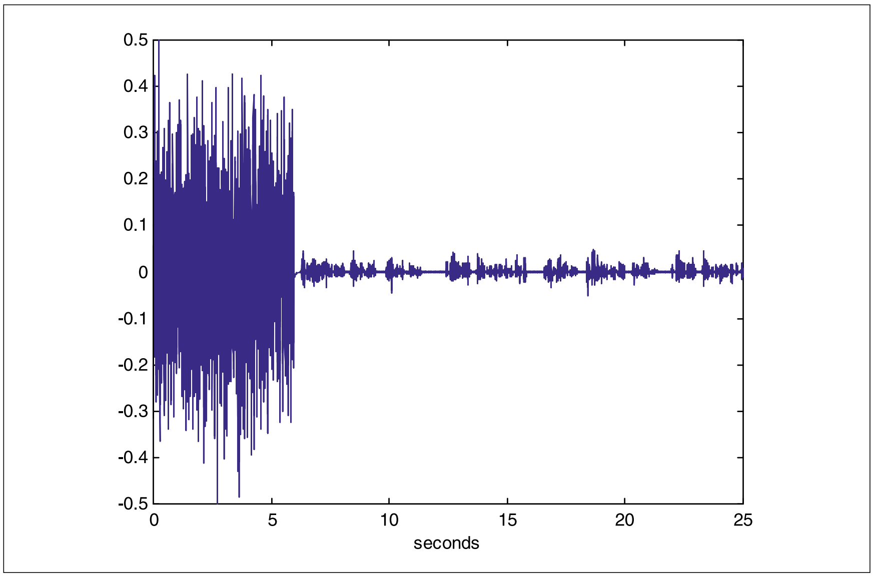


*Fig. 4. Linear reproduction of loud party noise followed by soft speech. CR = 1:1.*

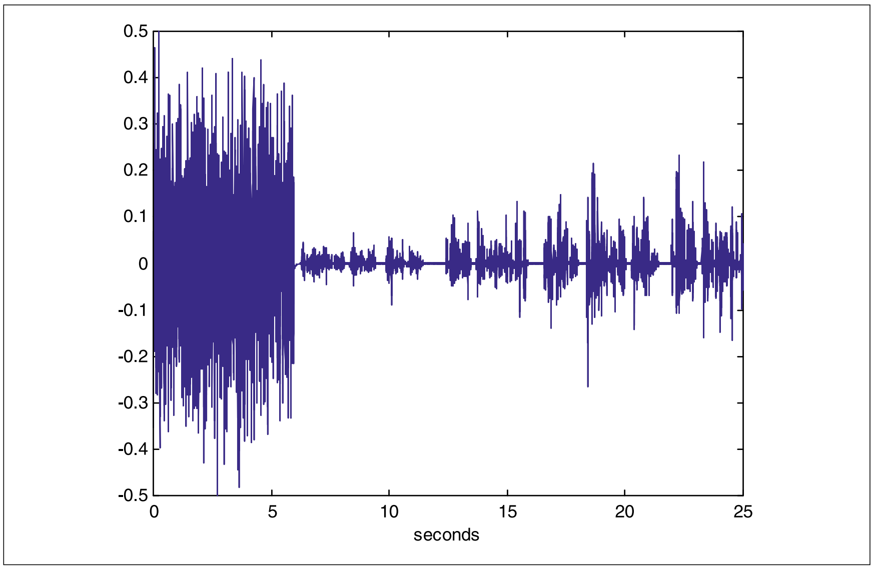


*Fig. 5. Loud party noise followed by soft speech (as fig. 4) through a 3-channel WDRC hearing aid with a release time of 10 seconds. CR = 1:2.5 in all channels.*

