AN UNCOUPLED OSCILLATOR MODEL FOR EVOKED POTENTIAL DYNAMICAL MODELLING

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Abstract — A mathematical model for evoked potentials is outlined. The model has been developed by considering phase synchronisation of the underlying neurological processes. The model, consisting of an ensemble of uncoupled linear oscillators with a gaussian distribution of frequencies is shown to reproduce the typical response of P100 visual evoked response. The model structure is parallel in form and is considered to be physiologically realistic. It is also shown that the calculated behaviour of the ensemble can be generated by a 2nd order linear differential equation with time varying coefficients, thus highlighting the fact that entirely different physical structures can generate identical responses.

I. INTRODUCTION

The analysis of EEG data for the presence of evoked potentials has traditionally been carried out by a signal averaging process. However, a number of methods have been proposed which employ the information contained within the pre-stimulus interval to aid the identification process [1] [2]; it is generally assumed that the evoked response is an additive contribution to the on-going spontaneous EEG activity.

However, it has been suggested that the external stimulus acts to phase-modify the spectral components of the spontaneous activity [3]. It has been further suggested that evoked potentials and event related potentials reflect external stimulus and endogenous synchronisation, frequency stabilisation, frequency selective enhancement and phase re-ordering of the on-going spontaneous EEG activity.

Since $p(\omega)$ is a probability density function,

$$\int_{-\infty}^{\infty} p(\omega) d\omega = 1$$

independent of $\mu$ and $\sigma$. If the first integrand is denoted as eqn. (5).

$$I_1 = \frac{1}{\sigma \sqrt{2 \pi}} \int_{-\infty}^{\infty} e^{i\omega t} e^{-\frac{(\omega-\mu)^2}{2\sigma^2}} d\omega$$

If $t$ is replaced by $-t$.

$$I_2 = \frac{1}{\sigma \sqrt{2 \pi}} \int_{-\infty}^{\infty} e^{-i\omega t} e^{-\frac{(\omega-\mu)^2}{2\sigma^2}} d\omega$$

This can be configured into the form of eqn. (7).
Experimentally measured $P100$ was observed from the summation of the outputs on resetting the phases, Fig. 2. This simulated response can be described analytically by eqn. (11). Thus, a measure of the variance of the oscillator frequencies can be obtained. The $P100$ has been modelled by assuming that our measurement system observes the outputs of two communities of oscillators, in the vicinity of active and reference electrodes, reset in sequence by a wave travelling through the brain. Thus

$$P100 = y(t)$$

This is the result for resetting all the phases of the oscillators to zero. For $n$ oscillators the expected sum will be

$$y(t) = n \cdot e^{-\sigma^2 t} \cdot \sin \mu t$$

This function is graphed in Fig. 1 for $\mu = 10$ and a range of $\sigma$ values.

A differential equation solved by this $y(t)$ is

$$\frac{d^2 y}{dt^2} + 2\sigma^2 t \frac{dy}{dt} + \left[\sigma^2 + \mu^2 + \sigma^4 t^2\right] y = n \mu \delta(t)$$

This differential equation describes a linear time-variant system. One solution is for $y(0) = 0, \frac{dy}{dt}(0) = 0$.

III. Experimentation and Analysis

Investigation of the full field monocular pattern shift reversal Visual Evoked Potential (VEP) was carried out [8]. A sample rate of 2000Hz was employed, with the checkerboard pattern being reversed at a rate of 1Hz. The $P100$ waveform was detected following ensemble averaging of 100 trails. Using a 2-D assembly of oscillators (15x15) a response similar to the

REFERENCES