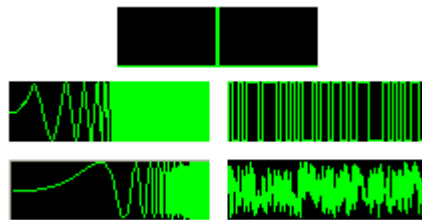




Technical Note

DIRAC STIMULI



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1 Introduction

Dirac provides many internally generated stimuli for different measurement situations. The Acoustics Engineering website, and the Dirac product CD contain a number of stimuli in different formats that can be used effectively in open loop measurements.

This technical note describes the available stimuli.

2 Basic stimuli

The basic stimuli that Dirac generates internally are the Maximum Length Sequence (MLS), and the sweep. The different stimuli can be selected in the measurement dialog.

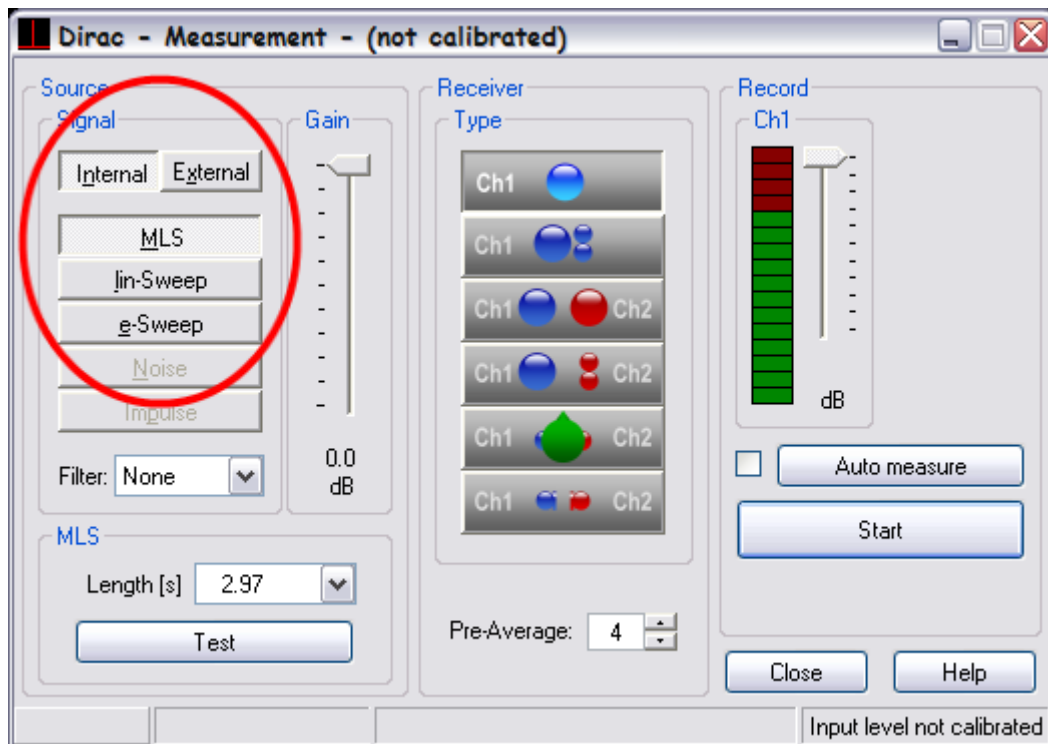


Fig 1: Dirac Measurement dialog - Stimulus selection

2.1 MLS

The MLS [1][2] is a pseudo random binary sequence having a flat frequency spectrum. MLS stimuli have been popular in impulse response measurement systems because they can be

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generated using a simple shift register, and because deconvolving the response to an MLS stimulus can be performed very quickly using a cross correlation based on the Hadamard Transform.

An MLS signal is rather sensitive to system nonlinearities and time-variance. These effects cause spikes or noise that are distributed over the full length of the response, but are particularly visible in the impulse response tail, and reduce the INR [6] or the IR decay range.

