



USER MANUAL

EigenStudio®

Version 2

Rev. D

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1 Introduction

mh acoustics' EigenStudio® application (hereafter referred to as "EigenStudio") is a stand-alone software application written by mh acoustics for the em32 Eigenmike® microphone array that allows for recording, processing, and control of the em32's microphone array system. The application covers three fundamental use cases:

- A wide range of beamforming applications
- Eigenbeam (spherical harmonics, higher order Ambisonics) encoding
- Basic editing of raw em32 recordings

EigenStudio can render up to 30 distinct beamformed output channels simultaneously. There are multiple preset beampatterns to choose from. Each beam can be steered independently to any direction in 4π space. Input channels can be selected from either the real-time em32 microphone signals, previously recorded em32 data files, or from previously recorded encoded Eigenbeam data files. The rendered output channels can be played back through an audio driver as well as stored to file.

EigenStudio can also be used to encode the em32 microphone signals (live or previously recorded) into Eigenbeams (spherical harmonics, HOA signals). Eigenbeam encoded files can be used as an input to EigenStudio's beamformer processing or processed by third-party Ambisonics decoders.

Another fundamental feature allows the user to easily cut out a desired section of a larger em32 microphone recording that can then be used for further processing.

EigenStudio can be run for processing and playback without being connected to an em32 system. When the em32 system is not detected, the EigenStudio application allows the user to select any ASIO (Windows) or Core Audio (macOS) device that is defined for audio output. To use a Windows PC's internal sound card for output, select e.g. ASIO4ALL (downloadable from the internet¹) or e.g. "Built-In Output" for macOS. EigenStudio also allows for faster than real-time offline rendering of processed output files (note that processing time will depend on the CPU power of the computer).

¹ Systems shipped with a MacBook Pro and Boot Camp have the ASIO4ALL Windows driver pre-installed.

2 Installing and Running EigenStudio

On pre-configured systems sold with a laptop, mh acoustics has taken care of the installation. For Windows the user will find the EigenStudio application in "%HOMEPATH%\mh acoustics\EigenStudio\" or "/Applications" for macOS. A desktop shortcut is typically also placed on the main screen of both OS's to allow for quick launch of the application.

When the EigenStudio application has been downloaded from the web, the user must perform the installation. Since the EigenStudio application is distributed as a compressed installation package the user first has to extract the file. In most cases double-clicking the downloaded file does this. Otherwise follow the instructions of your archiving tool to do this. After extraction, the user is presented with a folder that contains the following files:

- Readme.txt: A revision history of the EigenStudio application is found in this file.
- EigenStudio User Manual: This document.
- How to Record: A quick-start guide to recording with EigenStudio and the em32.
- Best Practices for Recording with the em32: A document that contains some important guidelines for recording with the Eigenmike em32 hardware.
- Eigenmike Setup Guide: Instructions for setting up the Eigenmike em32 microphone array hardware and installation of the audio driver.
- EigenStudio-osx-installer / EigenStudio-windows-installer: The installation package for the EigenStudio application.
- TCATDice-x.y.z: The installation package for the audio driver.

Before proceeding, it is highly recommended to review the "Best Practices for Recording with the em32" document. This short document can help the user to avoid potential pitfalls.

The next step is the hardware setup and audio driver installation. If this was not already done previously, please follow the instructions in the "Eigenmike Setup Guide". Note that the TCAT Dice audio driver is part of this package and does not need to be downloaded.

The final step is the installation of the EigenStudio application itself. To start the installation, double-click the EigenStudio installer package and follow the on screen instructions.



Figure 1: The EigenStudio application icon

To start the EigenStudio application, click or double-click (depending on the location of the application) the application icon (Figure 1). The program will start in the state it was last closed. Note that the startup can take a few seconds since the application is scanning the MIDI system for a connected em32 Eigenmike array. The application presents a pull-down menu listing all available audio interfaces if no em32 Eigenmike array system is connected. Choose one and click ok. On the first launch the EigenStudio app will also ask for the default audio data file pool directory location (see section 3.12.1.3 for details). This location can be changed later. The EigenStudio application is ready to use once the GUI is displayed.

3 The User Interface

Figure 2 shows the main GUI window that appears when EigenStudio is launched. The GUI is split logically into multiple areas from the top-left to bottom-right: the main timeline bars, input source selection, level meters (with signal selection), outputs source selection, signal monitor selection, input control, beampatterns (horizontal and vertical; beam shape and steering), beamformer (control of beamformed outputs), output control (Eigenbeams and Beamformer) and audio transport control (Stop, Pause, Play, Loop, Record and Offline Processing). In addition to the GUI panels there are "Settings" and "Info" menu pull-downs in the upper left corner of the main window for Windows and the standard upper screen bar on macOS. Another part of the GUI is the title bar, which displays the current sample rate of the audio driver. Each of these GUI elements are described in the following sections.

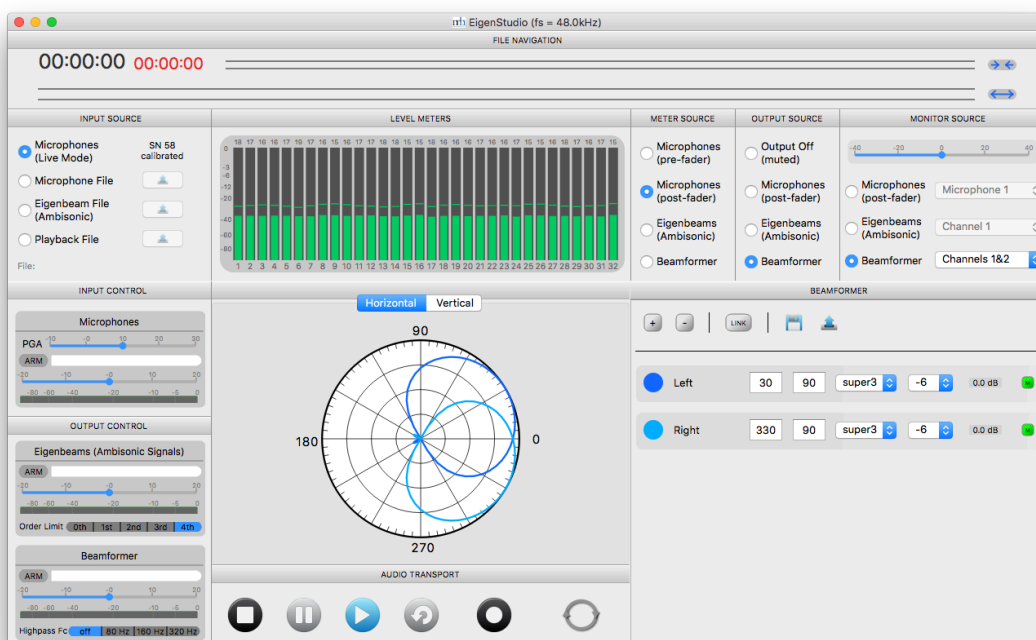


Figure 2: EigenStudio main screen

(note that the Input Source shows that data is being played live from a connected em32)

3.1 Title Bar

The title bar of the EigenStudio application displays the current recording and playback sampling rate. The sample rate is set via the corresponding audio driver (TCAT if EMIB is used) and needs to be adjusted before EigenStudio is launched. Available sample rates are 44.1kHz and 48kHz. To change the sample rate, first exit the EigenStudio application, then open the audio driver control panel² to change the sample rate. Finally, re-launch the EigenStudio application.

