

EARFISH HRTF MEASUREMENT

www.earfish.eu

I INTRODUCTION

This manual describes how to measure your own HRTF using the Earfish HRTF measurement kit. To arrive at a high-quality HRTF, it is important that you meticulously follow all guidelines in this manual.

By providing the measurement kit and the software necessary for the measurement, we respond to the people contacting us to acquire their own HRTF by opening up our technology to everyone interested in personalized 3D audio.

This service is not a commercial activity though, but is part of a research project at the University of Antwerp. Therefore, the measurement kit should be viewed as a prototype, a beta version, rather than a finalized commercial product. We are researchers, not software engineers, and we cannot guarantee that the software will work for all possible system configurations (though we can guarantee that we will help you to get it to run wherever we can).

Indeed, the measurement application and the manual are a work in progress and we are always looking for ways to improve the guidance of the measurement process. So, if you have feedback or suggestions on how to improve upon the measurement procedure, please let us know.



Figure 1: the measurement kit.

II UNPACKING THE MEASUREMENT KIT

The kit contains several off-the-shelf components:

- Sparkfun Openlog Artemis IMU
- Axagon ADA-17 USB - HQ MINI AUDIO
- USB cable USB-A male to USB-C male
- USB cable USB-A male to USB-A female

and some in-house built components

- pair of condenser in-ear mics
- head tracker mount for headphone/headstrap

III PREPARATIONS

In addition to the measurement kit, you'll need a laptop (either Windows/Mac), a quiet room that is sufficiently large (see the next section), a swivel chair, and a music player connected to a (preferably single-driver) loudspeaker.

Understanding the method

To carry out the measurement properly, it is important that you get a basic understanding of how the HRTF is measured using our approach.

The basic idea is very simple. You are seated in front of your loudspeaker at home and while the speaker emits brief chirps, you rotate your head in all possible directions. From the viewpoint of your head, the chirps are always coming from a different direction. In-ear microphones register the sounds that would enter your ears, while your head orientation is being tracked with an orientation sensor (so-called IMU), and this allows us to measure how you hear sounds coming from different directions. After about 15 minutes of moving your head around (while slowly turning around on the swivel chair), you have collected the necessary data for us to calculate your personal HRTF, using our proprietary algorithms. We provide your HRTF file in SOFA format, ready to be used.

The measurement procedure is also outlined in this [YouTube video](#). The video itself is a bit outdated, since the measurement is now carried out using a laptop instead of a smartphone, yet, it still illustrates quite well how the measurement is carried out, and more specifically, how to move your head in order to sample the sphere around your head properly.

The room setup

The measurement can be carried out in an ordinary room at home, which **should be silent**. During the measurement you're seated on a **swivel chair**, directly in front of a loudspeaker, as shown in the setup in Figure 2 (a). The loudspeaker should be facing the swivel chair, at a distance of about 1.25-1.5m from the (rotation axis of the) chair, and it should be at approximately the same height as your head. It is important that the swivel chair does not move during the measurement, except for rotations around its axis.

In order to be able to remove room reflections from the measurements, the room should be at least (length, width, height) =(3m, 2.5m, 2.5m) in size, and as empty as possible in the area surrounding the action. Make sure that the room is free of objects: no reflecting walls, no furniture, no garbage bins, etc., in the grey ellipsoid area shown in Fig. 2.

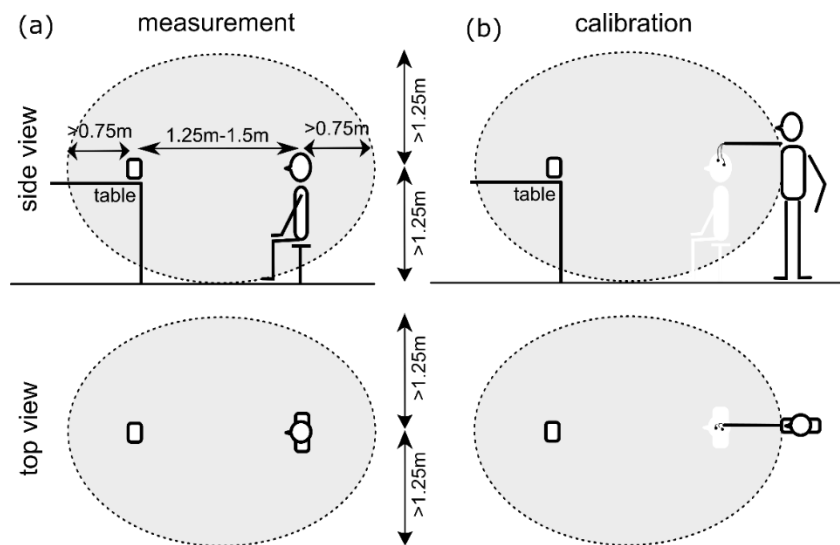


Figure 2: (a) Room setup, top and side view. The grey ellipsoid volume should be free of reflecting objects/walls (except for the table, the loudspeaker and yourself). (b) Calibration setup.

