Application Note

3D ELECTRODE COORDINATES FOR WAVEGUARD™ CAPS

GENERATED ON THE MNI BRAIN

Berlin, 2025-01-23

Approval DRN-ID:	DRN-14033

DISCLAIMER

All information provided in this document is intended as general information for research purposes only.

For detailed product related information please always consult the latest version of the respective product's user manual. This document is not intended to replace the user documentation. For indications on individual feature certification status (clinical vs. research only) please refer to the aforementioned user documentation.

We have attempted to write this document as accurately as possible. However, mistakes are bound to occur, and we reserve the right to make changes whenever needed or whenever new information becomes available. In addition to this, please note:

- These coordinates have not been acquired for a subject specific head model only
- The intended use is to support our end-users with approximate and standardized electrode coordinates
- This effort leaves them independent of hardware pre-requisites and any deviances across subjects.

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AIM

This document aims to inform the reader with the background knowledge based on which we have generated standardized 3D electrode coordinates for a variety of our **wave**guard™ caps using the Montreal Neurological Institute (MNI) brain [1]. We will also share details on the head model used to arrive at the electrode coordinate values as well as elaborate the method required to use our automatic electrode positioning tool. Finally, some software platforms are listed where our electrode location files can be used for topographic mapping or source reconstruction. **wave**guard™ cap coordinates are available for all cap types in (extended) 10/20 layouts as well as equidistant layout. These can be requested via our Support channels, support@ant-neuro.com.

BACKGROUND

For mapping the potential distribution of EEG recordings, or performing source analysis on this distribution, standardized electrode locations are needed [2].

NEED FOR STANDARDIZED ELECTRODE COORDINATES FOR CAPS IN (EXTENDED) 10/20 LAYOUT

While the 3D coordinates for each electrode position that is part of the 10/20 or 10/5 layouts remain approximately the same in 3D space, subject specific coordinates can always be acquired using electrode digitizer or 3D tracker platforms such as **xensor**™. However, this requires additional hardware which is not always easily accessible to all users. Finally, different labs might use individual approaches to acquire electrode coordinates which leads to the need for a standardized set of cartesian or polar coordinates for each electrode location to enable comparison and cross-checking of results amongst peer groups and research labs.

To circumvent such issues, Oostenveld et al. (2001) proposed a method to acquire standardized electrode coordinates which we used as the basis of the automatic electrode positioning tool that gives us the coordinates easily for the extended 10/20 layout [2]. However, there is quite some challenge in extending this algorithm to the equidistant layout as the naming convention as well as the positioning scheme differs per hardware manufacturer. This document describes both methods used to derive 3D coordinates for the **waveguard**™ caps in both (extended) 10/20 and equidistant layouts.

The process of localizing EEG activity to obtain the electrode coordinates of underlying neural underpinnings involves three main steps – modeling the EEG activity, modeling the head volume to allow linking of neural activity to EEG recordings and finally reconstructing the brain electrical activity to acquired scalp potentials or EEG recordings. The first two steps of modeling describe the forward problem in EEG as they elaborate on the distribution of electric potentials across source locations and signals, the third step is termed the EEG inverse solution as it is employed to map back voltage measurements to a particular source location or electrode [3,4].

Localization of EEG activity using source reconstruction methods such as sLORETA, LORETA, dipole modelling etc. is important in both basic and clinical neuroscience research. For example, in the domain of cortical organization and integration, preoperative planning and epilepsy [3,5].

The Montreal Neurological Institute (MNI) head model:

The 3D head model on which the electrode coordinates can be laid out is available as standard data on our native **ASA**™ platform. This model uses the standard ICBM152 MNI template, computed as the average of 152 normal MRI scans thereby representing the average neuroanatomy from a large subject pool. Both hemispheres are equally represented in this symmetric average model which makes comparison of left-right hemispherical activity possible and can be extended to a wide range of application fields [1,4,6].

