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Pre-Amble

This document describes online demonstrations of adverse acoustical conditions and a software demonstrator of the Binaural Speech Intelligibility Model (BSIM) developed in WP3, which are all accessible on the HearCom web portal. Together, the demonstrators and this document represent the concluding deliverable of WP3. It builds on preceding deliverables of WP3 on the Auditory Virtual Environment (AVE), D-3-4 and D-3-7, since two of the demonstrators employ the AVE for the generation of the provided sound samples, and on deliverables on the BSIM, D-3-1, D-3-3 and D-3-5, which describe the speech intelligibility model in more detail.

The purpose of these publicly accessible demonstrators on the HearCom web portal is to disseminate the work and results achieved in WP3 to professionals and the general public and to raise awareness of acoustically adverse conditions in everyday life with their often problematic implications on human communication, especially if hearing-impaired people are concerned. Furthermore, demonstrating the capabilities of the AVE software and providing a downloadable restricted demo version of the BSIM software are also intended for supporting the exploitation efforts on marketing commercial versions of these softwares.

1 Executive Summary

The present deliverable concludes the work carried out in WP3. It demonstrates some of the outcomes of this work by providing a downloadable demo software version of the Binaural Speech Intelligibility Model (BSIM) on the HearCom web portal, as well as some demo sound samples, partly generated by the AVE, of acoustically adverse conditions. This document describes these demonstrations.

There are three kinds of audio demonstrations in the "adverse conditions" section on the portal:

1. A table with offline-generated playable sounds demonstrating the **effects of noise and reverberation on the intelligibility of speech**. The table contains speech in seven languages in four conditions: in quiet, with noise, with moderate reverberation and with strong reverberation.
2. A simple room acoustic demo offering a limited set of speech and noise source positions in a room whose size and degree of reverberance can be set to two different settings. Apart from the sounds that can be listened to for each selected condition, corresponding BSIM predictions of the respective speech intelligibility are provided in that demo. The focus of this demonstration is on the **binaural gain** that can be observed in adverse listening conditions with spatially distributed sound sources.
3. An **interactive auditory virtual environment**. Here, a Java applet allows configuring a virtually unlimited number of complex spatial conditions by setting arbitrary listening directions (head orientations) and positions of up to three independent sound sources in a room. An additional ambient noise can be activated optionally. The size and the damping of the simulated listening room can be chosen from lists of three possible settings to vary the reverberation time. The resulting sound is computed by the AVE generator in realtime.

In addition to these audio demo samples, a restricted **demo version of the BSIM** as a stand-alone software is described and offered for download. This demo software provides a graphical user interface to load two arbitrary stereo sound files representing noise and target speech. Based on these sounds and an audiogram specified by the user, the software computes a measure for the expected intelligibility of the loaded speech when mixed with the loaded noise, for a listener with the specified audiogram.

2 Introduction

The present deliverable is the concluding deliverable of the HearCom Work Package 3: "Ambient Acoustics", which is part of sub project 2: "Adverse Conditions In Communication Acoustics". The work carried out in WP3 has been concerned with two main scopes: (1) The further development and evaluation of the Auditory Virtual Environment (AVE) and its adaptation to make it accessible over the Internet, and (2) the (further) development, extension and improvement of binaural speech intelligibility models for "normal" and "non-normal"[1] listeners. Both tasks have successfully been accomplished.

Public demonstrators are a means of supporting the dissemination and exploitation of project outcomes. This strategy has been and will continuously be utilised extensively in the HearCom project in general. In WP3, audio demonstrations of adverse conditions in ambient acoustics and a demonstrator software of the Binaural Speech Intelligibility Model (BSIM) have been created and published on the public HearCom web portal. The BSIM predicts the speech intelligibility in such adverse conditions for normal and non-normal (primarily hearing-impaired) listeners. The present document describes these demonstrations. Together, the WP3 demonstrators on the HearCom web portal and this accompanying document represent the deliverable D-3-10.

As stated before, the purpose of the sound demonstrations is to illustrate the meaning of "acoustically adverse conditions" and to raise awareness of such acoustically adverse conditions in everyday life with their often problematic implications on human communication, especially if hearing-impaired people are concerned; and finally, to give a rough idea of the great demands on the models developed in WP3 that are to quantitatively predict the (possibly combined) effects of noise and reverberation on the intelligibility of speech in any spatial conditions, for normal and non-normal (e.g. hearing impaired) listeners.