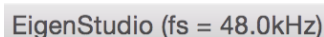


Figure 3: The title bar of the EigenStudio application.

This instance shows a sample rate of 48kHz.

3.2 File Navigation

Figure 4 shows the *File Navigation* panel that provides graphical feedback about the current position in the audio file during playback. The panel allows the user to select specific audio sections, to move to a certain position, and more. The specific panel items are:

- Playback Timer: numeric timer with the black font at the upper left of the panel displays the current position in the audio file in the format hours:minutes:seconds.
- Record Timer: numeric timer with the red font at the upper left of the panel (to the right of the Playback Timer) displays the current length of the recorded audio. The format of the timer is hours:minutes:seconds.
- Upper Timeline: The top timeline always represents the full audio file. It displays a gray bar that reflects the selection that is covered by the lower timeline. By clicking and holding down the left mouse button on the gray bar the selection can be moved within the file by moving the mouse left/right. Note that this is only appropriate if the bottom timeline selects a part of the file and not the full file.
- Bottom Timeline: The lower timeline enables the user to select certain parts of the audio file for listening or processing, by using the user adjustable start/stop flags.
- Start/Stop Flags: The two markers in the bottom timeline represent the start (left marker) and stop (right) position. Playback begins at the start flag and ends at the stop flag. This allows the user to focus on a small section within the bottom timeline. The selected section is highlighted in light blue. The flags are moved by clicking on the mouse and holding down while dragging the flag to the desired location.
- Zoom In: The zoom-in "<->" button is located to the right of the lower timeline. Clicking this button will expand the current audio selection over the full length of the lower timeline. Note that the gray bar in the top timeline shrinks to reflect the update in the lower timeline. The zoom-in feature is useful in large files if the user wants to narrow in on a short section of audio.
- Zoom Out: The zoom-out button ">-<" is located to the right of the upper timeline. The zoom-out button will reset the lower timeline to the full file length.

² On macOS, this can also be done via the "Audio MIDI Setup" application

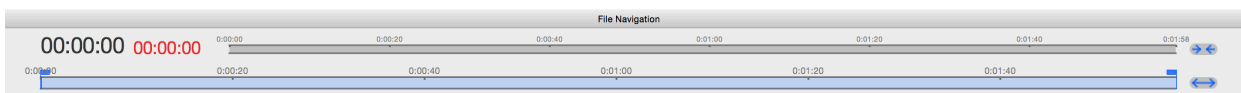


Figure 4: File Navigation panel

The timeline bar and counter at the top of the application is used only during playback from file operation. During playback, the time counter indicates the time from the beginning of the playback file as well as a visual indication on the bottom bar as to how far the user is into the playback file.

One useful feature of the *File Navigation* is to select a section of audio. The *Audio Transport* buttons (section 3.11) at the bottom of the UI will now act only on the selected part of the audio. Selecting a section of audio is done by moving the start/stop flag (blue markers) in the lower timeline bar. Clicking and holding the left mouse button on the flag and moving the mouse left/right moves the markers. The selection is marked by a light-blue colored bar. If the "Loop" button is enabled in the transport, playback will loop over this defined time range until either the user stops playback or selects another time region of interest. To remove the selection, simply move the flags to the outer edges of the lower timeline or click the "expand button".

The user can also enter the start/stop time directly to set the selection. The start time is set by double-clicking on the start flag (left marker). A dialog will be displayed where the user can enter the desired start time in the format hours:minutes:seconds. The stop time is set in a similar manner.

For long files it can be useful to increase the resolution of the timeline. This can be done via the "expand button" to the right of the lower timeline. The selection will be expanded across the whole lower timeline. A light gray bar in the upper timeline displays the position of the lower timeline within the file. The position of the area covered by the lower timeline can be moved by shifting the highlighted gray area in the upper timeline to the left or right. The selection in the upper timeline is moved by clicking and holding the left mouse button anywhere in the gray highlighted area and then moving the mouse to the left or right.

Another feature of the "File Navigation" panel allows one to quickly jump to any desired location in the file simply by left clicking at the desired location inside the lower timeline bar selection. A dark blue line indicates the current position in the file.

3.3 Input Source

The *Input Source* panel allows the user to select the audio stream source. Available sources are (see Figure 5):

- **Microphones (Live Mode):** Live audio input from a connected Eigenmike em32. This option will be disabled if no em32 is connected.
- **Microphone File:** The 32 audio input signals are retrieved from a previously recorded em32 microphone array wav file.
- **Eigenbeam File (Ambisonic):** Audio input signals are retrieved from a previously recorded encoded Eigenbeam file. The recorded file should contain all Eigenbeams (spherical harmonic signals, HOA signals) for a specific order, up to 4th order (i.e. 1,4,9,16, or 25 channels). Note that the Eigenbeam Output Control will be disabled.
- **Playback File:** Audio input signals are retrieved from an existing file. All processing is disabled for this input option. There is no constraint on the number of channels.

The descriptive text entry for the *Live Mode* input displays some status information regarding the em32 Eigenmike microphone array. If no microphone array is present it will say "em32

not found!" If an em32 is connected the entry will show the calibration status and serial number:

- Calibration Status: The words "calibrated" or "not calibrated" will be displayed if an em32 system is connected. To avoid degradation in performance it is important to verify that the system is "calibrated" when recording the em32 microphone signals. A non-calibrated status is typically due to a failed MIDI connection. Make sure that the "TCAT Dice EVM Platform" MIDI device is present and restart the EigenStudio application.
- Serial Number: The serial number of the connected em32 Eigenmike array is displayed when the em32 system is connected.

Each of the file inputs has an "open" button to the right of the input source label. To choose a recorded file click on the "open" button. An "open file" dialog will appear. After acknowledging the file selection with "ok", the file will be loaded. The base file name will be displayed in the *File:* label area at the bottom of the *Input Source* panel. Hovering over the base file name will display the full file name that includes the path and the file extension.

