Modeling of EOG for Electrode Position Optimization for Human-Computer Interface

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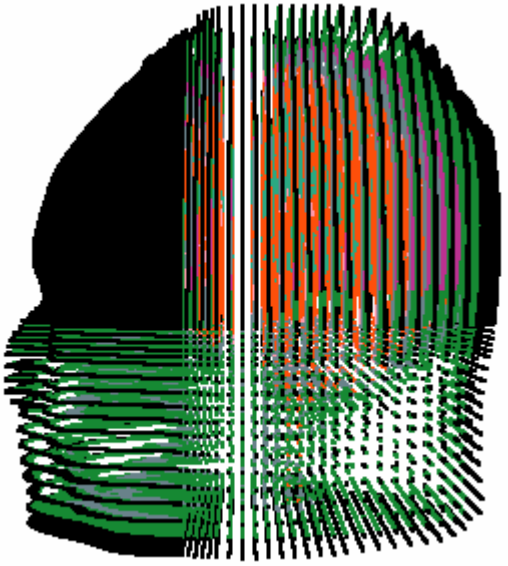
Introduction 1/2

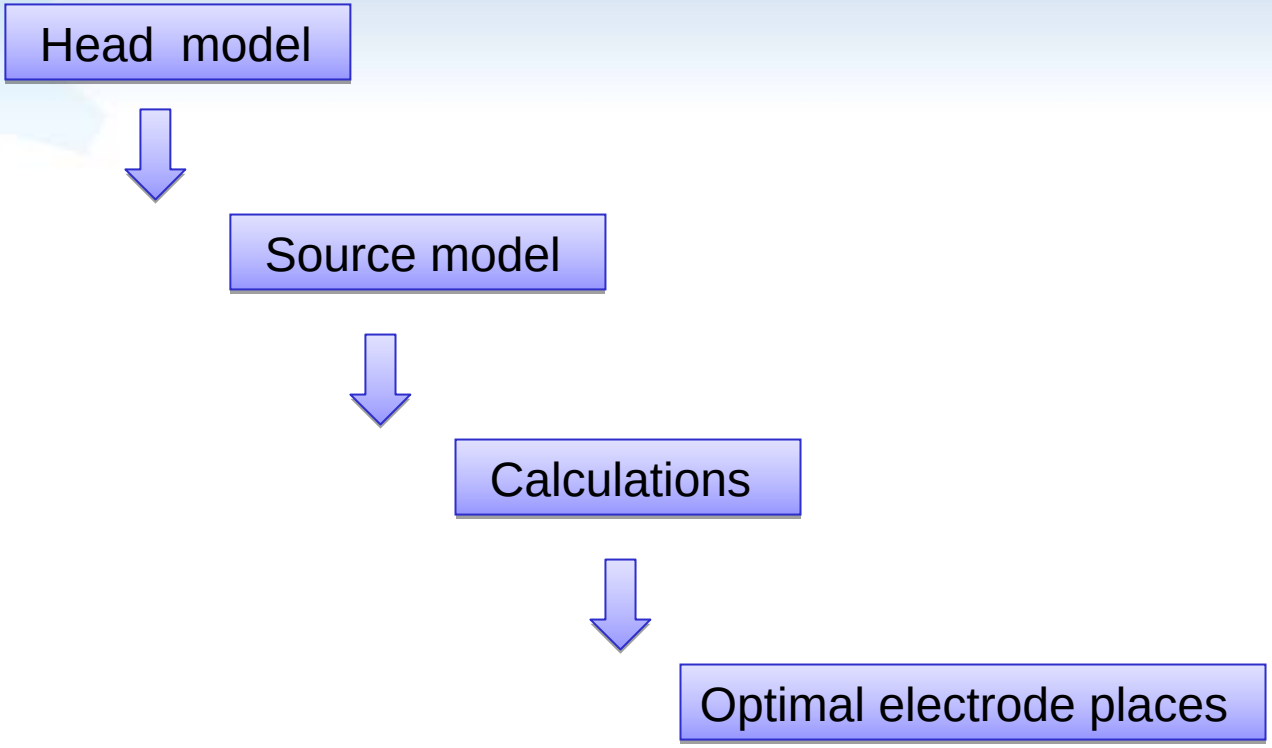
- Wireless head cap enables the measurements of facial muscle activations and the movements of the eyes.
- Human-computer interface: the gaze direction could move the cursor with some facial expressions to correspond clicking
- Wireless data transmission in the current head cap enables the data transmission of six measurement channels.