Speaker setup

- Download the Earfish audio file **EarfishAudio.wav** on the media player.
- Connect it to the speaker **via a wired connection**. Do not use Bluetooth as this may cause glitches due to missing data.
- Use a **small loudspeaker**, preferable with a single driver, because you want the source to be well localized. Make sure that audio is playing through this speaker only.

Laptop

- Install the Earfish measurement app **EarfishMeasurement.exe** on your laptop. On macOS, it is required that you install the files in the Documents-folder.
- Switch of all other applications on your laptop that might interfere with the measurement: Wi-Fi, Bluetooth, virus scanner, ... and close all other programs.
- Unplug the external power so the laptop runs on its battery only, but make sure that the laptop doesn't go in sleep/hibernation mode, or turns off the screen during the measurement.
- If the IMU is not recognized (Windows), then you'll have install the CH340 driver, as outlined here: <https://learn.sparkfun.com/tutorials/how-to-install-ch340-drivers/all#drivers-if-you-need-them>.

Head mount

- Attach the head tracker and the audio adapter to opposite sides of the head strap as shown in Figure 3, and plug in the respective USB-cables. Guide the cable from the IMU next to the audio adapter. Plug the in-ear microphones in the pink 'input' port of the audio adapter, and mount the head strap, with the IMU at the center on your forehead, and the audio adapter with the cables at the back of the head.
- Next, guide the in-ear microphones from top-down under the elastic strap, one microphone on each side. Insert the microphones, one at a time, in your ears as follows: first squeeze the memory foam with your fingers, inserting the microphone in the entrance of your ear canal, the microphone pointing outwards, and hold the microphone there for an instant, until the memory foam has relaxed and seals off your ear canal. Make sure they sit sufficiently tight, so they attenuate the sounds emitted during the measurement and won't move or pop out during the experiment.
- Guide the USB cables over your shoulder to the laptop on you lap. Convince yourself that cables are sufficiently loose, so that you can freely move your head during the measurement. (We always hold the cables with one hand on the shoulder, the other hand holds the laptop).

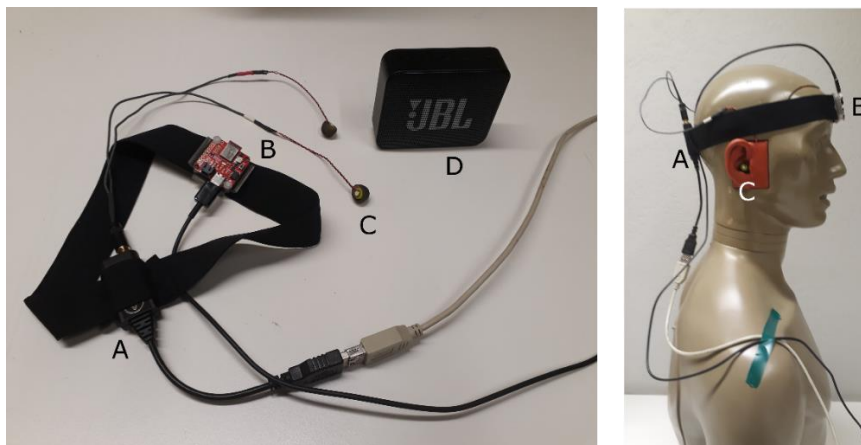


Figure 3: The measurement setup consists of (A) high-quality sound card (B) 9DOF IMU, (C) in-ear microphones and (D) a single driver loudspeaker.

Head movement

The success of the measurements largely depends on how you carry out the head movements during the measurement, see this [YouTube video](#). In the new setup with the laptop, you get feedback on which (approximate) directions have already been sampled. How to move your head, can be summarized as follows:

- move your head freely,
- rotate the chair preferably slowly and in one direction only,
- while keeping your shoulders fixed to the chair,
- try to sample the whole sphere, using the visual feedback on the laptop,
- avoid gaps, by pushing your neck to the limits

- don't move your head too fast, again using the visual feedback on the laptop.

III CARRYING OUT THE MEASUREMENT

- Go sit on the swivel chair and start the measurement application. Place the laptop on your lap, with the screen open such that you get visual input from the screen. The application will guide you through the rest of the measurement.

Important: if for some reason the application stopped working (e.g. because the head tracker or USB sound card were disconnected during operation), you don't have to go through all the previous steps again! You restart the application and continue from the point where you left off.

Step 1: preparation check

This is merely a check whether you carried out all the preparations described above.

Step 2: head tracker

- The application will try to connect to the head tracker. If the connection fails, you'll be asked to plug in the head tracker. If the connection was successful, the animated head should follow your head movements.
- The animated head will help you during the actual measurement, as it will show the (approximate) directions that you have already sampled.
- It is likely that the animated head does not follow your movements precisely, for this reason you have to calibrate the head tracker. Press '**calibrate**' and rotate your head in all possible directions, while rotating the chair as you would do during a measurement.