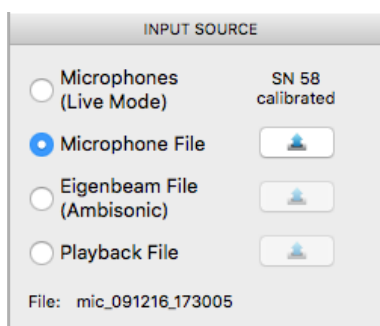


Figure 5: Input Source panel with an em32 connected.

The connected em32 has serial number 58 and the calibration was successful.

The EigenStudio application and the em32 Eigenmike microphone array support two sample rates: 44.1 kHz and 48 kHz. EigenStudio will use the sample rate that is set by the audio driver for the currently selected audio device. To set a specific rate the user needs to set the sample rate in the audio driver before opening the EigenStudio application. A warning will be given in case the sample rate of the connected audio driver and the sample rate of an input file don't agree, along with an option to attempt to automatically change the sample rate. Currently EigenStudio does not provide resampling of the input file. Instead the user needs to use a different tool to resample the audio file (or change the sample rate of the audio driver).

3.4 Signal Levels

Signal levels are displayed as a group of VU meters in the *Levels Meters* GUI panel (see Figure 6). There are 32 VU level meters. Channel numbers for each level meter are shown below each meter. The level is displayed in dBFS (with 0 dB PGA gain, 0 dBFS corresponds to approximately 124 dB in SPL). The solid bar represents the RMS level while the thin line shows the peak level. The level indicators will turn red if the level exceeds -9 dBFS.

The number above each level meter displays the maximum value that the corresponding channel experienced (peak-hold functionality). Double-clicking on a particular number will reset the peak-hold display for this channel. Double-clicking anywhere else in the level meter group will reset all peak-hold values.

The input signals to the level meters are selected via the list of radio buttons in the *Meter Source* panel to the right. Available signals are (compare also with the signal flow diagram in section 3.12.2.3):

- **Microphones (pre-fader):** These are the 32 mic signals from the em32 (live or file), *before* the Input Control software gain is applied.
- **Microphones (post-fader):** These are the 32 mic signals from the em32 (live or file), *after* the Input Control software volume is applied.
- **Eigenbeams (Ambisonic):** These are the Eigenbeam (Ambisonic) signals after being encoded by the Eigenbeamformer. For Eigenbeam (Ambisonic) processing of order N (as set in the *Output Control* panel), there will be $(N+1)^2$ signals.
- **Beamformer:** The output signal of the Eigenmike modal beamformer. The number of channels depends on the number of beam tracks in the *Beamformer* panel.

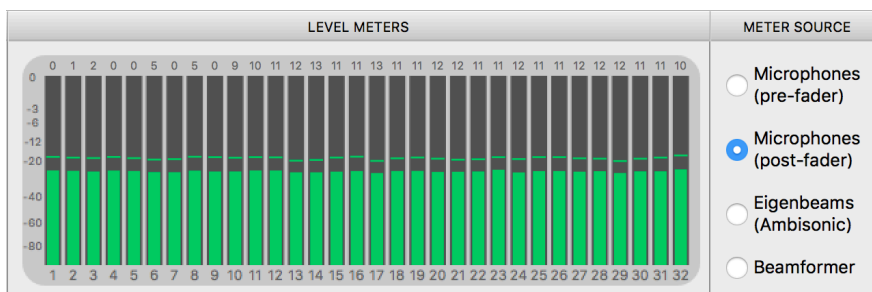


Figure 6: Input Levels and Output Levels.

3.5 Output Source

The *Output Source* selection allows the user to choose which signals will be routed to the audio hardware outputs. When an em32/EMIB hardware system is connected, the hardware outputs will typically be the 8-channel ADAT out (and optionally the 8-LO outputs; see section 3.12.1.1 for more information). When other audio interface hardware is connected, this will correspond to the output channels for that hardware (see your audio interface documentation). If the number of available hardware output channels is less than the number of signals in the selected *Output Source* only the first M signals will be routed to the output where M is the number of available hardware outputs. Except for the "Output Off" option, the signals in the *Output Source* selection are the same as those described above in section 0.

3.6 Monitor

The *Monitor Source* selection allows one to audition any of the input or output signals. The radio button group allows the user to select the monitoring signal. The selected signal can be auditioned through the EMIB headphone jack (if an EMIB is connected) or other hardware output channels (if generic or internal audio devices are connected). The monitor output channels can be set in the "Settings->Monitor..." menu (see section 3.12.1.1). Depending on the monitor format that is also selected in the "Settings->Monitor..." menu, the beamformer signals are available as a single channel (mono) or in groups of two (stereo). Note that the monitor output can overwrite an audio beamformer output for generic or internal audio devices. Refer to section 3.12.1.1 for selecting the monitor output channel.

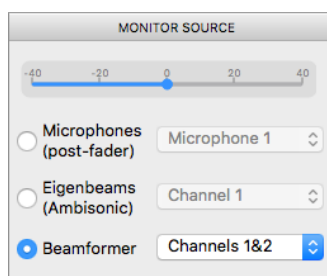


Figure 7: Monitor Source GUI panel.

3.7 Input Control

The *Input Control* panel provides the microphone elements programmable gain amplifier (PGA) level control, volume control, audio file recording arming, and level meter display for the input section of EigenStudio applications processing (see also the signal flow diagram in section 3.12.2.3). Figure 8 shows the Input Control panel.

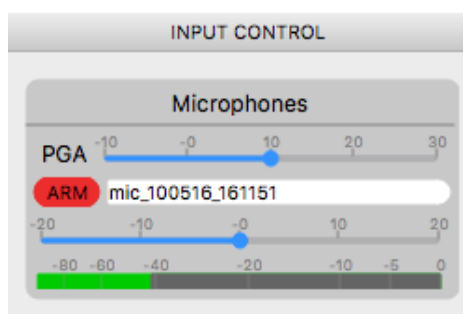


Figure 8: Input Control panel.

The slider labeled "PGA" sets the gain of the microphone PGAs (Programmable Gain Amplifiers) that are part of the A/D converters inside the Eigenmike array. This gain is applied to the analog microphone signals *before* the A/D converter. The available range is from -10dB to +30dB. Note that the "PGA" slider is only active when live input from an em32 system is

present. The “PGA” slider is disabled when the sound input source is set to an input from a file (see section 3.3).

The em32 microphone elements are rated to less than 1% THD below 130 dB in SPL with a sensitivity of approximately 30 mV/Pa. The input gain must be reduced to -10 dB to prevent clipping of the A/D converters when the input level reaches the maximum SPL rating of the microphone elements. On the other hand, for low input signals it is advised to apply increased PGA gain to the microphone signals to fully exercise the 24-bit A/D converters. The dynamic range of the microphones (max SPL with less than 1% THD to microphone self-noise) is approximately 115 dB and the SNR of the A/D converters is approximately 95 dB, which is approximately 20 dB less than the dynamic range of the microphones

The other volume slider in the panel applies a digital gain to all input signals (live em32 signal or input from file). Its range is from -20dB to +20dB.