During the runtime of this work package, three kinds of audio demonstrations have been created with different auralisation softwares and published on the portal. The increasing complexity and capabilities of these demonstrations reflect the continuous work progress in this work package. The first demonstration of adverse conditions which was rendered with the professional room acoustics simulation software "ODEON" (Christensen, 2005) consists of a collection of speech samples in different languages that are either clean (i.e. without noise and reverberation), with added

[1] Here and in the following, the term „non-normal“ listeners is used to subsume hearing-impaired listeners and persons listening to a foreign language.

background noise, or with added reverberation using synthesised room impulse responses.

The second demonstration of adverse conditions, rendered with the auralisation software “tinyAVE” (Borß and Martin, 2009), consists of 252 pre-calculated audio examples for different spatial configurations which can be selected by an interactive web interface. In addition, the expected speech intelligibility based on the extended and improved BSIM model is provided for the selected configuration (speech and noise source position, room geometry and damping).

The third demonstration provides an interactive auditory virtual environment. For that purpose, the latest Internet version of the AVE generator “IKA-SIM” (Silzle, Novo, and Strauss, 2004) is utilised to allow real-time generation of sounds for a virtually unlimited number of simulated complex spatial conditions with up to four independent sound sources and no restrictions of source positions and listening direction (listener’s head orientation).

Apart from audio examples, a restricted demo software version of the BSIM is presented and provided for download on the web portal.

These four demonstrations will be described in more detail in the following.

3 Demonstrators on the HearCom web portal

All described demonstrations on adverse conditions and speech intelligibility are located in the English professional section of the HearCom web portal (www.hearcom.eu), subsection “adverse conditions”. It is planned to mirror these pages on the main site for the general public as soon as a corresponding subsection for demonstrations has been created in that domain.

3.1 Speech intelligibility and reverberation - sound demos

3.1.1 Objective

The first demonstration page provides a number of offline-generated sound samples that give examples of speech in acoustically adverse conditions that handicap acoustical communication. Noise and reverberation are the main factors of acoustically adverse conditions. Consequently, the sound samples provided on this web page demonstrate the effect of these factors on the intelligibility of speech separately, i.e. by additive noise only or reverberation only. As already stated in the introduction, the purpose of these sound examples is to illustrate the meaning of “acoustically adverse conditions” and to give a rough idea of the great demands on the models that are to quantitatively predict the (possibly combined) effects of noise and reverberation on the intelligibility of speech in any spatial conditions, for normal and non-normal (e.g. hearing impaired) listeners.

3.1.2 The web page

The web page with the sound demos is found at:
http://hearcom.eu/prof/RoomAcoustics/WP3ReverberationSoundDemos.html

A screen shot of this page is shown in Figure 1.

After an explanatory text, the page displays 28 icons representing different sound samples, arranged in a table according to acoustical condition (rows) and language (column). Examples in seven languages are provided: Danish, Dutch, English, French, German, Polish, and Swedish. The first row of the table contains the reference condition which is a clean speech sample, i.e. without additional noise or reverberation. In the second row, a speech-shaped, stationary noise signal is added at a signal-to-noise ratio (SNR) that typically yields 50% intelligibility for normal-hearing listeners. The signals in the last two rows were simulated with the “ODEON” software (Christensen, 2005) and demonstrate the effect of two rooms with considerably different reverberation times on clean speech (without an additional noise interferer).

By default, clicking on the icons with the left mouse button will play the sounds; downloading the underlying sound files is possible using the context menu which can be evoked by the right mouse button.