2.2 Sweep

The sweep [3] consists of a sine wave that slowly changes over time from the lower to the upper edge of the spectrum. The sweep is less sensitive to time-variance, but sounds more intrusive.

There are two sweep variants in Dirac: the linear sweep (lin-sweep), where the frequency increases linearly over time, and the exponential sweep (e-sweep), where the frequency increases exponentially over time. Note that the e-sweep is sometimes referred to as a log-sweep in the literature.

The linear sweep is comparable with the MLS in the sense that it also has a flat (white) frequency spectrum. The e-sweep has a pink ($1/f$) spectrum, and therefore has equal energy in each octave band. This property of the e-sweep is useful in the many situations where it is difficult to get a good signal to noise ratio at lower frequencies. The e-sweep also has the property that noise caused by system non-linearities or time-variance, can easily be separated from the actual impuls response.

Bandlimiting

With MLS signals, all the energy is spread evenly over the full spectrum for the duration of the stimulus. This in contrast with sweep signals where all energy is concentrated at a single frequency for each moment in time. This concentrated energy can cause problems for speakers at very low frequencies and at very high frequencies. To prevent damage to the sound source, it is possible to use bandlimited sweeps that only excite frequencies relevant for the measurement of acoustical parameters.

In Dirac the bandlimited sweeps can be enabled in the Options dialog on the Measurements tab:

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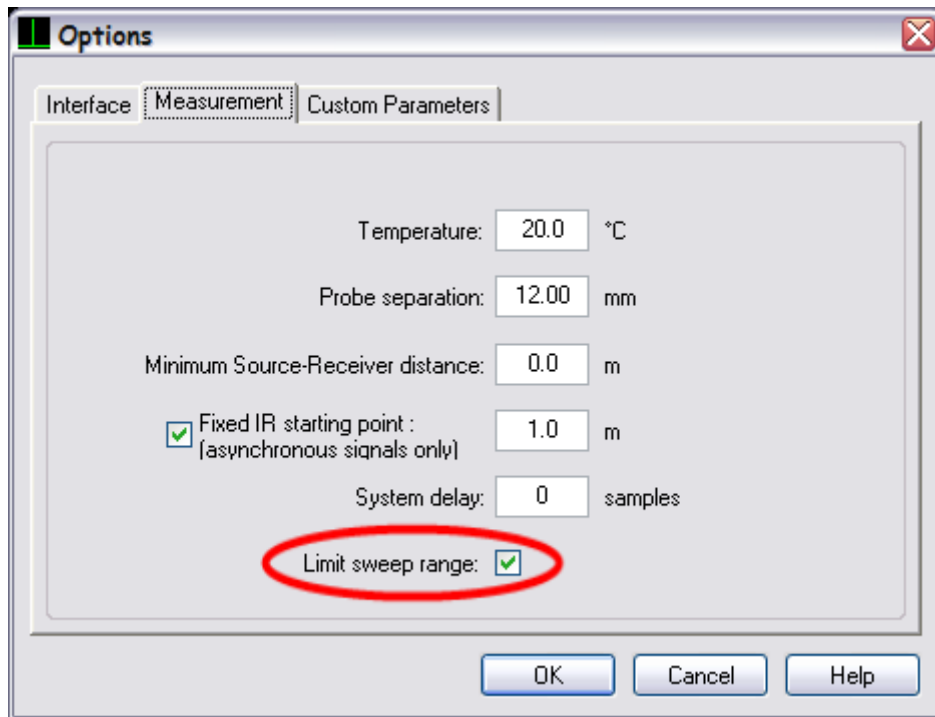


Fig 2: Options dialog - Sweep bandlimiting

3 Filters

The basic stimuli described above can be filtered to handle specific measurement situations. The available filters can be selected in the Measurement dialog.