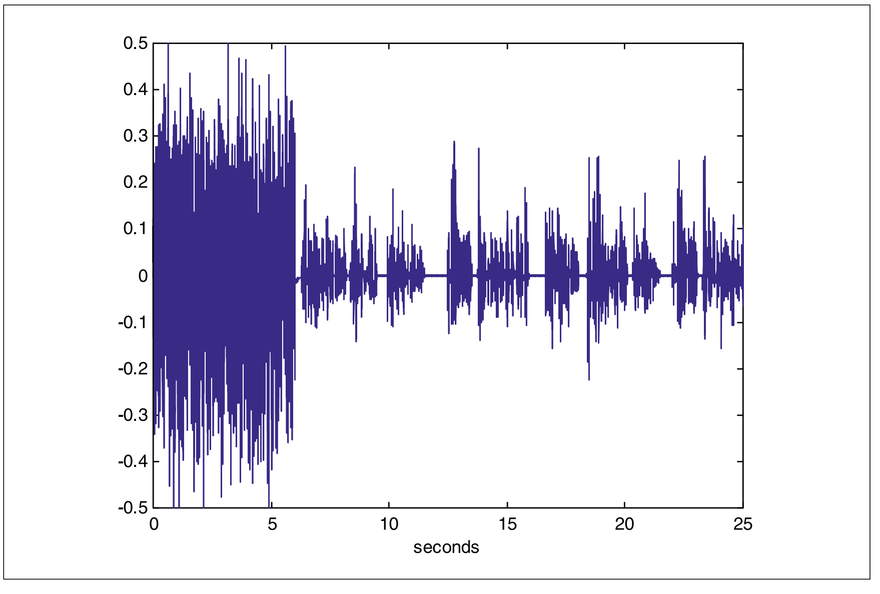


*Fig. 6. Loud party noise followed by soft speech (as fig. 4) through a 3-channel WDRC hearing aid with Sound Stabilizer. CR = 1:2.5 in all channels.*

[2] Not all users notice or are annoyed by these side effects.

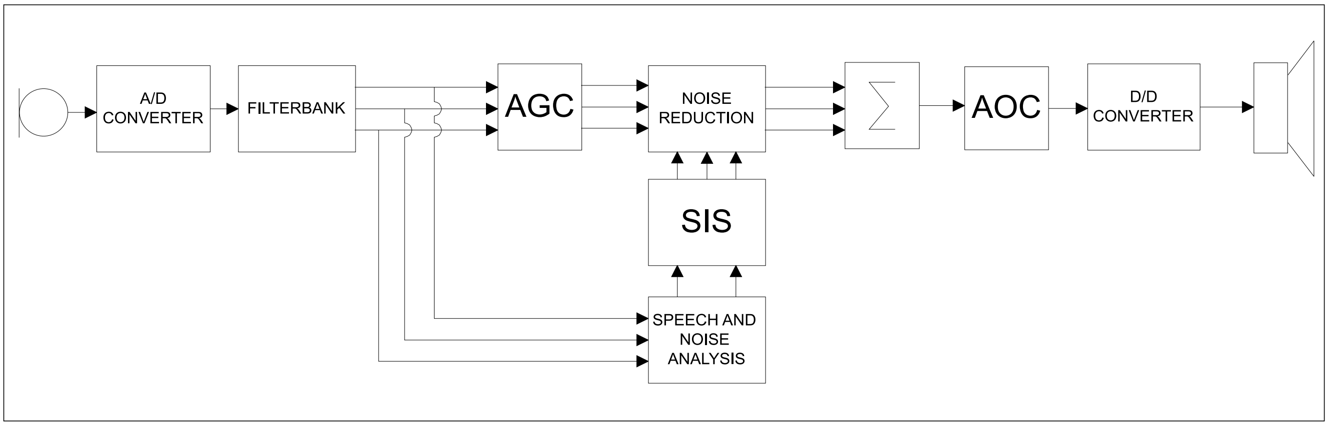


*Fig. 7. Block diagram showing the SIS principle.*

creating audible side effects. Our results showed that a fast regulation speed can be used without discomfort when the input sound has a volume and combination of frequencies that mask the distortion which inevitably arises in connection with a fast regulation speed, so that the distortion is not audible. Based on experiments with hearing impaired test persons, we have defined the details of a fast regulation speed in such a way that there will be no side effects in the form of audible distortion and pumping. We have found that in certain situations the regulation speed can be increased by a factor of 100 without creating discomfort.