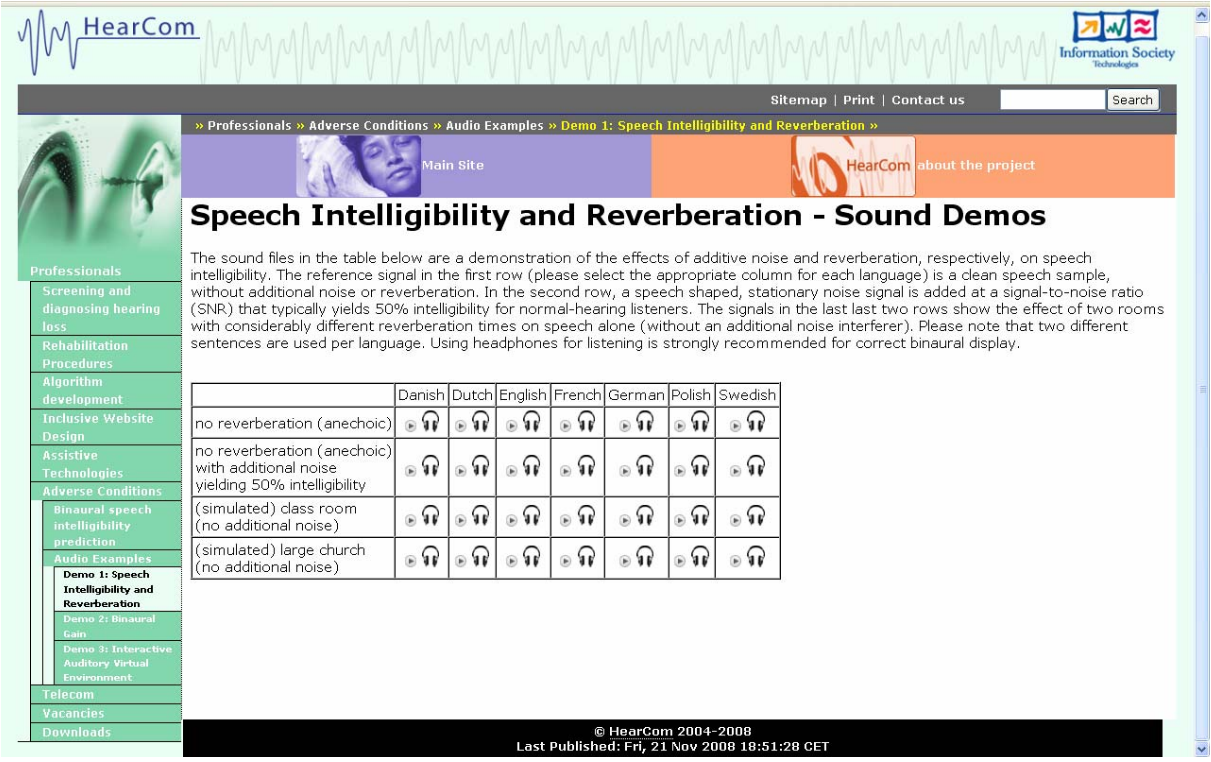


Figure 1: Screenshot of the web page with sound demonstrations of acoustically adverse conditions

3.2 Binaural gain

3.2.1 Objective

This demonstration is to illustrate the effects of binaural listening, in particular: the binaural gain, in different spatial conditions. The user can specify different spatial configurations (i.e. positions of speech and noise source relative to the listener and room size) and listen to the resulting sound that was pre-processed (offline) by the AVE generator “tinyAVE” (Borß and Martin, 2009). In addition, a measure for the expected speech intelligibility computed by the Binaural Speech Intelligibility model (BSIM) for the specified spatial configuration is given at the top of the figure.

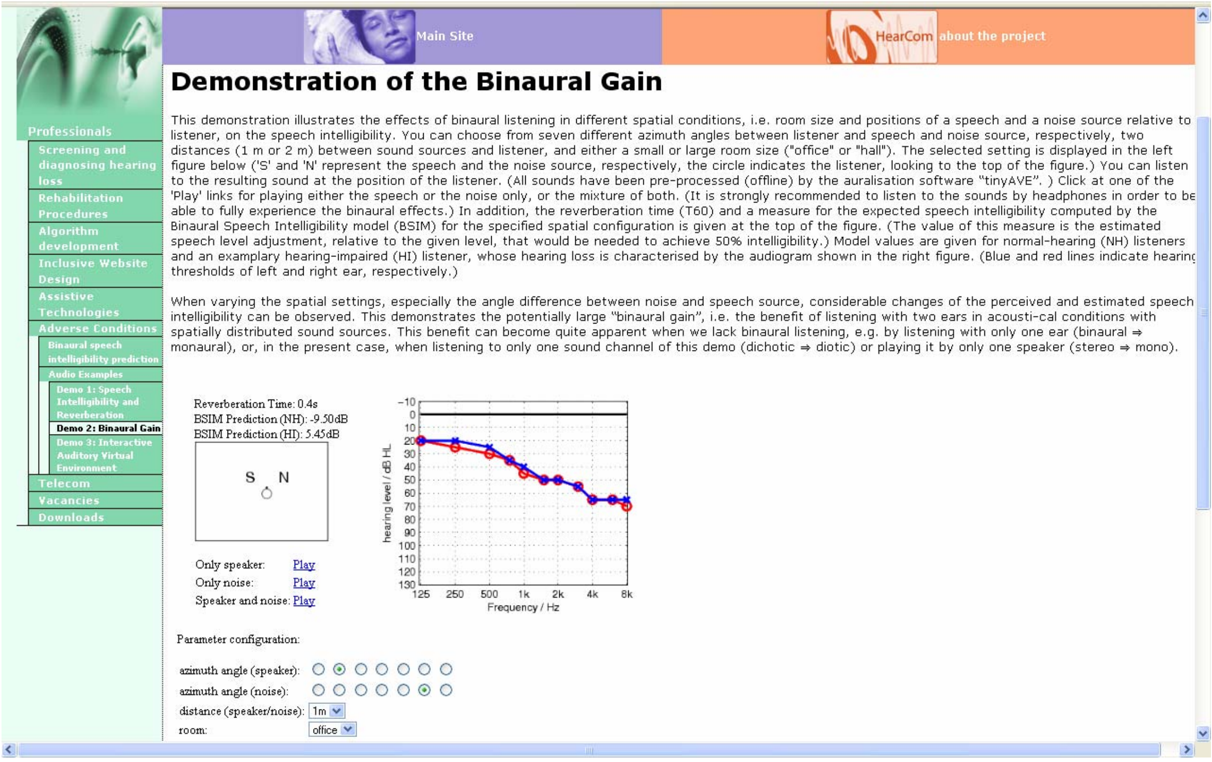
In the description given on this page, it is explained to the user that when “varying the spatial settings, especially the angle difference between noise and speech source, considerable changes of the perceived and estimated speech intelligibility can be observed. This demonstrates the potentially large “binaural gain”, i.e. the benefit of listening with two ears in acoustical conditions with spatially distributed sound sources. This benefit can become quite apparent when we lack binaural listening, e.g. by listening with only one ear (binaural → monaural), or, in the present case, when listening to only one sound channel of this demo (dichotic → diotic) or playing it by only one speaker (stereo → mono)."

