Technical description of interference in the EEG signal caused by mains hum

This article describes the problem of 50 Hz interference in the EEG signal, which is caused by electrically unearthed or insufficiently earthed devices (mostly laptops/notebooks).

Causes and backgrounds

An essential prerequisite for the measurement of interference-free signals in the electroencephalogram (EEG) is a good electrical grounding of all components of the measuring system, including the computer and monitor, to prevent the 50Hz alternating voltage of the power grid (in the USA it is 60Hz) from being transferred into the measuring signal. "In the past" computers and monitors were always electrically grounded, but rapid technological development in recent years has led to the fact that, for example, the housings of notebooks are usually made of non-conductive plastic, which means that electrical grounding is no longer necessary for safety reasons. An electrical grounding can also be done via an additionally connected monitor. However, nowadays the latter often have no electrical connection to ground, in which case the computer/monitor system is only capacitively connected to the ground of the power supply system and is therefore susceptible to "mains hum".

As a result, we have seen a rapid increase in queries regarding strong interference in the EEG signals on all channels since 2019. These interferences first appear as a very "thick" EEG track in the display of the measurement software (see "EEG" graph in Figure 2), and then – with a high temporal resolution – a large 50 Hz oscillation can be detected as a coupling from the power grid due to missing grounding. (If this interfering signal were to be output via a loudspeaker, a low (50 Hz) hum could be heard, which is why this type of interference is generally referred to as "mains hum").

How can one determine whether an EEG or neurofeedback system is potentially vulnerable?

The easiest way to determine whether a system is potentially susceptible to 50Hz mains hum is to look at the plugs that connect the computer and all its associated devices to the wall outlet / power supply. If these are only flat plugs without a protective conductor, such as the "Europlug" (see Figure 1), there is no connection to earth

of the power grid.

Figure 1: Flat "Europlug" without protective conductor to the ground of the power supply

In an EEG measuring system connected to the mains supply without protective earth contact, the 230V/50Hz alternating voltage can also cause mechanical vibrations of the devices, which can be clearly felt on a notebook case, for example.

How does the 50Hz alternating voltage now get into the NeuroAmp or into the EEG measurement?

The NeuroAmp is connected to the computer via the USB interface and is thus also at its potential. As a medical device, the NeuroAmp is galvanically decoupled from the power supply system, so that it is impossible for a patient to ever receive an electric shock from the computer connected to the power supply system. If the measuring system is not electrically grounded, a capacitive coupling of only a few millivolts (and thus completely harmless) of the 50Hz AC voltage to the patient's side via the USB interface can occur, whereby the voltage is fed via the electrodes into the NeuroAmp's measuring system and becomes visible as an interference signal on the EEG.

What measures were taken in the neurofeedback software to eliminate "mains hum" from the EEG display?

Besides the 50Hz "mains hum", an EEG can also be contaminated by other disturbances. In order to eliminate as much as possible of the mains interference in Cygnet, very effective filters are in place. In Cygnet's signal analysis, for example, a strong (but very low-delay) notch filter monitors the frequency range around 50 Hz and filters out any "mains hum" interference from the EEG.

Does a 50 Hz disturbance influence the feedback loop and thus the neurofeedback therapy?

In Cygnet, the EEG signal is displayed both in the time domain ("EEG" graph) and in the spectral domain ("Spectral" graph). In both displays, despite filtering, a 50 Hz disturbance may still be visible because it has much higher amplitudes than the signals of brain activity.

The good news, however, is that the feedback loop is not affected by any of this. In addition to the filtering mentioned above, Cygnet uses other signal processing mechanisms, so that the control signals for the ILF "signal" component (formerly called "reward") and the "inhibit" component are unaffected by a 50 Hz "mains hum" disturbance (possibly visible in the "EEG" graph).

What does a 50 Hz disturbance in the EEG look like in Cygnet?