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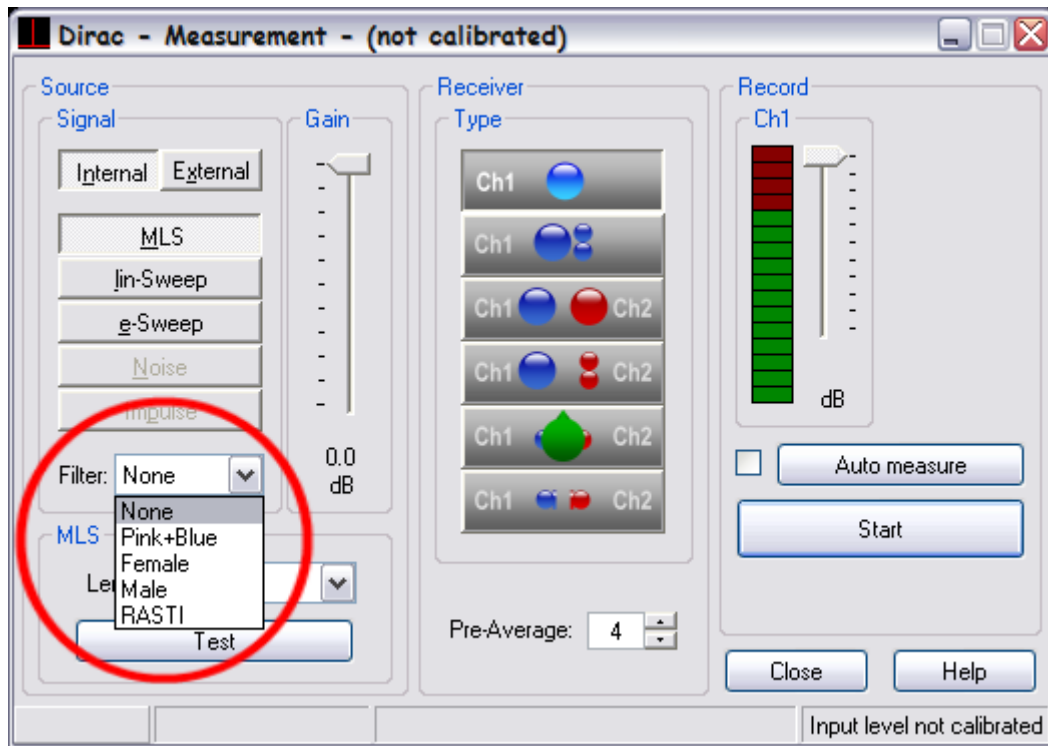


Fig 3: Measurement dialog - Filter selection

3.1 Pink + Blue filters

In some measurement situations it is difficult to reach acceptable INR values in the lower frequency bands. This may for instance be due to higher background noise levels at low frequencies, or due to a lower output level from the sound source at these frequencies. Increasing the power output in the low frequency bands can help alleviate the problem. The e-sweep stimulus has a $1/f$ spectrum that can be used effectively in these situations. The flat MLS or sweep stimuli spectra can be shaped to $1/f$ by the pink filter. To compensate for the pink filter, a blue filter is used on the recorded signal before the deconvolution calculations. The Pink+Blue filters are only available for the MLS and lin-sweep stimuli.

3.2 Speech filters

For speech intelligibility measurements [5] where the actual background noise is relevant, it is necessary to use test signals that have a prescribed (speech-like) spectrum. For this purpose, Dirac has female and male speech filters for STI and STITEL measurements, and a RASTI filter for RASTI measurements. These filters will shape the (initially flat) spectrum of a

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stimulus to conform to the requirements set out in IEC 60268-16 [4]. Note that the speech filters are only available for the MLS and lin-sweep stimuli.

4 External stimuli

The internal stimuli generated by Dirac are normally fed to a sound source, while a microphone connected to the PC is used to record the response.