Introduction 2/2

- In this work electro-oculography (EOG) on the forehead is modeled with the anatomic realistic head model.
- Common positions of EOG measurement electrodes aren't applicable because of the shape of the head cap.

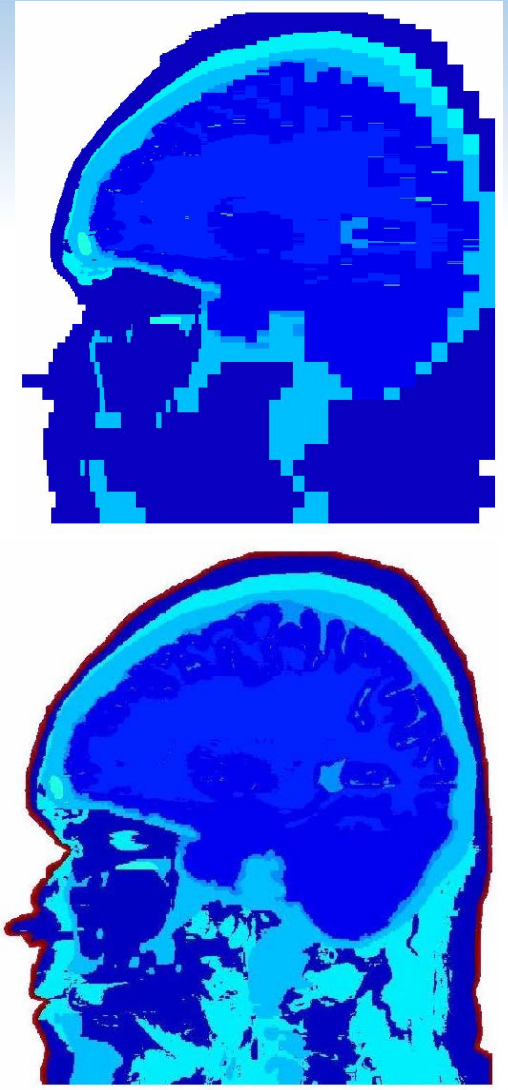


Methods 1/4 – The work flow



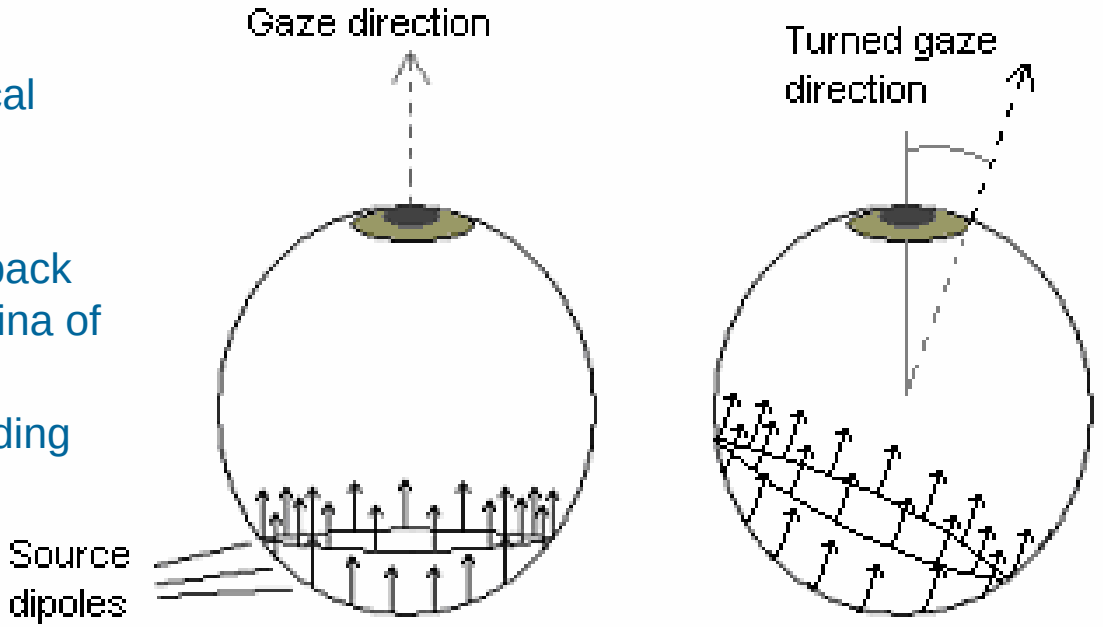
Methods 2/4 - Head model

- Medical images in the segmentation: anatomical cryosection images and CT slices from Visible Woman project (U.S. National Library of Medicine).
- Seven different tissue types: scalp, muscle, eye, skull, cerebrospinal fluid (CSF), grey matter, and white matter
- Resolution of 0.33 mm x 0.33 mm x 0.33 mm on the forehead
- For bioelectric simulation with FDM methods the number of elements in the resulting model exceeds the standard computer resources. -> In this work the resolution was decreased on the back of the head and under the eye level.

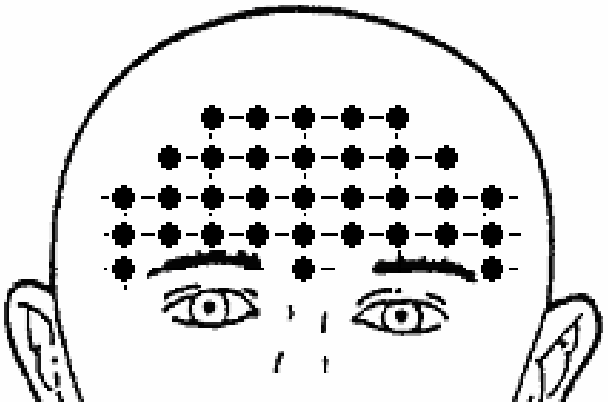