In the EEG, 50 Hz interferences usually show a quite characteristic shape. This will be demonstrated below using real examples of Cygnet test recordings:

- "EEG" and "Spectral" displays in Cygnet, during an EEG measurement with a non-grounded notebook: the two EEG traces in the "EEG" graph (time signal) show a broad noise contribution, while the images in the "Spectral" display suggest that the largest signal contributions (red range) are above 40Hz. In addition, due to the high amount of noise, Cygnet shows a "Check Electrodes" warning in the "EEG" graph

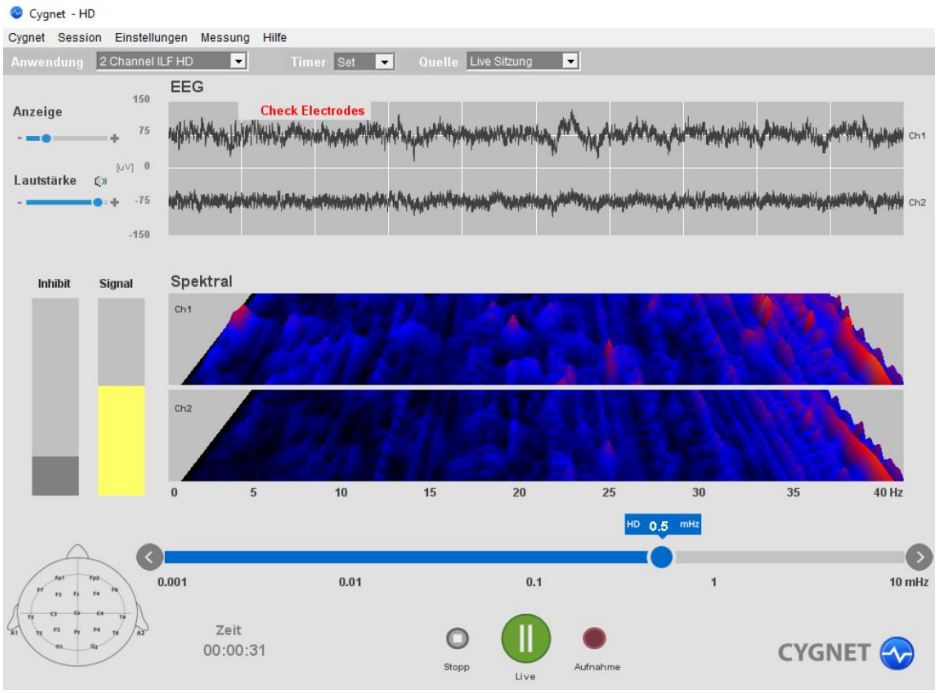

Figure 2: Screenshot of Cygnet during an EEG measurement contaminated with a 50Hz "mains hum" disturbance.

- " EEG" and "Spectral" displays in Cygnet, when measuring EEG with a notebook in battery mode, i.e. without connection to the mains. There are also no other devices connected to the mains connected to the notebook. During this measurement the EEG signals are free of 50Hz interference.