Step 3: audio settings

- The application will try to connect to the USB sound adapter automatically. Again, if the connection fails, you'll be asked to plug in the adapter.
- Start the sound file on the audio player and **set the volume of the loudspeaker at the loudest level that is still comfortable for you.** Remember you have to sit through the measurement for 15 minutes. Also, you don't want to push your loudspeaker to the limits because then the audio will be distorted.
- Next, you're ready to check the audio quality in the room. Face the speaker, with your head directed to the speaker, press the **check audio** button, and hold your head still for 5 seconds. The app will inform you if something obvious is wrong with the audio data and suggest a solution. If

you are asked to **alter the volume of the sound card/microphones**, this can be done (Windows) as follows: settings > system > sound > (choose USB sound card as input device) > device properties > (alter volume).

- If the audio check was okay, you are ready to go to step 4.

Step 4: measurement

Everything is ready now to carry out the actual measurement.

- Again, face the speaker and hit the **HRTF measurement** button. This will pinpoint the (approximate) position of the loudspeaker with respect to your head and start the measurement.
- Next, you have to rotate your head/chair as described above. To help you sample all parts of the sphere, you'll be given feedback on which directions already have been sampled. Hence, every additional dot gives an indication of the last direction that has been sampled.
- You have to rotate your head sufficiently slow. For this reason, there is a bar that indicates the speed at which you are moving your head. If you move too fast, the bar will turn red. Try to avoid this during the measurement.
- The measurement itself takes 15 minutes. You'll be informed on the progress with a progress bar.

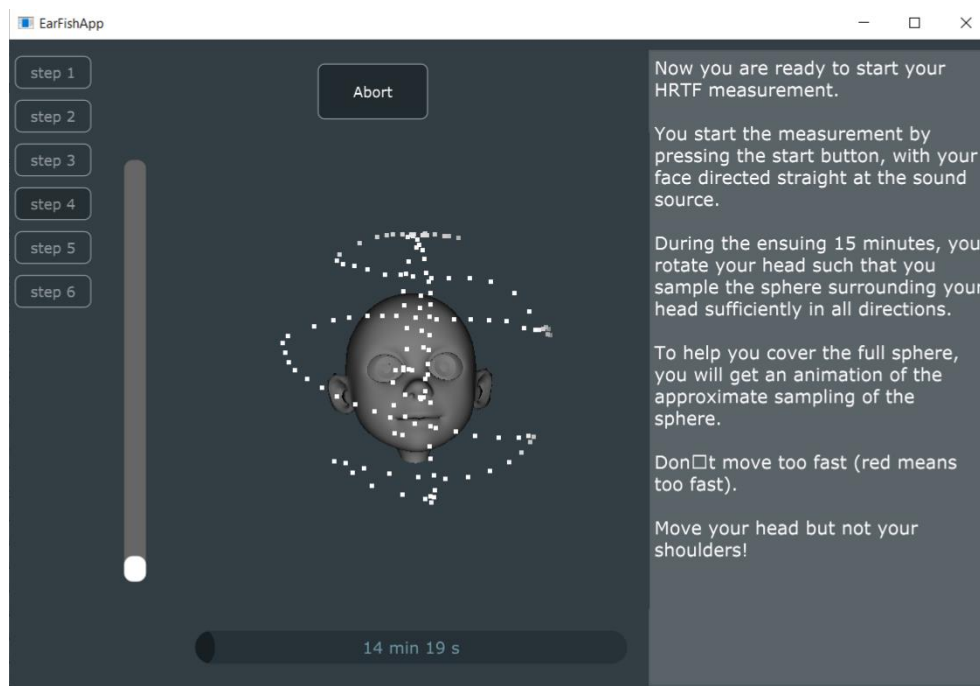


Figure 4: Still from the app GUI during the measurement. The directions that have already been sampled are indicated by the white dots.

Step 5: sound system calibration

In order to compensate for the system response of the speaker and microphones, it is advised to also carry out a calibration measurement, immediately after the measurements.

- You'll do basically the same measurement, but now for only 30 seconds and with the microphones dangling where your head was before, as shown in Fig. 2 (b).
- Leave the sound player as is, playing at the same volume. You may want to muffle the sound for yourself by plugging something in your ears or putting on headphones.
- Remove the chair, take the microphones out of your ears (but not out of the ear mounts), and the sound card out of the head strap, stretch your arm as far out as possible, and position the microphones, e.g. dangling from your hand, approximately at the position where your head was during the measurement. During the 30s measurement, you can move or rotate the microphones slowly around in this area. Make sure that you are standing **behind** the microphones (as seen from the loudspeaker), see Figure 2(b).
- You start the recording by pressing the **system calibration** button.
- If you have accidentally unplugged the audio adapter during the above manipulations, that is no problem. Simply restart the app and rerun Step 5. **No need to redo all the previous steps!**

Step 6: Zipping the data

- Press the **zip** button. This will zip the latest measurement and calibration file into one zip file, which is stored into your documents folder.
- Send us this file via we-transfer.