Methods 3/4 - Source model

- Reality:
  - There is a charge differential in the eyeball between the interior ends of the photoreceptors and the pigment epithelium.
  - Movement of the eye -> electrical field on the forehead changes.
- Model:
  - Source dipoles inserted at the back boundary of the eye i.e., the retina of the eye ball.
  - Source surface is moved according to the modeled gaze direction.

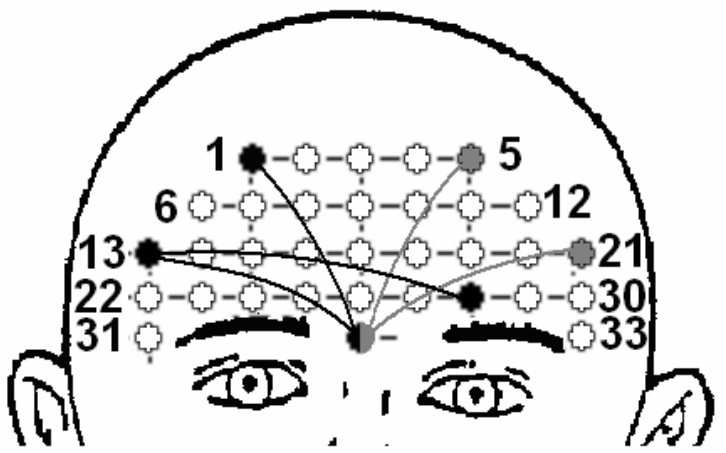


Methods 4/4 – Calculating the surface potentials

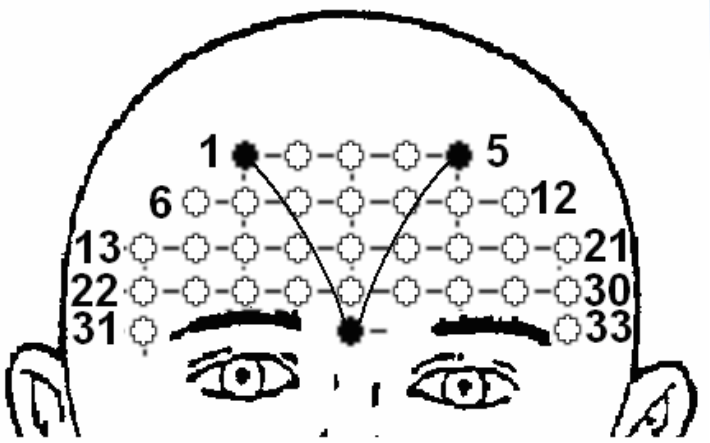


- Altogether 49 different gaze directions (5° steps between ± 60°) were modeled.
- Iterative FDM solver used to construct a finite difference method -model (FDM) of the segmented anatomical model
- Reciprocity theorem (Helmholz in 1853) and lead field concept were used to calculate the surface potentials.
- The surface potentials at the forehead were considered on 33 different electrodes. Different gaze directions treated as independent sources.