3D electrode coordinates for **wave**guard™ caps generated on the MNI brain

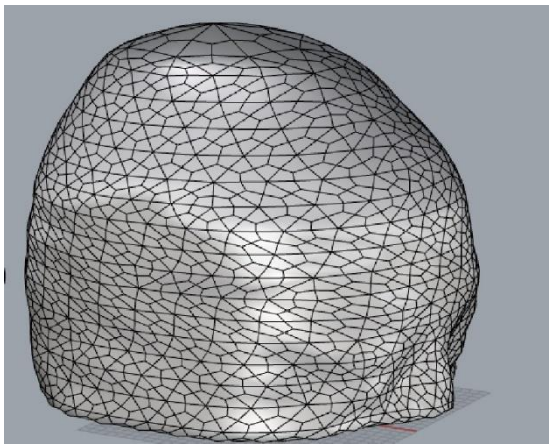


Figure 1: Impression of the ICBM152 standard MNI template on a head model

Available electrode layout for **wave**guard™ headsets:

The **wave**guard™ EEG headsets are available in (extended) 10-20 layouts such as the 10-10 and the 10-5 systems as well as in the equidistant layout.

In the 10-10 system, the electrode placement is based on skull landmarks, primarily, the nasion (Nz), the inion (Iz) and the left and right pre-auricular points (LPA and RPA). The hypothetical line longitudinally from Nz to Iz and transversally between LPA and RPA passes over the vertex and intersect at 50% of their lengths thereby giving us the electrode label Cz which corresponds to the vertex. In this layout each location has a specific name, and the same logic can be extended to the 10-5 system wherein the electrode channel density increases to accommodate a total of 128 channels. Figure 2 gives a schematic impression of the electrodes in the 10-5 layout.

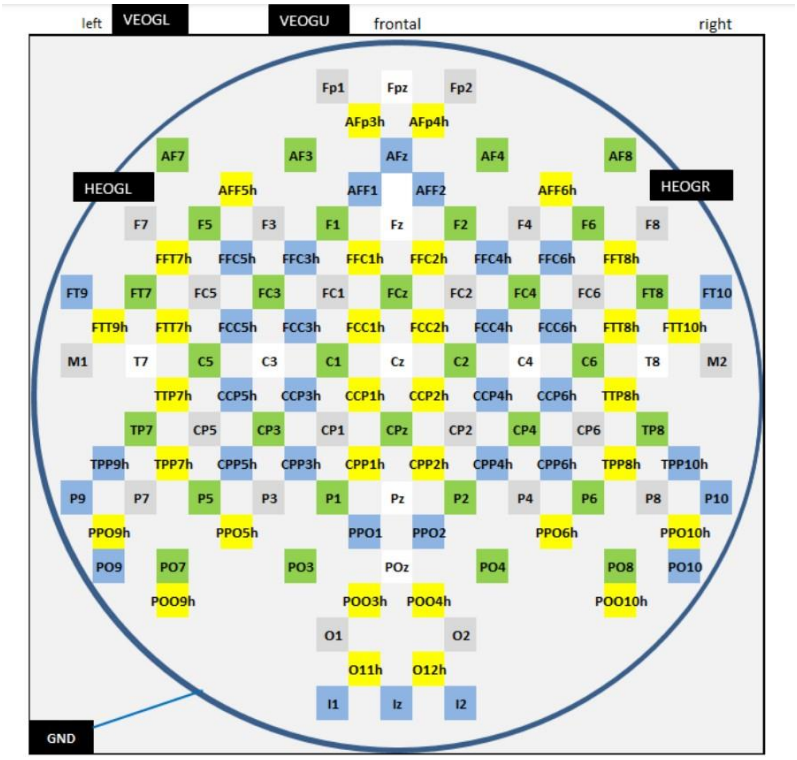


Figure 2: Electrode positions as per the 10-5 system. An extract from UDO-SM-0462 for **wave**guard ™ original cap (CA-203) has been included here for a preview of the electrode coordinates.

The equidistant layout helps with not under sampling or oversampling areas on the scalp based on anatomical landmarks. In this approach, the electrode positioning is based on the hexagonal 'duke'

scheme as illustrated in Figure 3. All electrodes are at equal distances from each other, ensuring enough neighboring electrodes for any source reconstruction or signal interpolation attempts. The positioning scheme as well as naming convention of electrodes are unique per cap and manufacturer.

