# MULTIPLE CORRELATIONS BETWEEN EEG AND GSR PATTERNS ON REMOTE MOVEMENT COMMAND AND CONTROL

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***Abstract***

*The description of a command and control loop, based on biosignals that are collected through projective functions from the cerebral cortex (GSR biosignals) or through EEG biosignals, involves establishing an experience database that contains signal structure patterns, which are formed in the interaction of the subject with all the stimuli in his cognitive field. Command and control will be provided through pattern recognition. This paper offers a number of correlations between patterns of GSR and EEG signals, collected simultaneously from the same person by manipulating a number of stimuli with a high degree of discrimination in the field of perception.*

***Keywords****: phasic stimulation , based experiences, stimulus, cognitive field, pattern recognition.*

## 1. Remote movement command and control by EEG and GSR patterns

The tackling of remote transmission of a command, as also ensuring the control of a movement by means of mental structures like *cognitive pattern*, assumes and *stimulus-pattern* correlation that will lead to intercepting the cognitive "behaviour" in a system of coordinates providing the facility to dissociate the basic issues that involves the decision, ensuring for the involved individual the possibility to manage remote control by biofeedback.

The block diagram of a system able to remotely transmit a command by the stimulus-cognitive pattern correlation is provided in ***Figure 1***. First of all, an

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*experience base* is achieved including all the correlations established between the stimulus and the cognitive pattern. To extract the facility, the pattern identified retains from the structure of the procurement biodata, the encoded shape of the pattern brought by the witness stimulus and it transmits it to a benchmarking block programmed ready-made with the pattern code of the witness stimulus, selected from the *experience base*, which ensures the classification role. When the "stimulus" code is identical with the "pattern" code, the benchmarking block sends a valid command to format de command. Remote command is taken by the execution element, which operates the formated theme at the command level, and the subject takes-over the control by biofeedback, involing the other witness stimuli in the command and control loop.

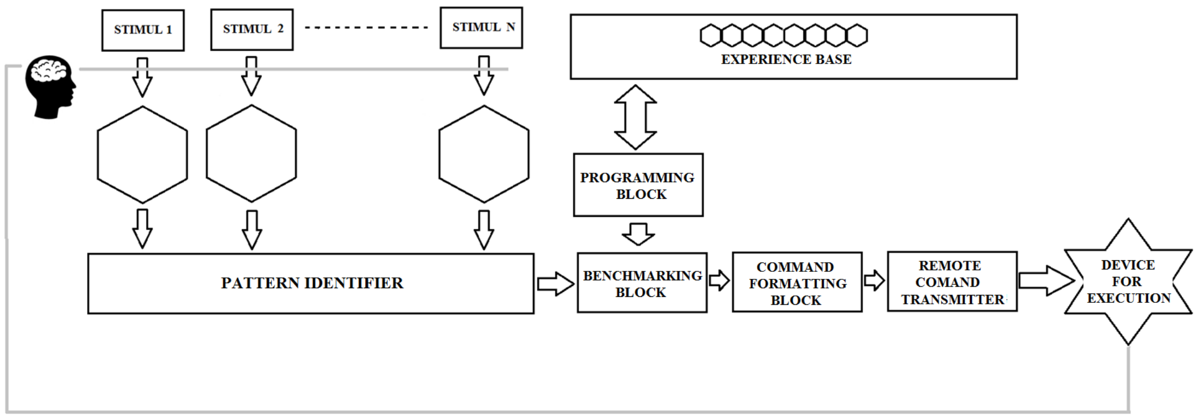


***Figure 1.*** *The block diagram of remote movement command and control*

### 1.1. EEG signals

An EEG signal measured on scalp level is generated by the inhibitory postsynaptic potentials (IPSP) and the excitatory poststynaptic potentials (EPSP). The differentiation between the EEG signals will be materialised in identifying and measuring some specific parameters for each type of signal.