The level meters display the maximum peak level of any of the input channels. This indicator provides continuous feedback of levels. For more detailed input levels on a per channel basis use the “Level Meter” panel and select “Input Post Volume” (see section 0).

3.7.1 Recording

The *Input Control* panel also allows recording the input signal. To do this, simply arm the record button located to the left of white label background (see Figure 8), indicated by the label “ARM”. The button will turn red when armed. The recording will start once the record button in the Audio Transport panel (see section 3.11) is clicked.

Once the ARM button is activated the white label background will display the current filename to be used for each recording. The default names will have a prefix of “mic” followed by the date and time when the record button was clicked. The file name can be changed by clicking on the file name and entering a new name. Each time after recording has stop, the filename is automatically updated with the suffix “_1”, “_2”, etc. to allow multiple consecutive recordings to retain the base file name (either auto-generated or custom).

All recorded data is stored in the “pool directory”. See section 3.12.1.3 for details on the “pool directory”. Note that the volume setting is applied to the signals before they are recorded. The EigenStudio application records the signals into a .wav file using a resolution of 24 bits per sample. For large files (>4GB) the RF64 wav file standard is used.

3.8 Beamformer

The *Beamformer* section is the main user control section for the Eigenmike beamforming processing. In this section, the total number of beamformer outputs can be defined, the beampatterns can be selected and steered to any desired angle, and the output gain of each beam can be set. The *Beamformer* panel is divided into two parts:

- Setup control (adding, deleting, linking, loading, saving of tracks)
- Individual beam track parameter control

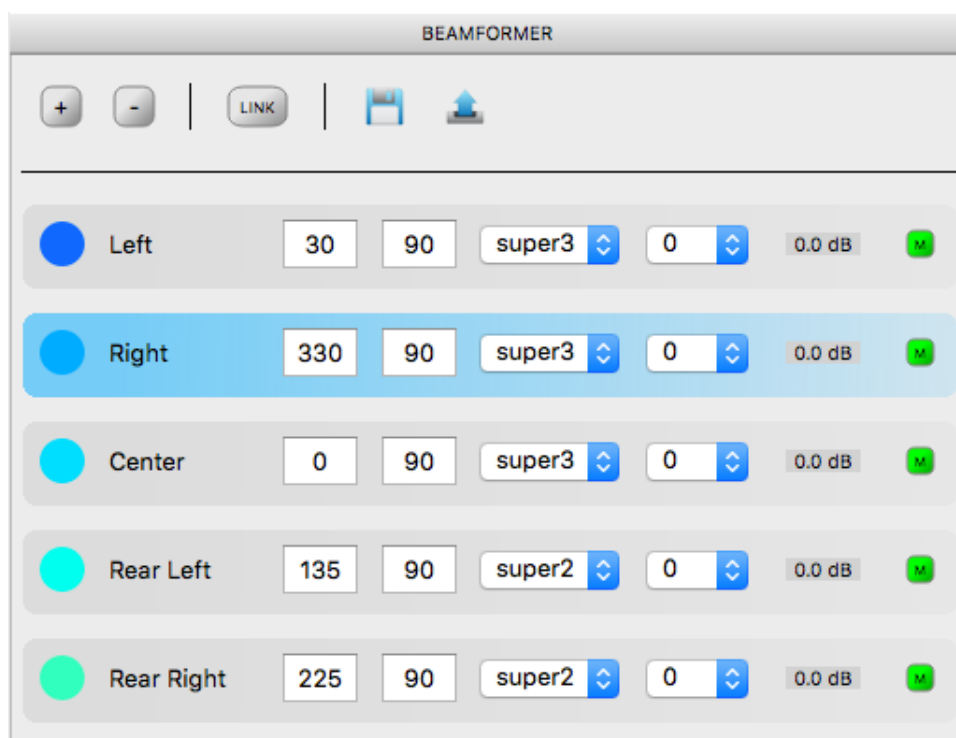




Figure 9: Beam Tracks GUI panel showing 5 beam tracks. Track "Right" is selected.

3.8.1 Beamformer Panel Controls

The beamformer track controls comprise the 5 buttons (see Figure 10) at the top of the *Beamformer* panel. These buttons have the following functions:

- **+** : The “+” button adds a new beam track. The new track will be added to the bottom of the track list. It is initially populated with default parameters. The maximum number of beam tracks is 30. Note that a scroll bar will appear to the right side of the beam tracks if there are more tracks than the “*Beamformer*” panel can show.
- **-** : The “-” button deletes the currently selected track. To select a track simply click on it.
- **LINK** : The “LINK” button links the horizontal parameter of all tracks. All tracks will rotate by the same amount if one beam is steered horizontally (azimuth) and the “Link” state is active. A yellow-colored “Link” button indicates an active “Link” state.
-  : The “Save” button saves the current beam track configuration to a file (see section 4.2). After clicking the button, the user will be asked to enter a name for the current configuration. A saved configuration can be loaded at any time via the “Load” button (see next item).
-  : The “Load” button retrieves a previously saved beam track configuration setup. A new installation of the EigenStudio application will only have the “default” configuration available.

When closing the EigenStudio application the user has the chance to save (and name) the current configuration if any changes were made to the last state saved.



Figure 10: Beam track control

3.8.2 Individual Beam Tracks

The individual beam tracks (see Figure 11) control the parameter settings. For each track the following parameters are available:

- **ID**: Beam tracks are identified by their color and label. The color is shown in the small circle on the left side of the beam track or – for a selected track – the whole background shows the track color. Double-clicking in the oval area allows one to set the desired track color.
- **Label**: The label allows the user to identify the beam track, e.g. ‘left’, ‘right’. The default labels are ‘beam X’ where X is a number that increases with the number of tracks. Double-clicking on the label allows the user to change the label.
- **Horizontal**: The steering direction (direction with maximum sensitivity) of the beam in the horizontal plane. The number is in degrees and ranges from 0 to 359. 0 degrees aligns with the “mh acoustics” logo on the shaft of the Eigenmike. The angle increases in the counter-clockwise direction. There are two ways to change the direction: a) double click the number in the beam track (a dialog will pop up where the user can change the angle by entering the number or by using the up/down arrows) or b) a selected beam can be steered via the “Beam Pattern” panel (compare section 3.9).