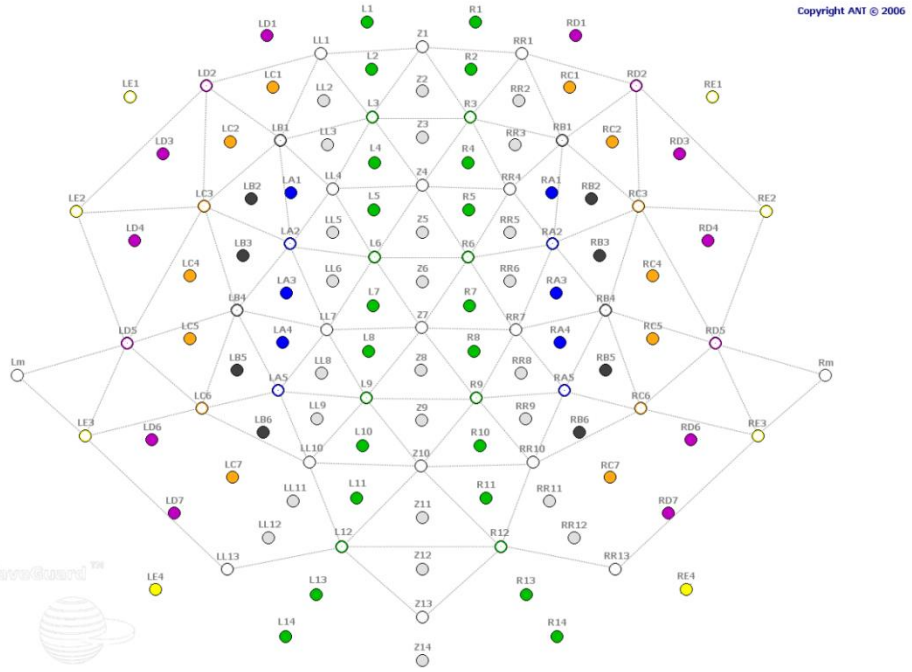


Figure 3: Equidistant or duke positioning scheme represented on a 128 channel **wave**guard™ cap.

METHOD:

This section describes the method used by us in-house for the generation of standardized electrode coordinates for the (extended) 10/20 caps and the equidistant caps.

Generation of 10-5 electrodes positions

A Python script was created to generate the coordinates of the standard 10-5 positioning of EEG electrodes, starting from a head model and the coordinates of the fiducials (nasion, inion, left and right pre-auriculars) based on Oostenveld et. al. (2001) [2]. The output of the script gives us a CSV file with the 329 electrode positions.

A mesh of the head was taken based on the MNI brain, and it is oriented such that the X-axis points towards the nasion, the Y-axis is oriented from right to left pre-auricular and Z-axis points upwards. Please refer to Figure 3 for a visual impression. The base routine of the script is based on the intersection between the mesh and a plane defined by three points. First Cz is defined as the average between the middle of the arc defined by Nz, Iz, and the vertex with the highest Z value, and the middle of the arc defined by left and right pre-auricular and Cz from the previous step. Finally, all electrode positions were derived from the mesh-plane intersection, and the 5% division of the resulting arcs. The coordinates for mastoid electrodes such as M1 and M2 which do not fall on the scalp level were calculated by taking into account the 10% rule downwards from TP9 and TP10 respectively.

3D electrode coordinates for **wave**guard™ caps generated on the MNI brain

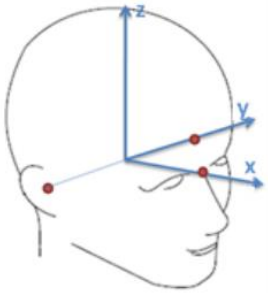


Figure 4: The axis definitions are defined as depicted here.

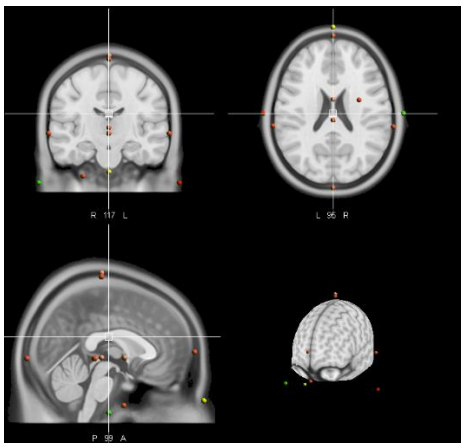


Figure 5: Preview of the MNI head model used for the electrode coordinate generation.