Results 1/3 – Electrodes most sensitive for different gaze directions



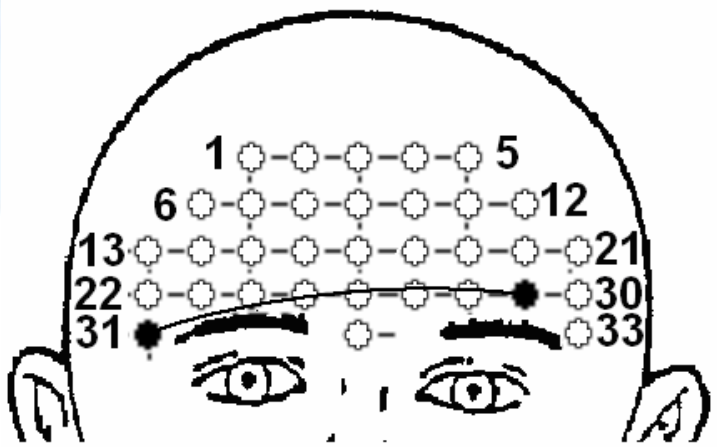
Optimal electrode positions for different horizontal gaze directions.

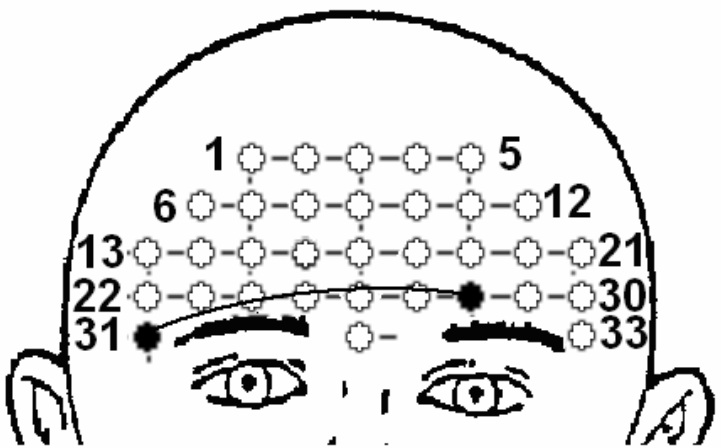


Optimal electrode positions for different vertical gaze directions.

Gaze directions

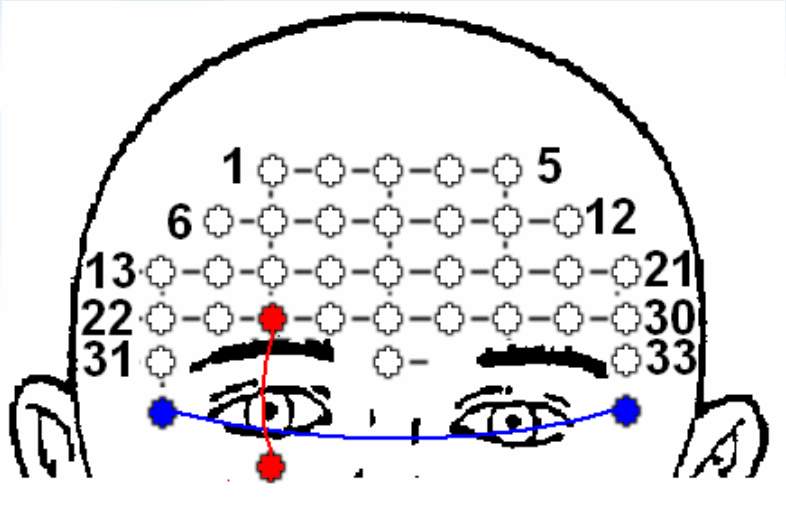
Results 2/3 – Electrodes most sensitive for the changes of gaze directions