The azimuth angle can also be steered indirectly via another beam track if the tracks are linked (compare section 3.8.1)

- **Vertical:** The steering direction (direction with maximum sensitivity) of the beam in the vertical dimension. The number is in degrees and ranges from 0 to 180. 0 degrees points away from spherical array from the top (the opposite side from where the shaft mounts to the Eigenmike). 90 degrees is the horizontal plane and 180 degrees in the direction of the shaft. As with steering the azimuth, there are two ways to change the direction: a) double click the number in the beam track (a dialog will pop up where the user can change the angle by entering the number or by using the up/down arrows) or b) a selected beam can be steered via the “Beam Pattern” panel (compare section 3.9).
- **Pattern:** The beampattern describes the direction dependent sensitivity of the microphone. EigenStudio allows the choice between multiple possible beampatterns: cardioid, supercardioid, hypercardioid, omnidirectional, and dipole. Except for the omnidirectional and dipole patterns, all patterns are selectable from 1st to 4th order. Note the Eigenbeam Order Limit setting in the Output Control panel should be set to a value equal to or higher than the beampattern order.
- **Specification (Spec.):** The specification represents a measure related to the allowable increase in the signal-to-noise ratio (SNR) of the beamformer output³. More negative values (lower SNR) of the specification allow the beamformer to increase spatial selectivity at lower frequencies with the tradeoff of a lower SNR. The available values for the specification depend on the beam pattern selection. The higher-order beam patterns provide five values (-12, -6, 0, 6, 12) while the first-orders have a fixed specification setting.
- **Volume:** The output volume for each beam track can be adjusted between -20dB and +20dB. Double-click on the volume display in the beam track to change the volume. A window with a slider will open. Multiple sliders can be open simultaneously to simplify the relative volume adjustments of the beam tracks. The label above the slider will identify the beam track it belongs to.
- **Mute:** This is the track mute button. In the muted state (red button) the output signal for the corresponding beam track is muted.

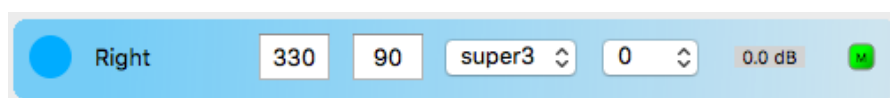


Figure 11: An individual beam track (in a “marked” state).

³ More specifically, the specification represents the minimum allowable White-Noise-Gain (WNG) in dB.

3.9 Beampattern: Feedback and Steering

The *beampattern* panel is a tabbed panel with two tabs: "Horizontal" and "Vertical". Figure 12 displays both diagrams. On the left side is the graphical representation of the beampatterns for the beam tracks in the horizontal plane. On the right side, the figure shows the beampattern in the vertical steering direction. The user selects the view by clicking the "Horizontal" or "Vertical" tab. Corresponding beam tracks are identified by the line color. A thicker line and a semi-opaque fill of the pattern will indicate the selected beam.

The beampattern panel fulfills two purposes: it provides an overview of the current spatial recording setup and it provides a simplified way of steering the beam tracks. Beampatterns can be steered either continuously or step-wise. Clicking and dragging the mouse cursor inside the panel area allows for continuous steering. Note that the steering operates on the selected beam. If the tracks are linked (compare section 3.8.1) all patterns will rotate simultaneously and maintain their relative angular positions in the *horizontal* plane (note that the beams are not linked in the vertical direction). To accomplish a step-wise steering simply click and release the mouse cursor inside the panel area and the beampattern will be aligned to the direction of the mouse position when the mouse-click is made.

In the vertical plane the look-direction can only be steered between 0 and 180 degrees. This is indicated by the grayed out area on the left half side.

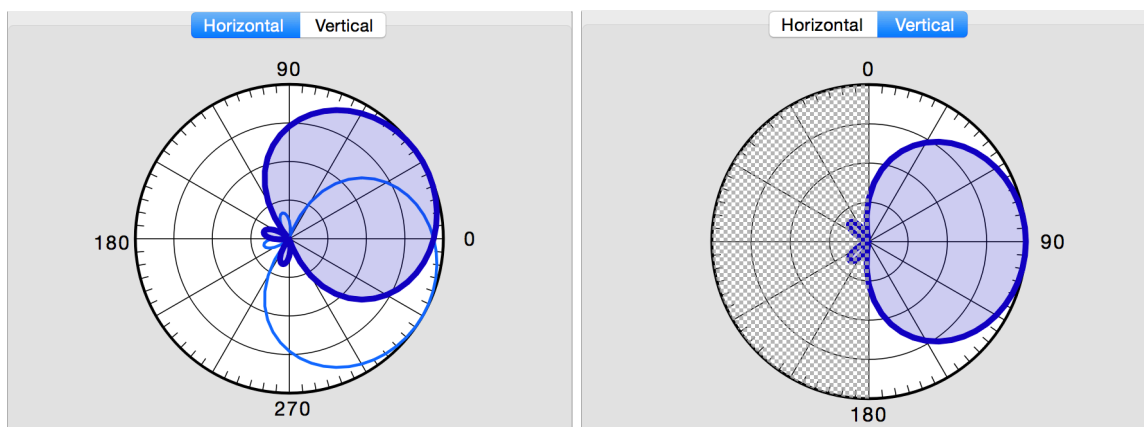


Figure 12: The beampattern GUI panel. The left polar diagram shows facsimiles of the beampattern in the horizontal plane. The right diagram indicates the look-direction in the vertical dimension.

3.10 Output Control

The EigenStudio application has two processing units: Eigenbeams (Ambisonic signals), and a Beamformer. Each of these groups has its own controls: volume control, file recording and peak level meter. The Beamformer outputs also have an optional highpass filter with multiple cutoff frequencies to choose from.

The *Eigenbeam (Ambisonic)* group allows the user to encode the microphone signals into Eigenbeams (spherical harmonics or HOA signals). The Eigenbeam signals can be saved to file for further use (e.g. by a third-party HOA decoder).

The Eigenbeam Order Limit selection allows control over the maximum order to which the input signals are encoded. For 0th order, this corresponds to a single omnidirectional signal. For first order, the addition of three dipoles yields four signals in total, that correspond to First Order Ambisonics (FOA). Above first order, the higher order ambisonics signals are encoded. The selected Order Limit determines the number of channels that will be present as Eigenbeam outputs, as well as in the recorded wav file. For order N , $(N+1)^2$ signals are generated.

In addition, the Settings menu offers several channel ordering and normalization options for HOA signals. Make sure you choose the options that are best suited for your purpose (refer to section 3.12.1.4 for more details).

The *Beamformer* control operates on all Beamformer outputs. To modify a single beam please refer to section 3.8.2.

The Beamformer group also offers a highpass filter setting that is applied at the end of the processing (and before the recording). The cutoff frequency can be set to *off* (no high-pass filter), 80 Hz, 160 Hz and 320 Hz. The filters are 6th-order Butterworth filters. The same filter response is used for all beamformer outputs.