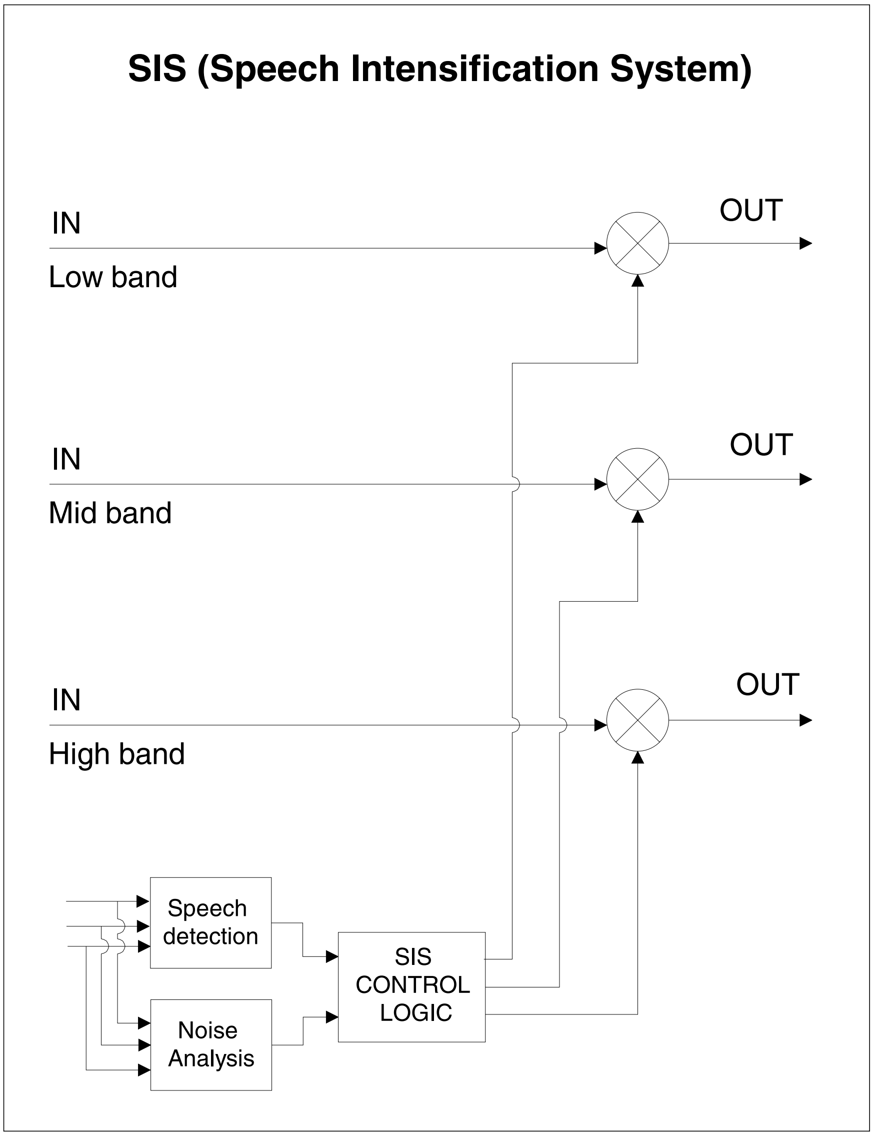


*Fig. 8. Detailed block diagram of the SIS feature.*

In many situations you cannot increase the regulation speed without affecting the comfort level. You have to weigh regulation speed against comfort. We have called this method of optimising the regulation speed a 'Sound Stabilizer' because it has the result that sound dropout has been nearly eliminated in even heavily varying sound environments.

In fig. 6 you can see the sound reproduction in the situation also shown in fig. 4, but this hearing aid is equipped with a Sound Stabilizer. As you can see from the figure, there is almost no sound dropout.

Imagine that the hearing aid user moves from a room with a loud noise level into a room where one person speaks and where there is no background noise. In the noisy room, an AGC hearing aid will reduce the amplification because of the loud noise level. When the listening environment changes to be very favourable, a hearing aid with a slow regulation speed may use 5-10 seconds to adapt to the new situation. The time passing until the hearing aid has adapted to the new situation will differ from type to type. This is illustrated in figs. 4-6. The big difference in sound level (noise and speech) is not typical, but we have chosen it to be able to illustrate how the amplification varies with time.

In order to measure the effect of the Sound Stabilizer, 11 SENSO+ users listened to a text read aloud, and presented at a sound level where it was barely intelligible. During the test, we presented a loud noise for a short period of time and the test persons were asked to indicate when the soft speech was audible again, and when it became intelligible. The test showed that when the Sound Stabilizer was activated, speech was both audible and intelligible much faster after the noise stopped. Thus the test confirmed the objective measurements shown in fig. 6.