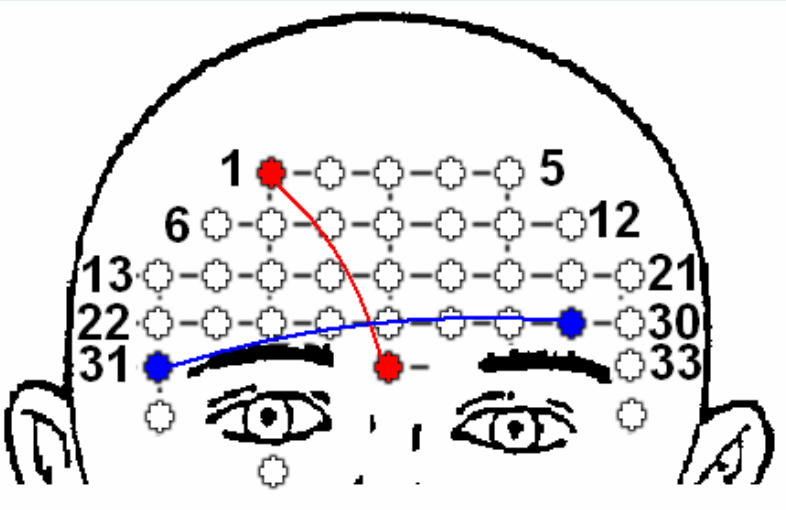


Gaze directions
±20°

Results 3/3 – The optimal electrode positions



Electrode postitions
recommended in the literature



Modeled optimal electrode positions

Vertical gaze direction

Horizontal gaze direction

Conclusions

- A new accurate model now in use for modelling purposes
  - The original model has over 160 million elements, resolution of 0.33 mm
  - The latest version has already 23 different tissue types
- The modeled electrode positions will be tested with the real measurements in the near future.

Acknowledgements

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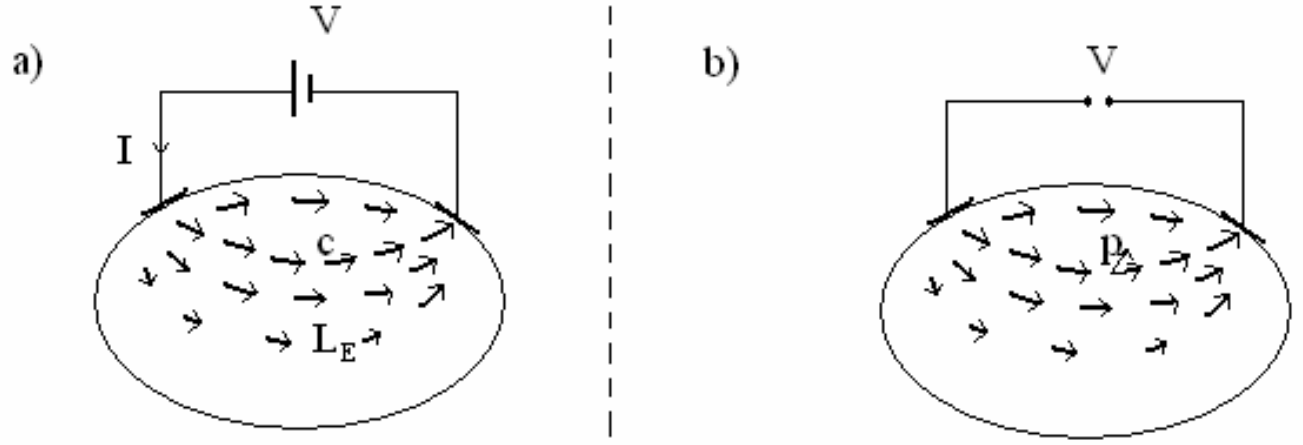
- Authors would like to acknowledge Noriyuki Takano for providing the iterative FDM solver, and Markus Hannula and Nathaniel Narra for segmenting the head model.

Thank you! Questions?