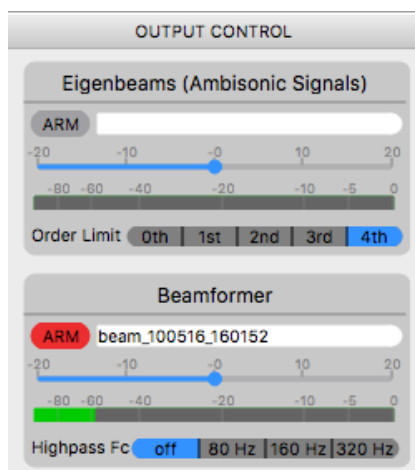


Figure 13: Output Control panel.

The volume slider in each group applies a digital gain to all channels in the corresponding group (Eigenbeams or Beamformer outputs). The volume range is from -20dB to +20dB. Double-clicking the volume slider will reset it to 0dB.

When recording is armed, the level meter displays the maximum peak level of any channels in the corresponding group. It is meant as an indicator to provide continuous feedback about the input and output levels. For more detailed input levels on a per channel basis use the "Level Meter" panel and select "Eigenbeams" or "Beamformer" (0).

3.10.1 Recording

The *Output Control* panel also allows one to record all signals within the group. To do this, simply arm the record button located to the left of white label background (see Figure 13), indicated by the "ARM" button. The button will turn red. Recording will start once the record button in the Audio Transport panel (see section 3.11) is clicked.

Once the ARM button is activated the white label background will display the current filename to be used for each recording. Default names will have a prefix of "eigen" (for the Eigenbeam group) and "beam" (for the Beamformer group) respectively. The Eigenbeam output file name is also followed by the order limit, channel ordering, and normalization scheme in use when recording Eigenbeams. Both file names end with the date and time when the record button was clicked. The file name can be changed by double-clicking on the file name and entering a new name. Each time after recording is stopped, the filename is automatically updated with the suffix "_1", "_2", etc. to allow multiple consecutive recording takes to retain the base file name (either auto-generated or custom).

All recorded data is stored in the "pool directory". See section 3.12.1.3 for details on the "pool directory". Note that the volume setting is applied to the signals before they are recorded.

3.11 Audio Transport

The *Audio Transport* panel controls the streaming of audio. There are six buttons and the active button is displayed in blue:

- **Stop:** Stops audio streaming. The current position in the audio file is reset to the beginning of the audio selection (see "File Navigation") or the beginning of the file if no audio has been selected. It will also stop recording and close the recording file(s).
- **Pause:** Pauses the audio playback at the current location. If the play or loop button are clicked the playback will continue from the paused location.
- **Play:** Starts playing audio from the current location until the audio streaming is stopped. Clicking on the stop button will stop the audio. There are also situations which stop the audio streaming implicitly:
 - If the end of an audio selection (see "File Navigation") is reached the application implicitly executes a *"stop audio"* command.
 - Any manipulation of the "File Navigation" timeline (e.g. new audio selection, new start position) implicitly executed as a *"stop audio"* command (followed by a *"update start/current position"*).
- **Loop:** Starts playing audio from the current location. Audio streaming that is started via the loop button can only be stopped explicitly via the *stop* button. All implicit *"stop audio"* situations as listed for the *play* button is implicitly followed by a *"play audio"* command. This results in a continuous streaming of audio and can be helpful in the following use scenarios:
 - While looping over a selection the user can change the parameters
 - When searching for a particular section of audio in a file the user can try a new position by left-clicking in the lower timeline. The audio will automatically start playing from the selected location.
- **Record:** Initiates recording of the armed input/output signals. Once each recording take has been completed, a updated file name will automatically be generated and displayed for the armed recoding files.
- **Offline Processing:** Starts the offline processing to record all armed input/output signals. The offline processing is significantly faster than real-time. Actual processing times will depend on the computational power of the computer. The EigenStudio application will display a progress bar to provide feedback for the user. There is no audio output during offline processing. However, the level meters will be active and provide feedback about the signal levels to the user.

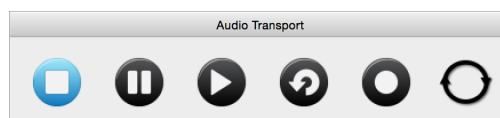


Figure 14: Audio Transport panel

3.12 Menus

3.12.1 Settings

Via the *Settings* pull-down menu item towards the left of the top menu bar the gives the user access to the following settings items:

- **Input...:** Under this menu the user can select the input channel offset (Note that this menu entry is only available with the optional MADI daughter board connected).
- **Output...:** Under this menu the user can select the active audio output channels
- **Monitor...:** Under this menu the user can select the routing of the monitor channels.
- **Pool Directory...:** Here the user can select the location of the audio data files pool directory. The "Pool Directory" is the folder in which all recordings are stored.
- **"Eigenbeam (Ambisonic) Format...:** This menu allows the user to set the Ambisonic channel ordering and normalization options. These options are applied for both Eigenbeam encoding and output beam processing with an Eigenbeam input file.

3.12.1.1 Output and Monitor menus

The Output and Monitor menus are displayed as a tabbed dialog box. The content of this dialog depends on the connected hardware. Figure 15 shows the dialog with the mh acoustics' EMIB box connected. In Figure 16 the dialog box is shown as it appears with generic or built-in audio hardware (Note that with the optional MADI card installed there will be a third *Input* tab).

The "EMIB Output" tab (see Figure 15, left) lists the available output options. At a minimum, the ADAT output group is shown. If the system contains the optional 8-channel line output board ("EMIB 8-LO") it is listed here as well. The user can activate/deactivate output groups and set the order. For example, with the setting as displayed in Figure 15, the beamformer output tracks 1-8 will be routed to the ADAT output and the beamformer output tracks 9-16 will be routed to the EMIB 8-LO line-out card.

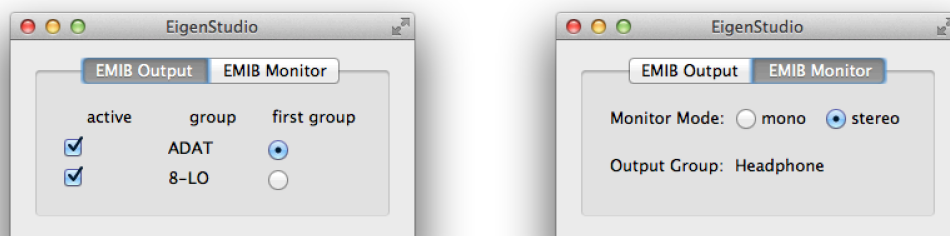


Figure 15: "Output..." and "Monitor..." dialog tabs with EMIB hardware attached.

The generic connected hardware output tab (Figure 16, left) allows one to select the number of audio outputs as well as the channel offset for other audio hardware. The "Hardware Channel Offset" determines the hardware channel index that will receive the first software

output channel. Note that the sum of “Number of active software outputs” and “Hardware Channel Offset” cannot be larger than the maximum number of channels supported by the connected audio hardware.