3.2.2 The web page

The URL of this demo page is:
http://hearcom.eu/prof/RoomAcoustics/AudioExamples/RoomAcousticsDemo.html

A screen shot of this page is shown in Figure 2.

The page contains an explanatory text and an interactive part, where the user can specify different spatial configurations by choosing from seven different azimuth angles between listener and speech and noise source, respectively, two distances (1m or 2m) between sound sources and listener, and either a small or large room size ("office" or "hall"). The selected setting is displayed in a dynamic figure (cf. lower left panel of Figure 2; 'S' and 'N' represent the speech and the noise source, respectively, the circle indicates the listener, looking to the top of the figure.) When the spatial configuration is specified, the user can play the resulting sound, which has been pre-processed (offline) by the auralisation software "tinyAVE". (Either the speech or the noise only, or the mixture of both can be selected to be played.) In addition, the reverberation time (T60) and a measure for the expected speech intelligibility computed by the Binaural Speech Intelligibility model (BSIM) for the specified spatial configuration is given at the top of the figure. (The value of this measure is the estimated speech level adjustment, relative to the given level, that would be needed to achieve 50% intelligibility.) Model values are given for normal-hearing (NH) listeners and an exemplary hearing-impaired (HI) listener, whose hearing loss is characterised by the audiogram shown in the right panel. (Blue and red lines indicate hearing thresholds of left and right ear, respectively.)