Reciprocity theorem

- Introduced by Hermann von Helmholz in 1853
- If we have a unit current injected to a model or if we have the same unit current as a source in the model, then a voltage between source electrodes or measuring electrodes, respectively, is the same.
- The electric lead field LE is defined as the field of lead vectors c. The lead vector indicates the sensitivity of the measurement to the dipole source at a certain point. The measured voltage **V**, the dipole moment **p** and the lead vector **c** are related as follows:

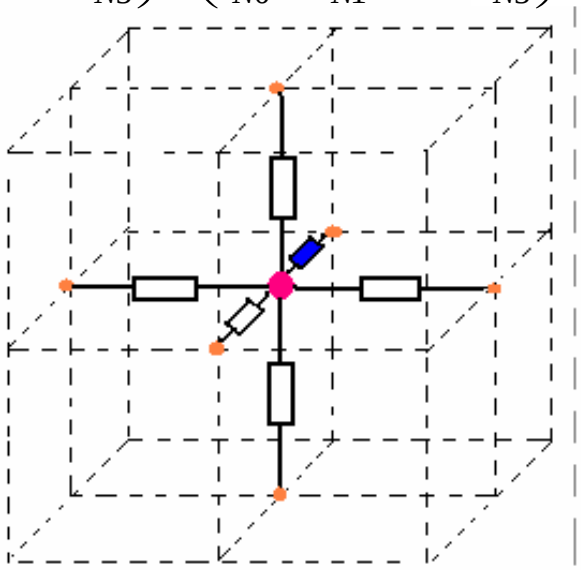
$$V = \underline{c} \circ \underline{p}$$

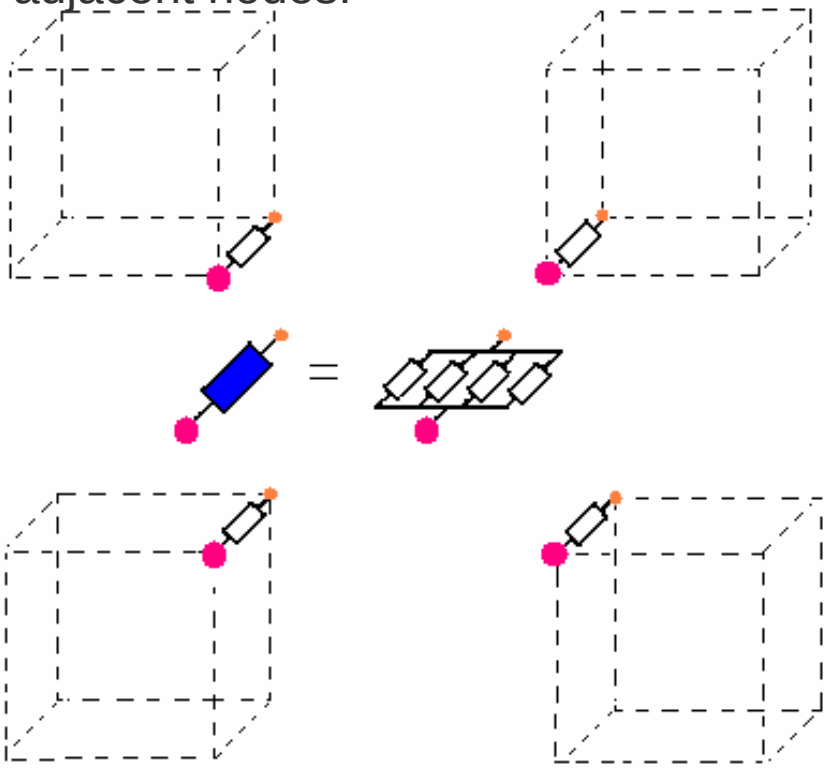


Finite Difference Method (FDM)

- Volume conductor model divided into little voxel
- Voxel resistivity dependent on corresponding tissue
- Node = connection point of 8 voxels
- Potential at each node calculated in terms of the Poisson equation, and the potential at each node is a linear function of adjacent nodes:

$$\Phi_n = \left(\frac{1}{r_{N0}} + \frac{1}{r_{N1}} + \ldots + \frac{1}{r_{N5}} \right)^{-1} \left(\frac{\Phi_0}{r_{N0}} + \frac{\Phi_1}{r_{N1}} + \ldots + \frac{\Phi_5}{r_{N5}} \right)$$





Wireless data transmission

- ZigBee is used
- Sampling frequency of the signal 1 kHz
- Thus the data transfer rate enables the use of 6 channels
- (2) fEMG, (2) EOG, EEG, accelometer
- More detailed information of the radio transmitter of our system found in:
  - Vehkaoja A., Verho J., Puurtinen M., Nöjd N., Lekkala J., Hyttinen J., ”Wireless head cap for EOG and facial EMG measurements”, IEEE-EMBS 2005: 27th Annual International Conference, issue 6, pp. 5865-8