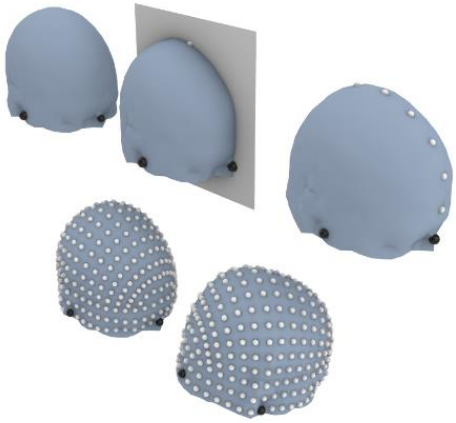


Figure 6: Process detailing the method employed to arrive at the 10-5 electrode positions. The nasion and pre-auricular points are marked on the scalp mesh.

Generation of equidistant positions:

Due to the unique positioning scheme and naming convention of electrodes, we extracted the 3D coordinates for each equidistant cap individually by using an electrode digitizer per cap. A scaled, 3D printed MNI head model of 55 cm (covering our medium head circumference range) was used as the surface on which the electrodes coordinates were generated using our in-house platform, **xensor**™. These coordinates were also centered and symmetrized per cap. Figure 7 depicts the electrode coordinates on a rendered head model.

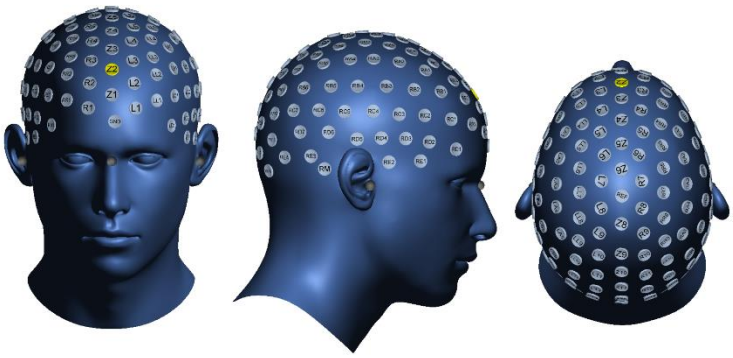


Figure 7: Different orientations of the head model depicting 128 electrode labels for which 3D coordinates were extracted using **xensor**™.

AVAILABILITY OF ELECTRODE COORDINATE FILES PER **WAVE**GUARD™ CAP:

Electrode coordinate files will be provided to our end-users as a text file, made available for each cap in .elc format which is accepted by most software platforms. In case of an additional request for specific cap coordinates and to acquire the currently available files, please contact support@ant-neuro.com or your nearest sales representative.

Please note that each .elc files will have two additional coordinates present such as the REF (reference) and GND (ground) electrode. Table 1 captures the list of currently available .elc files that exist for users.

DDE-OP-3350rev02 General electrodes positions.elc
DDE-OP-3345rev02 Electrode positions for the CA-208.elc
DDE-OP-3346rev02 Electrode positions for the NA-265.elc
DDE-OP-3347rev02 Electrode positions for the CA-203.elc
DDE-OP-3348rev02 Electrode positions for the CY-251.elc

3D electrode coordinates for **wave**guard™ caps generated on the MNI brain

DDE-OP-3349rev02 Electrode positions for the CA-209.elc
DDE-OP-3699rev01 Electrode positions for the CA-104.elc
DDE-OP-3700rev01 Electrode positions for the CA-105.elc
DDE-OP-3701rev01 Electrode positions for the CA-106.elc
DDE-OP-3702rev01 Electrode positions for the CA-116.elc
DDE-OP-3703rev01 Electrode positions for the CA-118.elc
DDE-OP-3704rev01 Electrode positions for the CA-119.elc
DDE-OP-3705rev01 Electrode positions for the CA-200.elc
DDE-OP-3706rev01 Electrode positions for the CA-201.elc
DDE-OP-3707rev01 Electrode positions for the CA-206.elc
DDE-OP-3708rev01 Electrode positions for the CA-207.elc
DDE-OP-3351rev01 MNI head model (stl file).zip
DDE-OP-3593rev01 Electrode positions for the NA-271.elc
DDE-OP-3597rev01 Electrode positions for the CA-212.elc
DDE-OP-3598rev01 Electrode positions for the CA-205.elc
DDE-OP-3600rev01 Electrode positions for the CA-126.elc
DDE-OP-3601rev01 Electrode positions for the CA-125.elc
DDE-OP-3599rev01 Electrode positions for the CA-130.elc
DDE-OP-3595rev01 Electrode positions for the CY-281.elc
DDE-OP-3596rev01 Electrode positions for the CY-261.elc
DDE-OP-3594rev01 Electrode positions for the NA-261.elc

Table 1: List of available electrode coordinate layouts.

