Appendix: Principles of the A-line AEP recording and analysis.

A) Introduction

The A-line monitor uses an AEP window of 80 ms. The pre-processing of the EEG sweeps consists of artifact rejection and 16-100 Hz Finite Impulse Response (FIR) 170th order band-pass filtering. An FIR filter was chosen instead of an Infinite Impulse Response (IIR) filter, because, even though the FIR filter requires many more coefficients than an IIR filter, it has linear phase, whereas the IIR filter does not. Linear phase is important to prevent the filter from changing the peak latencies in the AEP.

B) Auto Regressive with Exogenous input (ARX) model

1) Introduction

ARX modeling is the technology used for night vision in helicopters where the need is to rapidly extract a stable image from the infra red camera image that is disturbed by the vibration of the helicopter. Similar, the AEP waveform is disturbed by spontaneous EEG and EMG activity and signal processing should be applied to extract the AEP. The classical method is Moving Time Averaging (MTA). The principal disadvantage of the MTA is the need of a large number of repetitions of the stimuli, hence producing a delay of typically 1-5 minutes. On the other, the ARX model can extract a common component present in two signals obtained by relatively low numbers of repetitions, here 15 and 256 sweeps. Single sweep analysis has been carried out on visual evoked potentials by ARX modelling but as the amplitude of the AEP is much smaller a preaveraging of 15 sweeps has been applied.

2) Definition of the ARX model

The ARX model has two inputs: the moving time average of the last 15 sweeps (X_1) and the moving time average of the last 256 sweeps (X_2). The average of the 256 sweeps has a better signal to noise ratio than the average of 15 sweeps, but the average of 15 sweeps has a shorter delay than the average of the 256 sweeps. The objective of the ARX model is to merge the rapid response from input X_1 with the better SNR of input X_2.

The central equation of the ARX model is :

$$X_1(t) = b_1 \cdot X_2(t) + ... + b_m \cdot X_2(t-m+1) - a_1 \cdot X_1(t-1) - ... - a_n \cdot X_1(t-n) + e \quad \text{(Eq. 1)}$$

where the *a's* and *b's* are the coefficients of the model. The *n* is the model order. By setting up a number of equations with the same structure as equation 1, but shifted in time, it is possible to determine the coefficients. The coefficients are determined in a such way that the best prediction is obtained in Equation 1 in a least mean square sense. When the coefficients of the model are determined, the ARX-AEP is obtained by filtering of input X_2 with the *a* and *b* coefficients. Figure A.1 shows the diagram of the ARX-model and the AEP extraction.

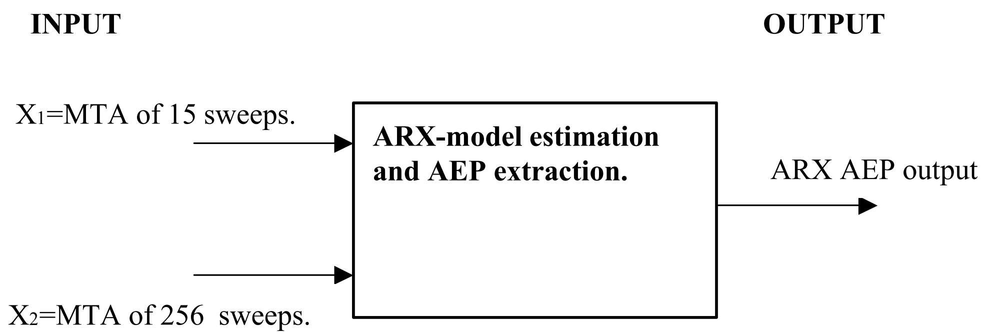

Figure A.1. The ARX-model and the AEP extraction, showing the two inputs, an MTA of 15 sweeps and an MTA of 256 sweeps. The output, ARX-AEP, is X_2 filtered by the a and b coefficients obtained for each new sweep.

The principle of the ARX model is that peaks that correlate between the two inputs are used to define the ARX coefficients in a such way that the output is the linear combination of the peaks common in the two inputs. The main advantage of the ARX model is that changes can be traced as rapidly as the changes appear in the input containing the 15 sweeps, but with much less noise than is present in the average of the 15 sweeps. The principal disadvantage of the ARX method is that peak components that correlate between the two inputs arising from noise, e.g. mains, will be modeled as well. For this reason, robust pre-processing is essential before applying the ARX model. The pre-processing should remove 50/60 Hz line interference and reject artifactual signals.

2) Model order.

The order of the ARX-model should ideally be calculated for each sweep, but this is a very time consuming process. Hence, to comply with the need of fast processing time, an average model-order of five for both *a*- and *b*-coefficients was implemented in the A-line.

3) Stability.

The coefficients of the ARX model are calculated for each sweep. The stability of the ARX model is important in order to ensure that the ARX extracted AEP is reliable. Stability is tested by a pole-zero analysis of the ARX polynomial; if a sweep has poles outside the unit-circle, then the sweep is rejected. Furthermore, if the amplitude of the ARX extracted sweep is more than 3 times that of the MTA extracted, then the sweep is rejected as well. Subsequently, the ARX-AEP is smoothed exponentially , using :

$$\text{ARX-AEP}_{mean} = 0.1\text{ARX-AEP}_{new} + 0.9\ \text{ARX-AEP}_{old} \qquad \text{(Eq. 2)}$$

C) Index calculation.

The last step in the A-line signal processing chain is the index calculation, the purpose being a mapping of the 2-dimensional morphological changes of the AEP into a single number, facilitating an easier clinical interpretation of the AEP.

The A-line ARX Index (AAI), is calculated as the sum of absolute differences in the 20-80 ms window of the AEP. The 20 ms start of the window was chosen in order not to include Brainstem AEP (BAEP) and auricular muscular artifacts, and the 80 ms end of the window was chosen in order not to include Long Latency AEP (LLAEP).