Note that the number of beam tracks can be larger (up to 30). Only the first N channels will be played where N is the number of output channels.



Figure 16: “Output...” and “Monitor...” dialog tabs with generic (or built-in) hardware.

The monitor tab (Figure 15 and Figure 16, right) selects the output hardware that will receive the monitor signal. The monitor signal is selected via the “Monitor” panel in the main GUI. The output will always be two channels (for convenient headphone listening). For the EMIB this will be headphone left/right jack that is on the front panel of the EMIB. For generic hardware this will be the “Channel offset” channel and the “Channel offset” +1 channel (e.g. with channel offset set to 0 the monitor output channels will be 0 and 1). In addition to the output channel the user can also select the format: mono or stereo. In the mono case a single beamformer track (or microphone input channel) is played back on both monitor output channels while for the stereo case two consecutive beamformer tracks are copied to the monitor output channels.

Note that for generic audio playback hardware the monitor channels can overwrite some beamformer output tracks. For example, with the settings depicted in Figure 16 the monitor output channels 0 and 1 overwrite the beamformer output tracks 0 and 1. To avoid this make sure that monitoring is not active (set via the Monitor panel of the main GUI) or select non-overlapping hardware channels for output and monitor, e.g. for the above example set the “Monitor offset” to 17 or the output “Channel offset” to 2. This of course requires hardware with a sufficient channel count.

3.12.1.2 Input menu

This option is available when the EMIB is connected through the MADi interface (optional MADi daughter board is required). It enables the user to select the channel offset for the em32 Eigenmike array microphone capsules. The EigenStudio app will auto-detect the offset for most common MADi hardware. However, in case the em32 microphone is connected through MADi and no input signals are observed the input channel offset might have to be adjusted.



Figure 17: Input dialog (available when MADi interface is active).

3.12.1.3 Pool Directory

The pool directory is the folder where all recorded audio files will be stored. The “Pool Directory...” menu will bring up a file dialog where the user can select the pool directory.

3.12.1.4 Eigenbeam (Ambisonic) Format

A number of different channel ordering and normalization schemes exist for encoded HOA signals. When supplying the HOA signals to an Ambisonics decoder it is important that the channel ordering and normalization matches the expected format of the decoder! The EigenStudio application supports various channel ordering schemes (ACN, FuMa) and normalizations (SN3D, N3D, FuMa, and MaxN). The Eigenbeam application will add the current channel ordering and normalization to the Eigenbeam (HOA) file name so the user will know at a later time which format was used for a particular file.

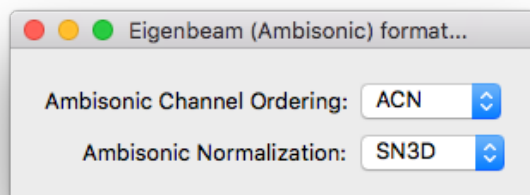


Figure 18: Eigenbeam Format window.

3.12.2 Info

In the *Info* menu, the user can check the audio settings, inspect calibration values of the connected em32 Eigenmike array, and view a signal flow diagram.

3.12.2.1 Audio

The Audio info dialog displays the fundamental audio settings:

- Audio Driver: Name of the audio driver in use. This will be “TCAT Dice EVM Platform” if the EMIB and em32 Eigenmike are connected.

- Sample rate: the current sampling rate. EigenStudio supports 44.1kHz and 48kHz.
- Buffer Length: The current audio buffer length. See below for more information about the buffer length.
- # of inputs: This is the number of input channels. This number will be 32 if the em32 Eigenmike array is connected.
- # of outputs: This is the total number of available outputs. This number will be 10 if the EMIB is connected without the optional 8-LO output card. There are 8 ADAT channels and 2 headphone channels. The optional EMIB 8-LO card adds another 8 channels. The actual number of output channels that are used for playback is set in the "Connections..." menu. This number will be equal or less than total number of channels available. Note that the number of beam tracks can be larger (up to 24). Only the first N channels will be played back where N is the number of output channels set in the "Connections..." menu.

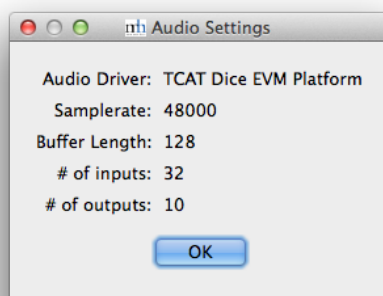


Figure 19: The "Audio..." settings dialog.

Like most computer-based audio programs, EigenStudio processes audio in blocks. The number of samples in a block (per channel) is the buffer length. The longer the buffer length the more efficient the processing becomes and the less likely there will be glitches in audio. Longer buffer lengths increase robustness against audio issues but come at the expense of an increased audio delay through the system between the input signals and the playback signals. This delay will only be relevant for live setups (record and playback). For processing/playback from file or simply recording of live signals the system delay is not critical. On Windows-based systems the user can set the buffer length via the audio drivers ASIO Control Panel before starting the EigenStudio application. On macOS based systems the buffer length is set by EigenStudio. It will be either 512 (em32/EMIB connected) or 1024 (no em32/EMIB connected). If – for any reason – the user runs into problems with the shorter buffer length, it can be changed via the configuration file. See the Appendix on details about the EigenStudio configuration file.

3.12.2.2 Cal

The *Cal* info sub-menu displays the microphone amplitude calibration values of the connected em32 Eigenmike array. The values are displayed in dB. These gains are used by EigenStudio

to compensate for microphone mismatch to maximize beamformer performance. Calibration values are shown for information purposes only.

3.12.2.3 Signal Flow

The block diagram in Figure 19 shows the signal flow in the EigenStudio application. All blocks inside the blue "EigenStudio GUI" area are implemented in software in the EigenStudio app. Blocks with a white background can be controlled via a GUI element.