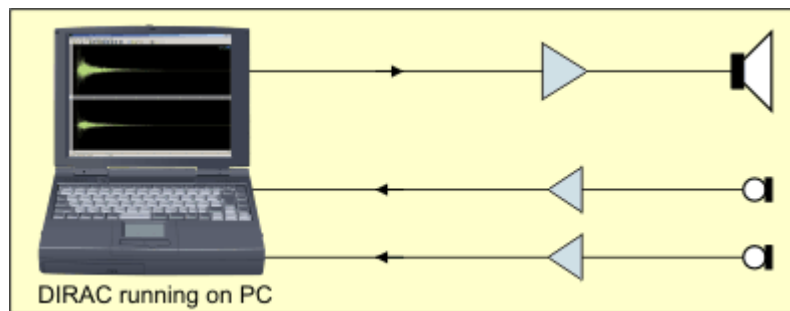


Fig 4: Closed loop measurement

In some situations it is very inconvenient or even impossible to have a direct connection from a PC to both the sound source and the microphone(s), for instance when the stimulus has to be fed into an existing PA system. For these situations Dirac allows the use of external stimuli being played from a CD- or MP3-player.

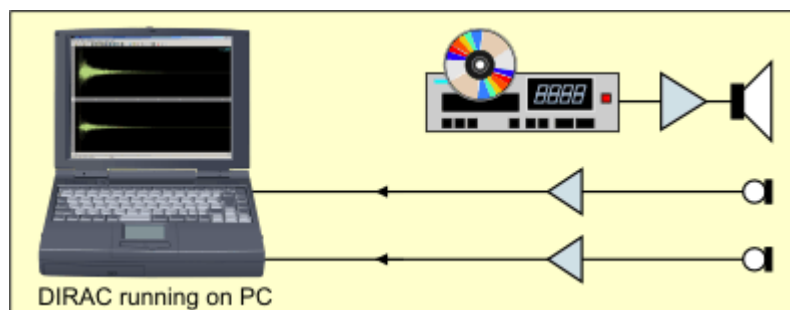


Fig 5: Open loop measurement

The MLS or sweep signals that are played by the external source must match exactly the stimuli generated by Dirac. Therefore the basic stimuli have been included on the Dirac CD as PCM data files (.wav files) and compressed MP3 files.

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Impulse and noise stimuli

In addition to the basic stimuli (MLS and sweep), two other external stimuli can be used with Dirac.

An external impulse can be generated with an alarm gun or a balloon. The recording of the external impulse immediately gives the room's impulse response, and no deconvolution calculations are performed. The reproducibility of external impulses is usually not very good.

In external noise measurements, a noise signal is fed to both the sound source and the receiver. Dirac deconvolves the noise signal with the measured room response to recover the impulse response. The external noise method is of course not an open loop measurement as a connection from the PC to the sound source is still required.

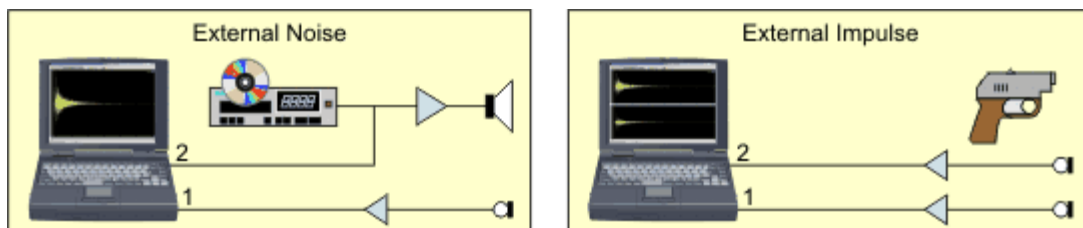


Fig 6: External noise and impulse measurements

5 Using the stimuli on the Dirac CD

The Dirac product CD contains a variety of files in the *stimuli* folder and its sub folders. These files can be used to create an audio CD, or can be copied directly to a playback device such as an MP3 player.

It is important to setup Dirac correctly when using these external stimuli. In particular, the following settings must correspond to the properties of the external stimulus:

- Basic stimulus (e.g. MLS, lin-sweep or e-sweep)
- Sequence length
- Sample rate
- Bandlimiting option (for sweeps only)

When either of these settings is not correct, the resulting impulse response will be unusable.