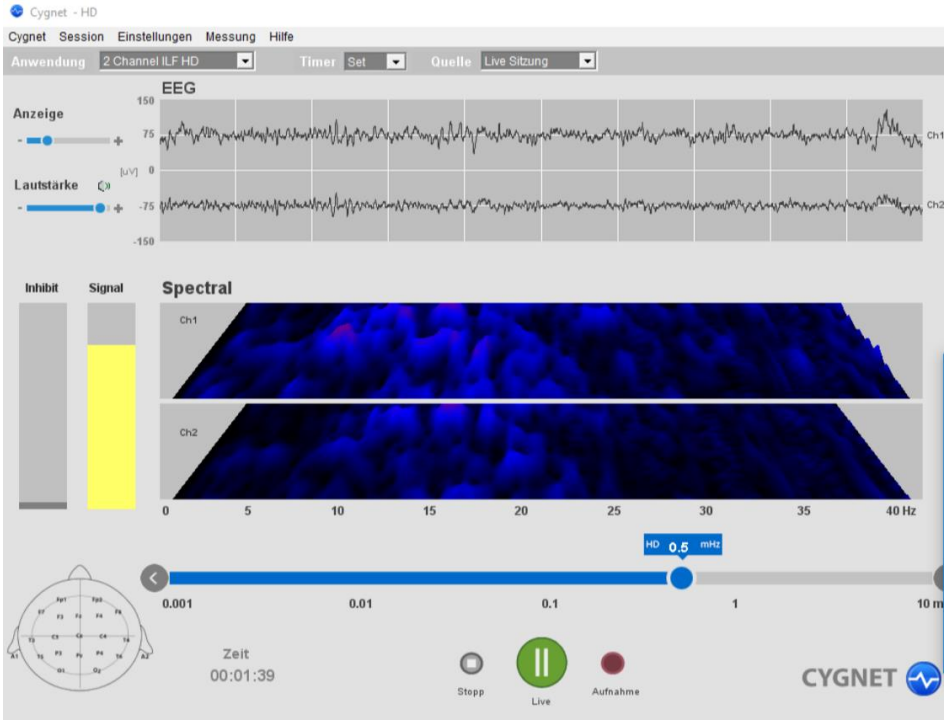

Figure 3: Screenshot of Cygnet during an EEG measurement. Both EEG signal tracks show the recorded brain activity. A 50Hz disturbance was not present during this measurement.

- The following example shows in Cygnet's "EEG" graph the effect when a notebook computer previously connected to the power supply without grounding is grounded via a grounding plug during an EEG measurement. The grounding was done at the marked position (vertical red line):

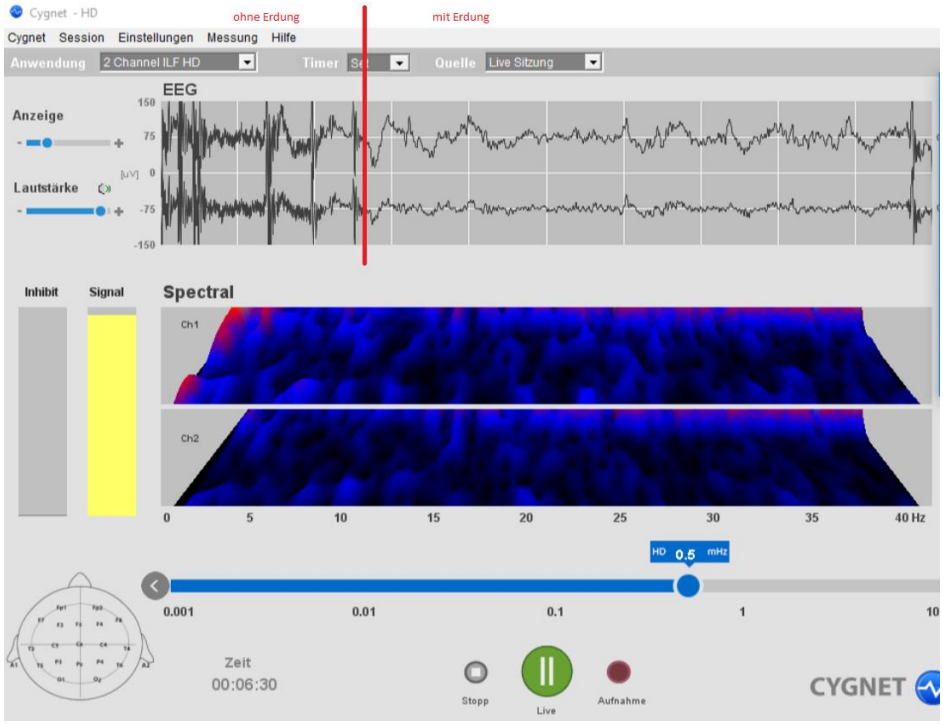

Figure 4: Screenshot of Cygnet during the 2-channel measurement of EEG signals, which are initially contaminated with 50Hz interference because the notebook used was connected to the mains supply ungrounded. At the time of the red line marking, the system was grounded via a grounding plug.

What can be done to prevent the occurrence of a 50Hz "mains hum" disturbance in the EEG?

To prevent "mains hum" disturbances from entering an EEG measuring system at all, electrical earthing is the most effective measure. It is sufficient if the computer used (laptop, notebook, etc.) is grounded, because normally all other devices of the measuring system are connected to it.

In order to facilitate grounding of EEG / neurofeedback systems, we have developed a compact, small grounding plug which can be used universally and can therefore also be easily used with the notebook / NeuroAmp system. The grounding plug has a USB socket on the rear side so that it can be connected to a USB port of a laptop/notebook via a standard USB device cable. Via this connection there is then an electrical contact between the housing/USB ground of the computer and the protective earth of the grounding plug. This simply has to be plugged into a mains socket, whereby the protective earth conductor of the grounding plug makes contact with the mains earth and thus the entire EEG measuring system is correctly grounded.

This grounding plug is available in our webshop.