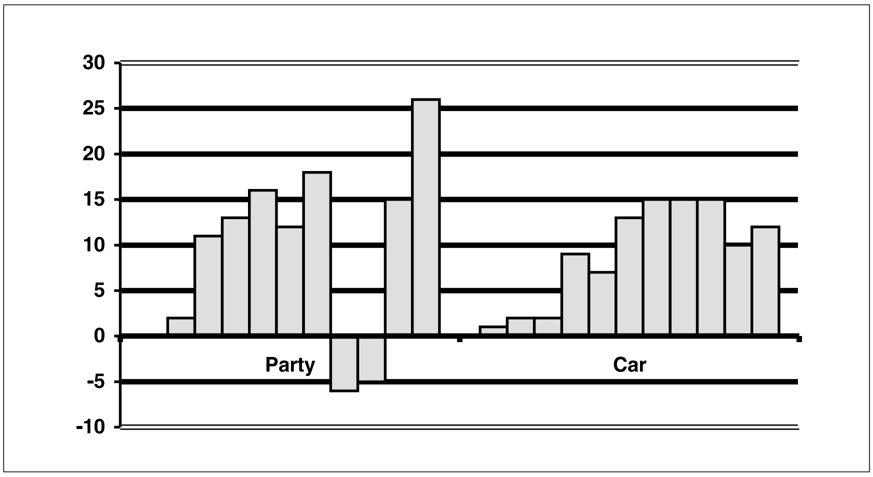


*Fig. 9. Improvement in percent of speech intelligibility when using SIS. 11 test persons have participated, and measurements were made in two types of background noise.*

## Speech Intensification System™ (SIS)

The noise reduction system in SENSO hearing aids regulates amplification in each channel based on a statistical analysis of the signal. When the analysis shows that the noise level within a frequency band is high, amplification in this band is adjusted so that the noise is reproduced at reduced loudness. When speech alone is present there is no reduction of noise. In both situations, SENSO reproduces the sound satisfactorily. Our listening tests have shown that in situations with simultaneous speech and noise we could achieve a better speech intelligibility by changing the frequency balance by putting more emphasis on the middle frequency band. This is exactly what the SIS does. This system reweights the contributions from the different frequency areas.

Two new blocks have been introduced: the SIS block and an analysis block controlling the SIS. Fig. 7 shows the SIS principle as a block diagram. Within the analysis block, the input signal is analysed and the listening environment is classified. When the analysis shows a listening environment with speech in background noise, a new weighting of the contributions from the three frequency bands is made. The purpose of this weighting is to optimise speech intelligibility by making the mutual masking between the bands as small as possible.

Fig. 8 shows how the analysis consists of a separate speech and noise analysis used for minimising the masking between the bands. In a typical listening environment with background noise with a low frequency dominance, the result of the SIS weighting will lead to a relatively higher amplification in the mid frequency area seen in relation to the lowest frequency area. Thus, the SIS weighting takes into account the masking conditions between the frequency components and, for most persons, this gives a better speech intelligibility in background noise.

In order to see whether the SIS has the desired effect, 11 SENSO+ users have participated in a listening test during which speech intelligibility in background noise was measured. Monosyllabic words were presented in two types of background noise taken from the Widex CD with environmental noise: party noise (Party #2) and car noise (In a Car). Fig. 9 shows the results. Generally, SIS results in an improvement of speech intelligibility in the two types of background noise. For car noise, the average improvement is slightly better than for party noise. This is probably due to the fact that this type of noise has a relatively high energy content at low frequencies causing substantial masking in the higher bands. Thus, we conclude that SIS succeeded in reducing upward spread of masking and thereby improved speech intelligibility for the vast majority of listeners.

## Conclusion

Both the Sound Stabilizer and the SIS are features which are only activated in special situations. This means that SENSO+ users will not notice the effects of the new features except in those specific situations where the features are activated. But in these situations, they are likely to experience a positive effect of either of the new features. It should be noted that a few of the test persons, who worked in noisy surroundings, preferred to wear their former SENSO hearing aid at work. Therefore, we have made it possible to turn off the Sound Stabilizer and the SIS. Based on our experience from the field test, this is only necessary in very few cases where former SENSO users prefer the sound they are used to.

## References


*Neuman, A.C., Bakke, M.H., Mackersie, C., Hellman, S., and Levitt, H. (1998). »The effect of compression ratio and release time on the categorical rating of sound quality«. J. Acoust. Soc. Am., 103, 2273-81.*

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