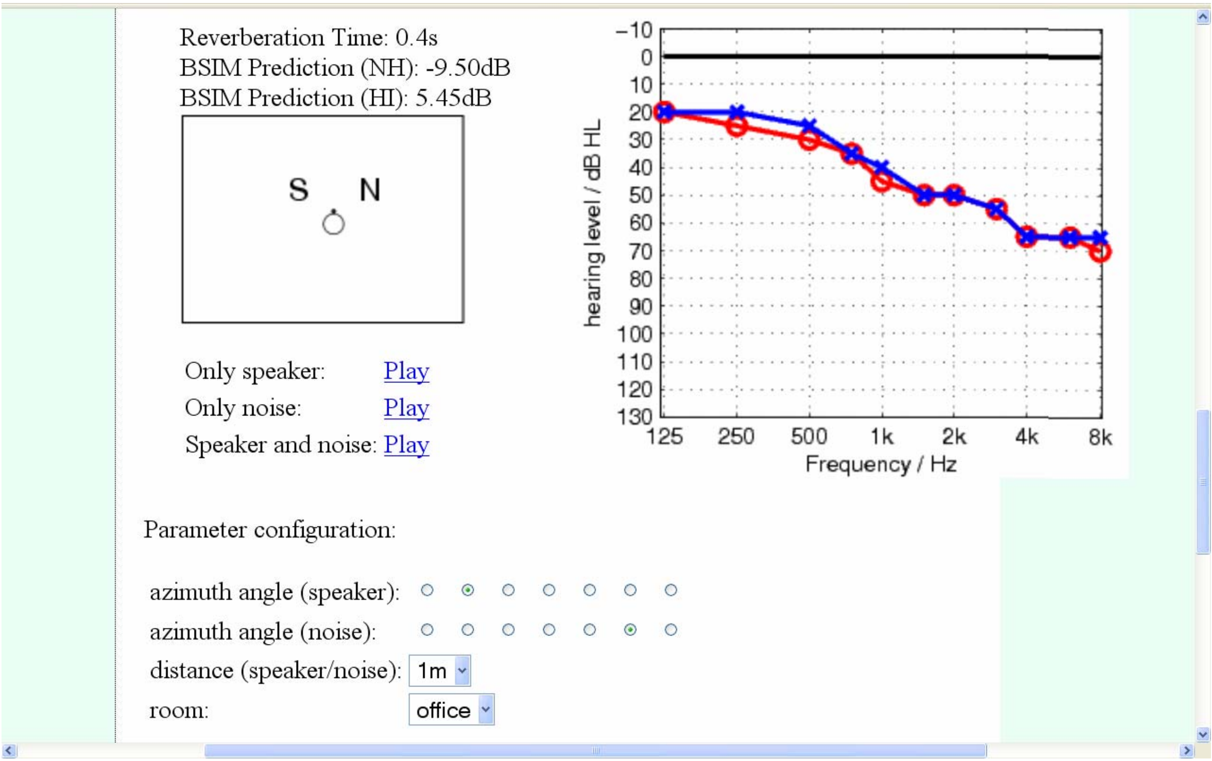


Figure 2: Screenshot of the web page for the demonstration of the binaural gain. Upper panel: Complete page; lower panel: interactive part for setting the spatial configuration and listening to the resulting sounds.

3.3 Interactive auditory virtual environment

3.3.1 Objective

The third demonstration page providing audio samples of acoustically adverse conditions includes a Java applet and offers an interactive, auditory virtual environment that allows online, real-time simulation and demonstration of complex acoustically adverse conditions. Like in the preceding demonstration of the binaural gain, the purpose of this demonstrator is mainly to illustrate the benefit of binaural hearing for understanding speech in spatial conditions with competing sound sources and reverberation. It demonstrates more complex and realistic situations (more and different sound sources) with less restrictions w.r.t the particular positions of the sound sources, thus allowing for a virtually unlimited number of conditions. Additionally, this page also serves to demonstrate the capabilities of a fully interactive Internet-based auditory virtual environment as described in D-3-4.

3.3.2 The web page

The web page of this demonstration is located at
http://hearcom.eu/prof/RoomAcoustics/AudioExamples/DemoAVE.html

Figure 3 displays a screenshot of the Java applet.

In contrast to the former demonstrator, the spatial configuration settings are not restricted to a limited set of pre-computed conditions with a relatively small number of discrete sound source positions. Instead, due to the online sound computation, any positions of the virtual sound sources are possible. Moreover, three instead of two sound sources (speech, flute, drum + electric guitar) plus ambient, diffuse noise (cocktail party situation) can be selected. The head orientation of the listener can be set without restrictions (full turn with few-degrees resolution). Three different room sizes and three degrees of reverberation can be selected. All settings can be changed and come into effect with low delay while the sound is being played continuously. The audio signals are rendered in realtime on a server using the latest version of the AVE generator “IKA-SIM” (Silzle, Novo, and Strauss, 2004). Due to the significant complexity of the required signal processing, the number of users who can concurrently use the demonstration software is restricted to the number of servers which are part of the AVE rendering farm[2].

[2] The rendering farm currently consists of two IKA-SIM servers.