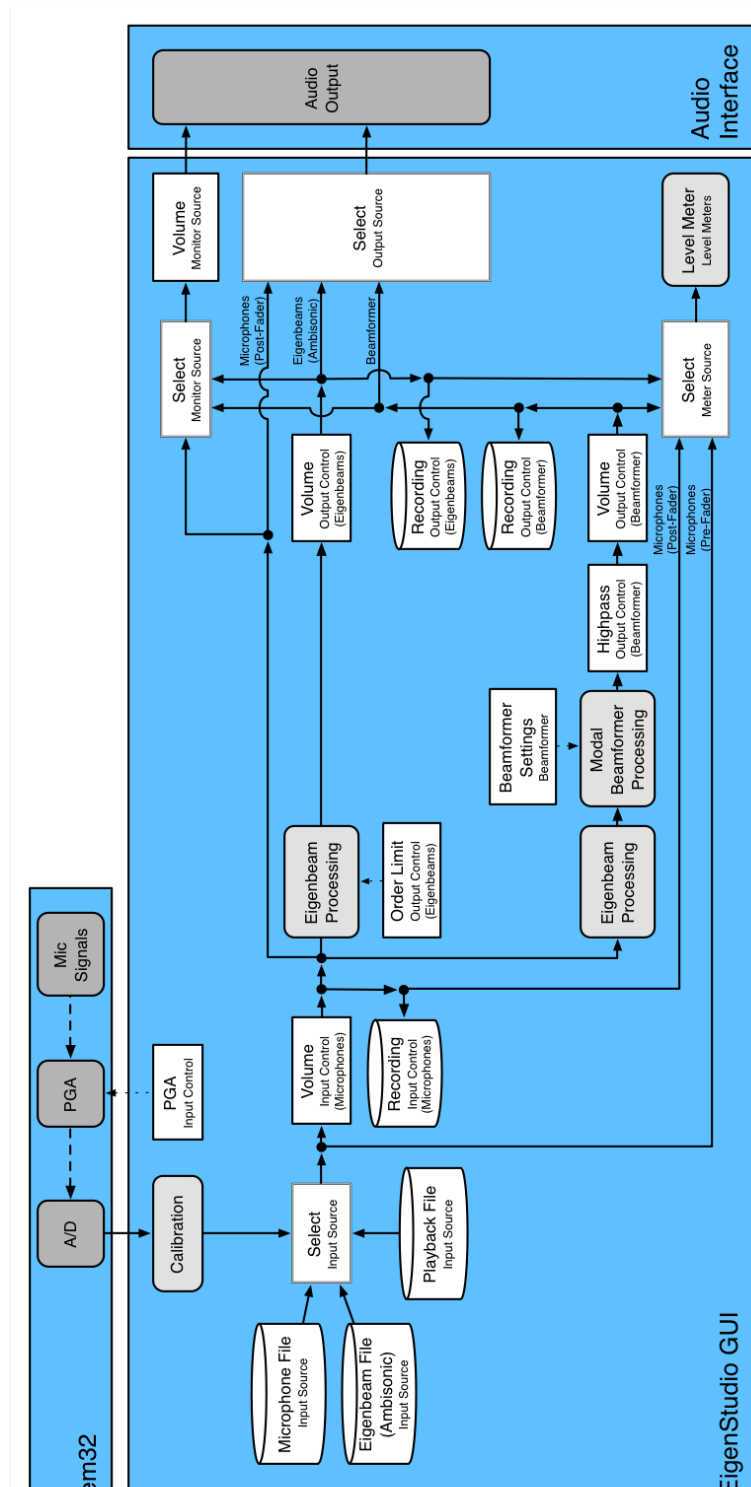


Figure 20: Signal flow diagram of EigenStudio

4 Appendix

4.1 The Configuration File

Note that this section is provided for advanced user control. Users should only access the configuration file in two rare events: a) to change the “live” buffer length on macOS systems (see section 3.12.2.1) or b) the file got corrupted (simply delete the file and the EigenStudio app will create a new one the next time it starts).

The EigenStudio application stores the last-used settings in the configuration file “EigenStudio.ini”. On Windows-based systems the file is stored in the folder “%AppData%\mh acoustics” under the user’s home folder. On macOS based systems the file is stored in the folder “~/config/mhacoustics.com”. The EigenStudio application will check for the existence of the file at startup. The application uses default parameters if no configuration file is present. It will store the file with the last-used settings at closing.

To change the audio buffer length in macOS:

1. Make sure the EigenStudio app is closed.
2. Open the configuration file with a text editor.
3. Locate the entry `rtBufferLength`. Change the associated number. Smaller numbers mean less delay and less robustness; larger numbers mean more delay and more robustness. The EMIB allows buffer length between 15 and 3000 samples.
4. Save the modified file and close the text editor.
5. The next time the EigenStudio application starts it will use the new buffer size (Note that this size is only used on macOS systems with an em32 Eigenmike connected).

4.2 Beamformer Setup Files

The EigenStudio app stores the Beamformer setup in files with the extension “ess”. On Windows-based systems the files are stored in the folder “%AppData%\mh acoustics” under the user’s home folder. On macOS based systems, the files are stored in the folder “~/config/mhacoustics.com”. It is NOT recommended to edit these files directly but rather use the “save” button in the EigenStudio GUI’s Beamformer panel to generate or modify these files. However, it is safe to copy these files from one computer to another for sharing beamformer setups or when migrating from one computer to another. Note that the location is fixed and can not be changed.

4.3 The Highpass Filter

The *Beamformer* output control contains a highpass filter setting as described in section 3.10. Figure 21 shows a plot of the frequency responses of the different highpass filters associated with the different cutoff frequency settings.

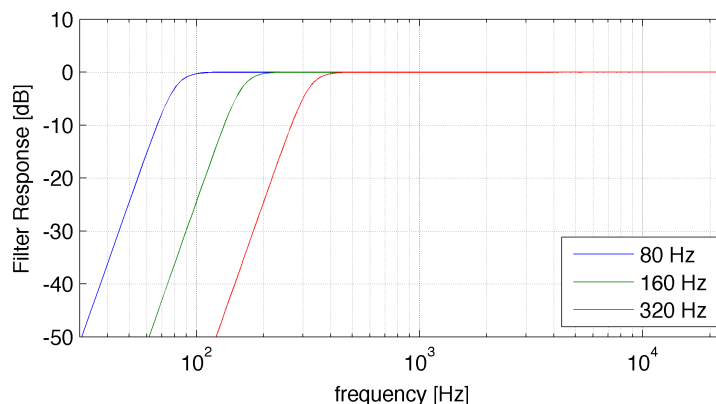


Figure 21: Frequency response of highpass filters.

4.4 Directivity Patterns and Eigenbeam Format

Information about the directivity patterns and Eigenbeam formats can be found in separate documents on mh acoustics’ website:

<https://mhacoustics.com/download>

4.5 Microphone Positions

The microphones are numbered in a pattern that is convenient for assembly of the em32 Eigenmike array. Table 1 shows the spherical angles in degrees for each microphone channel. The azimuth angle *phi* counts counter clockwise. Zero degrees in azimuth aligns with the “mh acoustics” logo on the microphone shaft. The elevation angle theta increases from the top (away from the shaft) to the bottom (aligned with the shaft). The radius of the em32 Eigenmike array is 42 mm.

Microphone	Theta	Phi
1	69	0
2	90	32
3	111	0
4	90	328
5	32	0
6	55	45

7	90	69
8	125	45
9	148	0
10	125	315
11	90	291
12	55	315
13	21	91
14	58	90
15	121	90
16	159	89
17	69	180
18	90	212
19	111	180
20	90	148
21	32	180
22	55	225
23	90	249
24	125	225
25	148	180
26	125	135
27	90	111
28	55	135
29	21	269
30	58	270
31	122	270
32	159	271