EXAMPLE

A range of software platforms request electrode coordinate files (in .elc or other formats) to allow the generation of topographic maps (topoplots) of EEG activity as a 2D circular view to represent subject information. Academic and commercial software packages such as Brainstorm, Cartool, EEGLAB and FieldTrip (MATLAB toolboxes for EEG, MEG or iEEG data analysis), BESA and others allow the import of electrode coordinate files to perform inverse modeling methods on acquired subject data [5].

Figure 8 gives an impression of an MNI head model onto which the electrode coordinates have been loaded for 32 channel EEG dataset where frequency mapping is being explored.

3D electrode coordinates for **wave**guard™ caps generated on the MNI brain

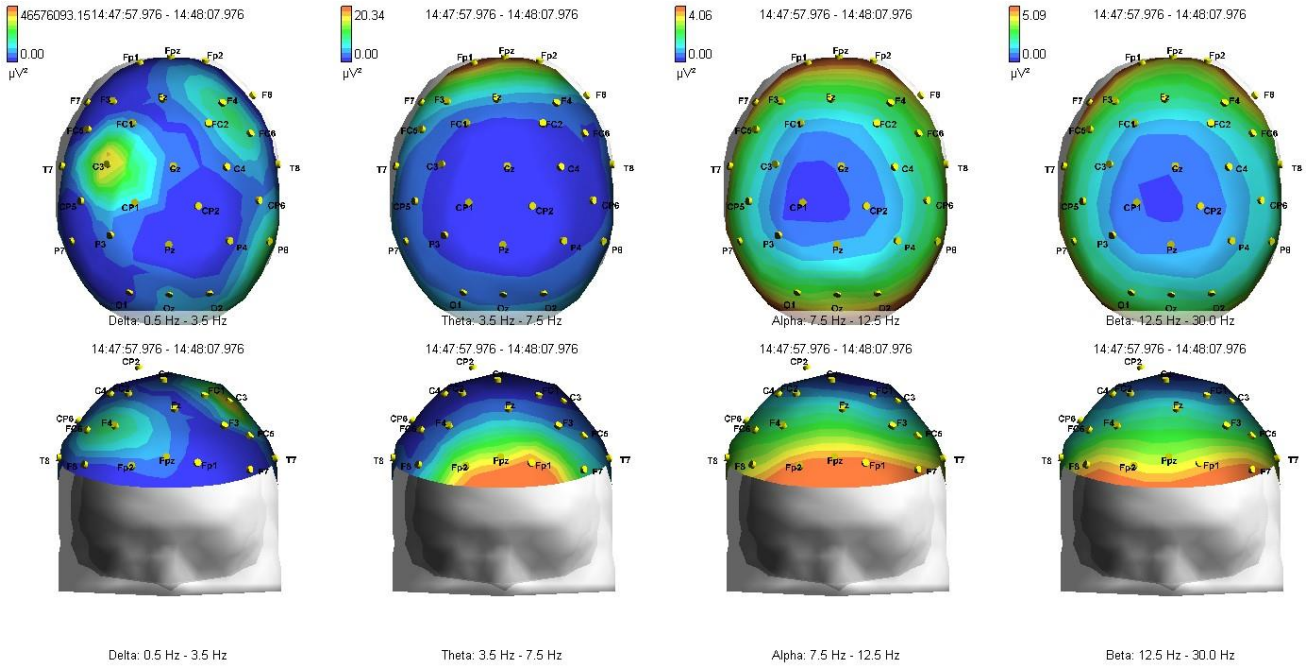


Figure 8: Frequency mapping visualized on a 3D (MNI) head model with electrode coordinates

LIMITATIONS

- The approximated electrode coordinates have been acquired on a standard head, to acquire coordinates on a subject specific head model we would recommend all users to use an electrode digitization platform for their subject. For example: **xensor**™
- We only provide Cartesian coordinates, the output of any transformations applied to suit other coordinate systems need to be thoroughly verified by the end-user.
- The electrode coordinates were acquired on a head circumference of 55cm for the MNI brain.