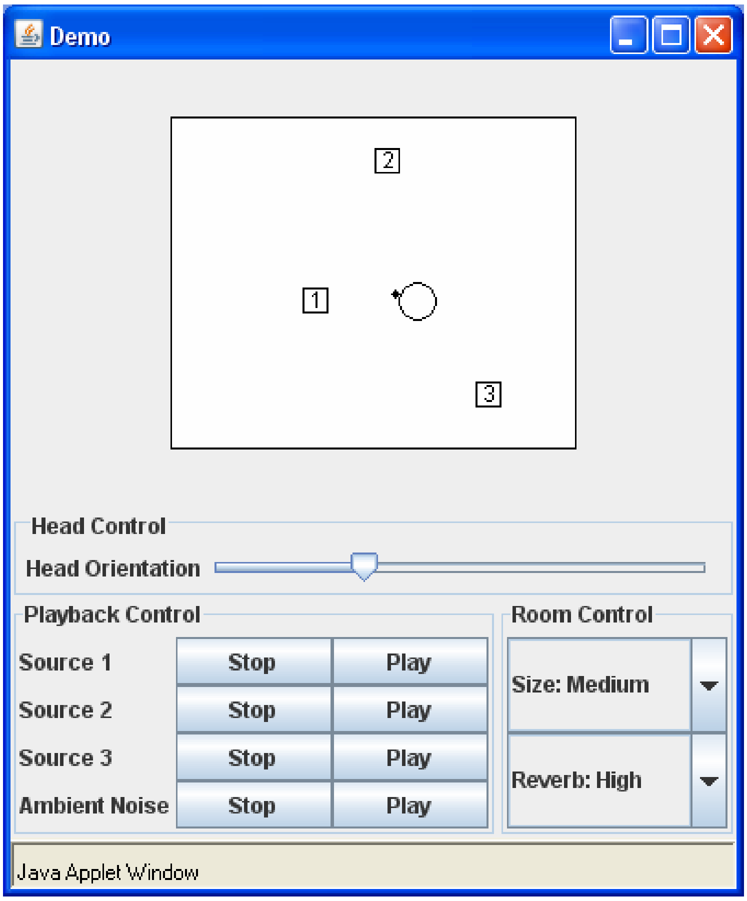


Figure 3: Screenshot of the Java applet running the interactive auditory virtual environment demonstration. The positioning of the listener and the sound sources is done by dragging the corresponding symbols in the figure with the mouse pointer.

3.4 Demonstration software of the Binaural Speech Intelligibility Model (BSIM)

3.4.1 About the BSIM

Objective

One of the items that have been developed within the HearCom project is a *binaural* extension of the Speech Intelligibility Index (SII, ANSI, 1997), a standardised model of speech intelligibility prediction. The SII was so far only intended for single channel input and was not specifically applicable to typical "cocktail-party" situations (Cherry, 1953; Bronkhorst, 2000), which involve, among other factors, multiple sound source locations and room reflections. The binaural extension of the SII (Beutelmann, 2006) evaluates binaural speech and noise signals and predicts the speech intelligibility benefit for spatially separated speech and noise sources in anechoic conditions as well as in realistic rooms. Predictions can be made for both normally-hearing and hearing-impaired subjects, based on the audiogram.

BSIM principle

The binaural extension of the SII does, in principle, not change the SII method, but acts as a front-end which determines the additional signal-to-noise ratio (SNR) improvement due to better-ear listening and binaural interaction. It was developed on the basis of the work by vom Hövel (1984). The binaural speech and noise signals are divided into ERB-wide frequency bands with the help of an auditory (gammatone) filter bank (Hohmann, 2002). In each of the frequency bands, the maximally achievable SNR is computed using the Equalization-Cancellation (EC) principle (Durlach, 1963). The EC process aims at eliminating the noise signal due to destructive interference by subtracting one of the channels from the other, after equalizing a potential interaural time delay and level difference. In order to match the model performance to human data, the process contains artificial inaccuracies of the equalization operations. The audiogram is incorporated in form of a hypothetical internal noise, which sets an upper limit for the SNR in each frequency band. The SNRs in each frequency band are passed to the SII, from which the speech intelligibility or a speech reception threshold (SRT, the speech level or overall SNR at which 50% intelligibility is reached) can be calculated.

For more details on the BSIM and its evaluation, please see Deliverables D-3-1, D-3-3, D-3-5 and D-3-9.

3.4.2 The BSIM demonstrator software

A demonstrator of the BSIM has been written in MATLAB® and compiled into a stand-alone executable for Windows OS. It has been made available for download on the HearCom web portal (see following section). It can be used with a freely distributable MATLAB® component runtime library independent of a locally installed MATLAB®. The demonstrator includes a graphical user interface (s. Figure 4) for the model back-end. The restrictions of the demonstrator compared to the full model are:

- The model accepts input signals only at a sampling rate of 44.1 kHz.
- Only the first 0.5 s of the input signals are used.
- Only the provided example audiogram (in addition to “normally-hearing”) can be used.
- Internal model settings and output parameters of the binaural stage are not accessible

The input signals need to be provided as separate wave files for speech and noise. Although it is in principle possible to use an actual target speech signal, it is recommended to replace it with stationary noise having the same long-term spectrum and an identical binaural configuration. This avoids unwanted deviations of the result due to the relatively small sample of speech statistics within 0.5 seconds.

An instruction for the usage of the BSIM demonstrator software is given in the Appendix 7.1.