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5.1 WAVE files

The MLS stimuli are all contained in the folder *Stimuli\Allpass\MLS*. They consist of a single sequence with a 48 kHz sample rate. The length of the sequence is encoded in the filename; the file named *MLS n .wav* has a length of 2^n samples. For instance *MLS17.wav* has a length of $2^{17} = 131072$ samples. At 48 kHz this is $2^{17}/48000 = 2.7$ seconds.

To use this sequence on a CD, you will first have to change the sample rate to 44.1 kHz, which you can do using the following procedure:

1. Open the required sequence (*MLS n .wav*) in Dirac.
2. From the **File** menu select **Change Sample Format...**
3. Change the **Sample rate** to 44100 Hz.
4. Make sure the **Resample** option remains unchecked.
5. Click **OK** and save the file.

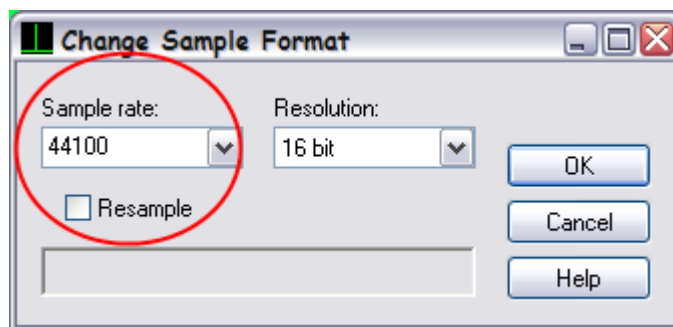


Fig 7: Changing the sample rate

Each sweep stimulus is contained on the Dirac product CD in 4 different variants as determined by the bandlimiting option (*Stimuli\Allpass* vs. *Stimuli\Bandlimited*), sweep type (*esweep* vs *lsweep*), and sample rate (*44* vs. *48*). Note that you cannot change the sample rate of the sweep sequences (as described above for the MLS), because the sweep start- and end-frequencies are dependent on the sample rate.

Because starting a measurement at the exact moment the playback of a sequence starts is practically impossible, it is necessary to concatenate the sequence a number of times. Also, a deconvolution based measurement requires the sequence to be played back at least twice. The first sequence to build up a steady state soundfield, followed by a sequence for the measurement. If averaging is to be used, the number of sequences needs to be increased

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correspondingly. You can use most sound editing software to concatenate a number of sequences in a single .wav file. You can of course also use Dirac as follows:

1. Open the required sequence in Dirac.
2. Press **Ctrl-A** to select the entire sequence, and **Ctrl-C** to copy the sequence to the clipboard. Alternatively, use the **Edit** menu to **Select** and **Copy** the sequence.
3. Click on the first sample in the impulse response window. The status bar of this window should now display a position and length of 0.

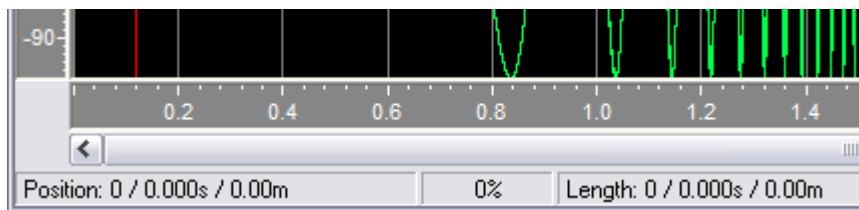


Fig 8: Insert position

If selecting the correct insertion point using the mouse proves too difficult, you can choose **Select...** from the **Edit** menu and fill the dialog as depicted below:

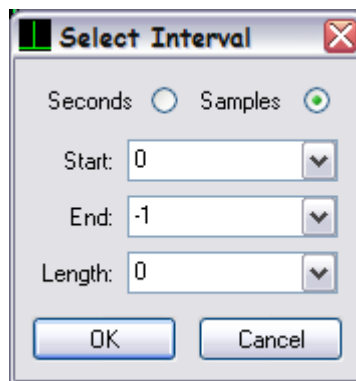


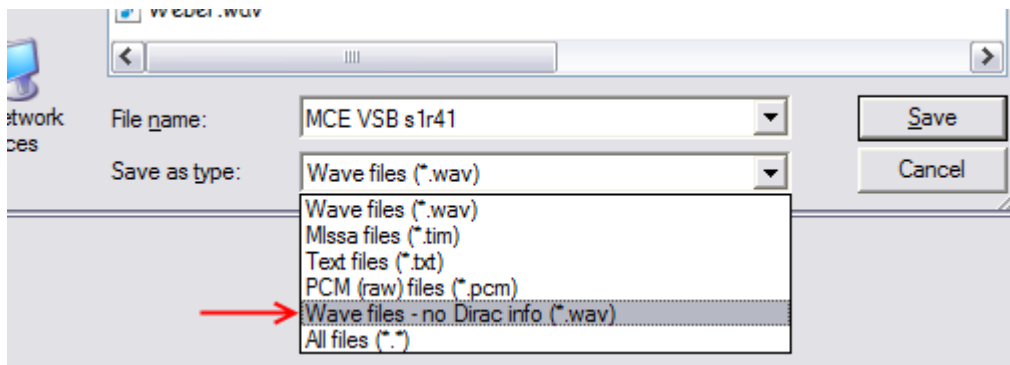
Fig 9: Select

4. Press **Ctrl-V** (or select **Paste** on the **Edit** menu) to insert the sequence from the clipboard.
5. Repeat steps 3 and 4 until the required number of sequences have been concatenated, and save the file.

When saving .wav files Dirac adds specific information to the file describing the measurement setup. This information can be seen and changed in the **File Properties** dialog

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in Dirac. Some programs (such as Windows Explorer) will not accept these .wav files when creating an audio CD. To remove the extra information from the .wav files, you can select the alternate .wav format from the 'Save as type' dropdown in the 'Save As' dialog:



Dirac will not write the extra information, and the resulting file(s) can be used by Windows Explorer to create an audio CD.

Note that you cannot write a single sequence to a CD, and then have the CD player repeat this sequence. The CD player will leave gaps between the sequences, which will ruin the measurement.

5.2 MP3 files

MP3 players have a number of advantages over CD players for field measurements. These are the same reasons that have made the MP3 player the most popular digital media player. The Dirac product CD contains a number of MP3 files that can be used with any MP3 player.

All MP3 files consist of a sequence that is repeated for 10 minutes. At the end of the file there is a 10 second pause to prevent an unnoticed automatic repeat by the MP3 player. The MP3 files were encoded at a constant bit rate of 160 kBit/s using the Lame encoder. The sequences used to create the MP3 files have a sample rate of 44100 Hz.

The basic MLS and (bandlimited) sweep sequences are contained in the folder *Stimuli\MP3*. The length of the basic sequence is part of the filename. For instance: '*ESWP 12s.mp3*' is based on an e-sweep sequence with a duration of 12 seconds.

The folder *Stimuli\MP3\Speech* contains speech filtered MLS and lin-sweep sequences that can be used for speech intelligibility measurements. For more information on the use of speech filters for speech intelligibility measurements, refer to the Dirac help file.

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6 References

- [1] M.R. Schroeder: Integrated-impulse method for measuring sound decay without using impulses. Journal of the Acoustical Society of America 66 (1979) 497-500
- [2] D.D. Rife, J. Vanderkooy: Transfer-function measurements with maximum length sequences. Journal of the Audio Engineering Society 37 (1989) 419-444
- [3] S. Müller, P. Massarani: Transfer-function measurements with sweeps. Journal of the Audio Engineering Society 49, No.6 (2001) 443-471
- [4] IEC 60268-16 Sound system equipment. Part 16: Objective rating of speech intelligibility by speech transmission index.
- [5] TN002 : Measuring speech intelligibility using DIRAC – <http://www.acoustics-engineering.com/files/TN002.pdf>
- [6] TN007 : Impulse To Noise Ratio INR – <http://www.acoustics-engineering.com/files/TN007.pdf>

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