REFERENCES

1. https://nist.mni.mcgill.ca/mni-icbm152-non-linear-6th-generation-symmetric-average-brain-stereotaxic-registration-model/
2. Oostenveld, Robert, and Peter Praamstra. "The five percent electrode system for high-resolution EEG and ERP measurements." Clinical neurophysiology 112.4 (2001): 713-719.
3. Vatta, Federica, et al. "Realistic and spherical head modeling for EEG forward problem solution: a comparative cortex-based analysis." Computational intelligence and neuroscience 2010 (2010).
4. Bhutada, Abhishek S., et al. "Semi-automated and direct localization and labeling of EEG electrodes using MR structural images for simultaneous fMRI-EEG." Frontiers in neuroscience 14 (2020): 558981.
5. Michel, Christoph M., and Denis Brunet. "EEG source imaging: a practical review of the analysis steps." Frontiers in neurology 10 (2019): 325.
6. Grabner, Günther, et al. "Symmetric atlasing and model based segmentation: an application to the hippocampus in older adults." Medical Image Computing and Computer-Assisted Intervention–MICCAI 2006: 9th International Conference, Copenhagen, Denmark, October 1-6, 2006. Proceedings, Part II 9. Springer Berlin Heidelberg, 2006.

EXTERNAL LINKS

1. https://www.ant-neuro.com/products/waveguard_original
2. https://www.ant-neuro.com/products/waveguard_net

3. https://www.ant-neuro.com/products/waveguard_touch
4. https://www.ant-neuro.com/products/asa
5. https://sites.google.com/site/cartoolcommunity/
6. https://neuroimage.usc.edu/brainstorm/Introduction
7. https://www.besa.de/
8. https://sccn.ucsd.edu/eeglab/index.php
9. https://www.fieldtriptoolbox.org/
10. https://www.ant-neuro.com/products/xensor

APPENDIX: Header and specifications of the .elc file type

The .elc format requires the mention of 'Positions' and 'Labels' per cap. Figure 7 includes an example .elc file for the 32 channel cap.

```
#Electrodes positions for the CA-209
#DISCLAIMER: These electrodes were acquired on a standard MNI brain, please refer to our user documentation (UDO-SM-1065rev01) for further details

# 32 electrodes
NumberPositions=    32
UnitPosition    mm
Positions
Fp1 :   98.4    29.0    31.7
Fpz :   103.2   -0.1    35.2
Fp2 :   98.6    -29.2   31.6
F7  :   59.2    72.4    30.5
F3  :   66.6    48.3    76.5
Fz  :   70.6    -0.3    95.1
F4  :   67.0    -48.9   76.3
F8  :   59.8    -72.9   30.2
FC5 :   35.2    76.5    64.3
FC1 :   41.4    31.5    110.2
FC2 :   41.7    -32.5   110.1
FC6 :   35.8    -77.3   63.9
AFz :   93.5    -0.2    68.4
T7  :   1.9 86.5    35.5
C3  :   6.5 61.4    99.1
Cz  :   8.8 -0.7    126.0
C4  :   7.0 -62.6   98.8
T8  :   2.6 -87.5   35.2
FT10    :   30.1    -85.2   -3.4
CP5 :   -27.9   79.4    73.4
CP1 :   -26.1   33.7    123.9
CP2 :   -25.8   -35.3   123.7
CP6 :   -27.2   -80.8   73.0
P7  :   -58.0   75.5    44.4
P3  :   -58.3   51.0    95.6
Pz  :   -59.4   -0.9    117.6
P4  :   -57.9   -52.8   95.4
P8  :   -57.3   -77.0   44.1
FT9 :   29.4    84.7    -3.1
O1  :   -96.4   29.8    55.6
Oz  :   -99.2   -1.0    60.2
O2  :   -96.2   -31.7   55.4
Labels
FP1 FPZ FP2 F7  F3  FZ  F4  F8  FC5 FC1 FC2 FC6 M1  T7  C3  CZ  C4  T8  M2  CP5 CP1 CP2 CP6 P7  P3  PZ  P4  P8  POZ O1  OZ  O2
```

Figure 9: Example of .elc file type specifications required for import into analysis toolboxes.