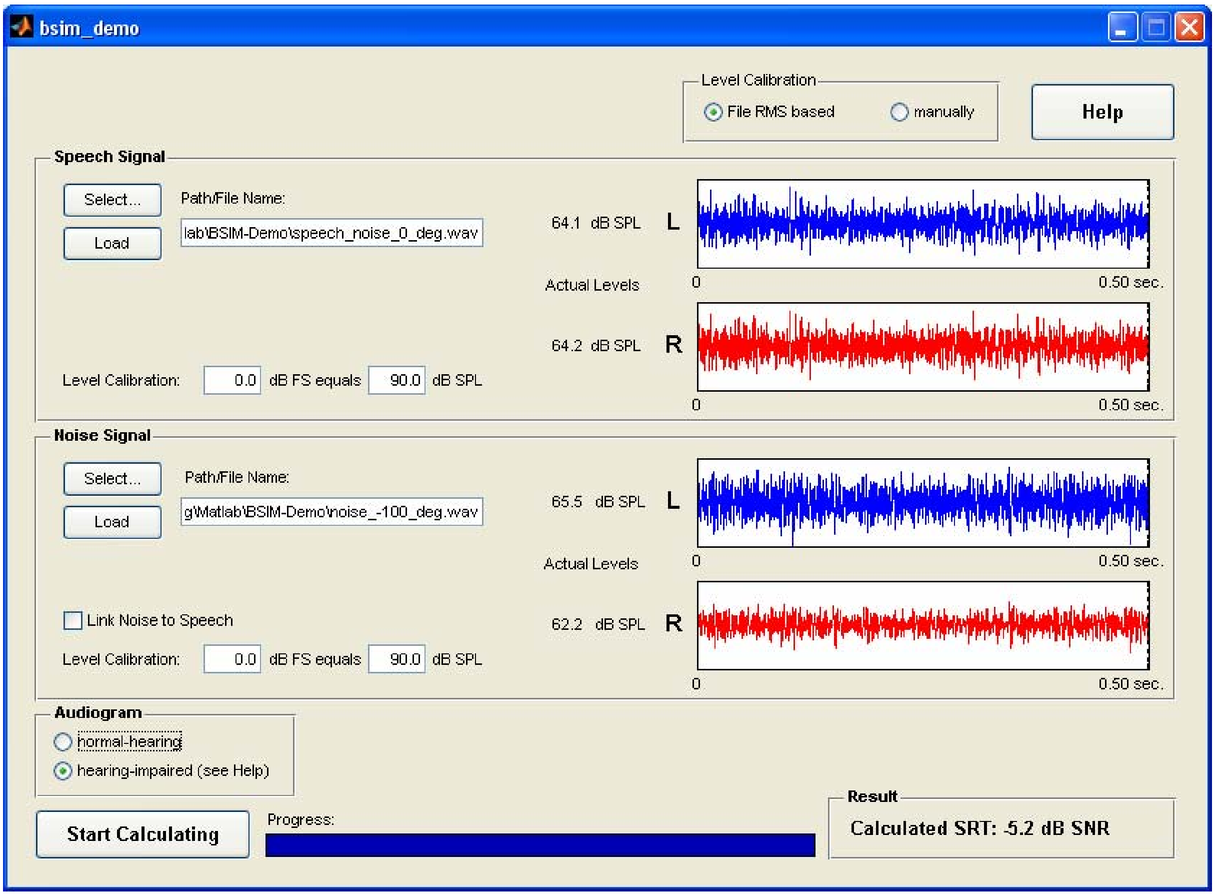


Figure 4: Graphical user interface of the BSIM demonstrator

3.4.3 The BSIM demonstrator web page

The URL of the web page describing the BSIM demonstrator is

http://hearcom.eu/prof/RoomAcoustics/BSIMDescription.html

The page contains a link to another page where the software can actually be downloaded:

http://hearcom.eu/prof/RoomAcoustics/BSIMDescription/bsim.html

The content of this page is displayed in Figure 5.

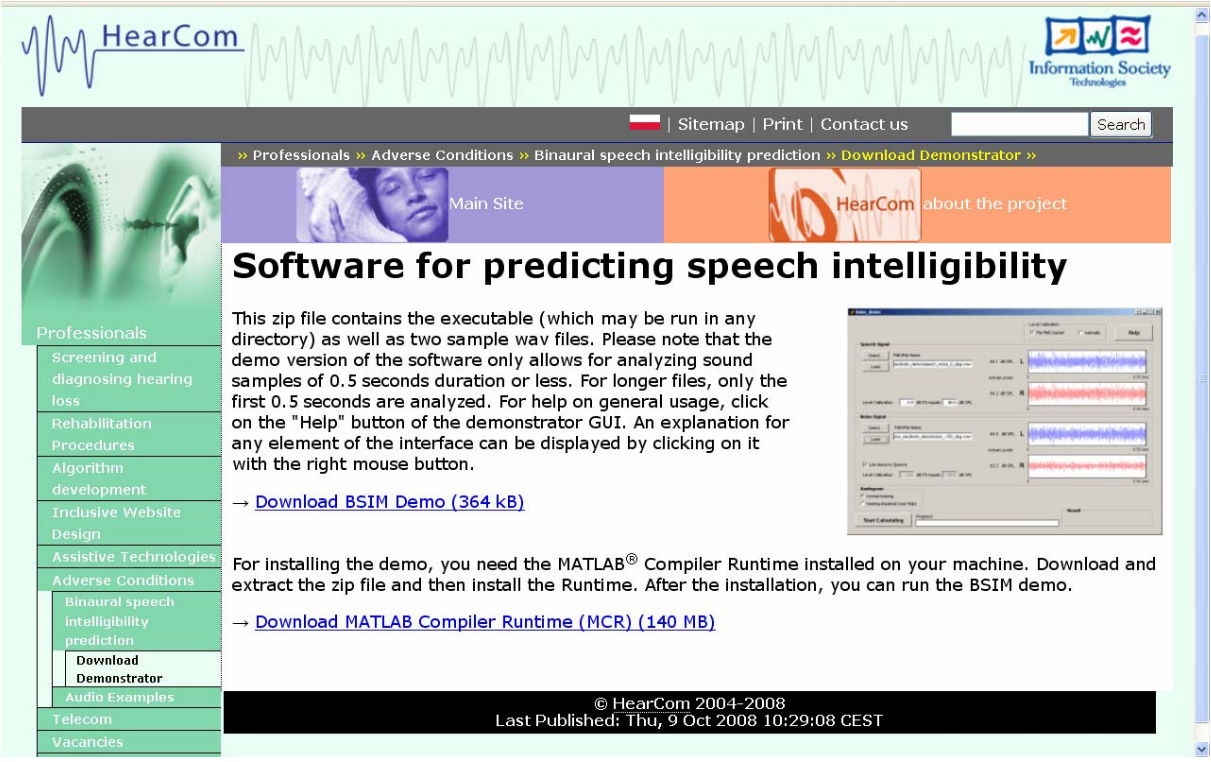


Figure 5: Screenshot of the web page providing the download of the BSIM demonstrator software.

4 Dissemination and Exploitation

The present deliverable itself is a pure dissemination and exploitation activity. Apart from this dissemination, the demonstrators presented in this deliverable are based on the AVE and BSIM. There are a number of publications of the work carried out in WP3 on the BSIM and the AVE which are reported in the preceding WP3 deliverables and/or in the HearCom publication list.

The BSIM demonstrator software is publicly available on the HearCom web portal. This version has a restricted functionality in order to allow the user to test the model and its use while still encouraging the purchase a potential future full, commercial version. The option of marketing such a commercial version by DE-HTCH is currently discussed between DE-UOL and DE-HTCH.

5 Conclusions

Three audio demonstrations on acoustically adverse conditions and a demonstration software of a speech intelligibility model have been published on the HearCom web portal and described in the present document. They appear qualified to fulfil their intended objectives stated in the Pre-Amble.

However, the demonstration web pages should also be made visible in the non-professional site of the HearCom portal. Users should be advised of demonstrations in the portal more obviously.

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7 Appendix

7.1 BSIM demonstrator software usage instruction

1. In order to set the input signals, use the "Select..." buttons, which open a file dialog to choose the wave files.

   - The signals need to be separated into "speech" and "noise". Both signals may be actual binaural recordings or convolved with HRTFs. The wave files have to be sampled at 44.1 kHz sampling rate. Only the first 0.5 seconds of the wave files are used in this demo, if the signals are longer than 0.5 s.

   - The speech signal may be actual speech, but it is recommended to replace the speech signal with a speech simulating noise with the same long-term spectrum as the actual speech. This allows for predictions from short signals with decreased variance due to statistical fluctuations within real speech signals.

2. The selected wave files are loaded, when the "Load" button is pressed. The wave forms are displayed in the axes on the right.

3. The target levels in dB SPL can be adjusted in two ways:

   a) "File RMS based": by entering a calibration reference between dB FS and dB SPL. The actual levels are then calculated from the wav file RMS levels. If the speech and noise wave files have different calibration references, uncheck the "link Noise to Speech" checkbox.

   b) "manually": by using the "actual level" edit boxes. The levels have to be the levels which would occur at the ear of the listener, i.e. including interaural level differences e.g. due to head shadow.

4. Choose an audiogram. If "normal-hearing" is checked, an audiogram of 0 dB HL at all frequencies is assumed. When "hearing-impaired" is checked, an example hearing loss with the hearing levels shown in the audiogram in Figure 1: Help Figure (press the "Help" button to display) are assumed instead of the normal-hearing threshold.

5. The "Start Calculating" button runs the model with the previously selected files and levels. Depending on the CPU speed, this may take a few seconds, indicated by the progress bar.

<u>Result:</u>

The calculated model output value is the level adjustment applied to both speech channels relative to the given levels that is needed to achieve 50% intelligibility.