The EEG signal is made of several types of waves differentiated in frequency bands:

- the Alpha waves (8 – 13 Hz, 10 – 120 V, in relaxation)
- the Beta waves (14 -30 Hz, 5 – 30 V, mental activity)
- the Theta waves (4 – 7 Hz, 30 – 70 V, frequent in children)
- the Delta waves (0,5 – 3 Hz, 50 - 150 V, in deep sleep)

The EEG signal can be characterised by a set of parameters as a result of some tests, of a *transformation process* of the *signal* function.

The processing of the EEG signals includes: filtering, storing, reconstruction, compression of data, conversion, amplification, multiplexing, modulating/ demodulating the signals; separating the noise information.

The transformation of analogue signals in numeric signals is a numeric processing and it takes place with a data procurement system. If the processing is only limited to analysing an EEG signal, then the numeric data are no longer reconverted in analogue signals, but these are exclusively meant for analysis and storage;

The EEG parameters can be divided in: temporal parameters; statistic parameters of amplitude; frequency parameters.

In the following, we will particularly refer to the *frequency parameters.* They assume a frequency analysis based on amplitude spectra provided by Fourier transform and on the power spectrums. The frequency parameters evidence the specific pace of EEG, of which distribution in frequency is associated with the mental-physiological conditions of the subject. Thus, the information on the fatigue level is provided by the EEG signal power, given by the area subject to the function of spectral power density, and certain pathological manifestations are associated with the movement of the frequency bands.

*The spectral power density*[3] is deduced starting from the definition of central frequency signal power $f_o$ and band $B$,

$$P(f_0,B) = \lim_{r\to\infty} \frac{1}{T}\int_0^r |x(t)|^2\, dt \qquad \textbf{(1)}$$

From where the spectral density receives the form:

$$S(f_0)\, df = \left(\frac{dP(f)}{df}\right)_{\mathrm{f=fo}} df \qquad \textbf{(2)}$$

which assumes the measurement of the average power in a narrow band $\Delta f$ around it $f_o$. The smaller $\Delta f$ is the closer comes the average power in that band to the spectral density.

The spectral EEG analysis is usually made with a system made of the filter which crosses the band targeted on $f_o$, a square detector and an integrator. These analysers can be: in parallel, series (with sweep), with dispersive filter, with time compression and *Fourier analysers*.

The Fourier Analyser is made of a *correlator* and a Fourier *transformer*. The Fourier transformer contains two multipliers, the memories for the weight functions, the memories *sin* and *cos,* a numeric integrator and a processing block.

The calculation will be as follows:

$$S_{xx} = \int_{-\infty}^{\infty} C_{xx}(\tau) e^{-i\omega\tau} d\tau \qquad \textbf{(3)}$$

where $C_{xx}$ is the self-correlation function of the EEG signal. The self-correlation function is extracted from memory and it is multiplied with the weighing functions, to smoothen the spectrum in case of signals with wider spectrum.

The memories *sin* and *cos* employ the exponential function. At the output of the processing block, the real and the imaginary parts, the module and the phase of the Fourier transform will be provided.

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[3] distribution of power in the band *B* of the signal *x*(*t*)

***The spectral power density.*** The analysis of the power spectrum of the EEG signal provides quantitative information about EEG frequency distribution, being easy to achieve by means of the FFT algorithm (Fast Fourier Transform).

The function of correlation of EEG with itself deduces the power spectrum based on the relation:

$$P(f)=R_n^2[X(f)]+I_m^2[X(f)] \tag{4}$$

where $X(f)$ is the Fourier transform of the EEG signal on one channel.

***Coherence*** quantifies the connection between different EEG channels, its size being given by the relation:

$$\text{Coherence} = \frac{crossed\ spectrum}{\sqrt{PX(f)-PY(f)}} \tag{5}$$

The ***crossed spectrum*** is given by the product:

$$crossed\ spectrum = X(f)\ Y^*(f)\ , \tag{6}$$

where $X(f)$ and $Y(f)$ are the Fourier transforms of the EEG signals from two channels and (*) is the complex conjugate.

***The phase*** of the EEG signal is given by the angle of polar representation thereof, coherence being a complex number. The phase can show interactions of brain activity recorded in different areas of the cortex.

*The linear EEG spectral analysis* assumes the procurement of the multi-channel EEG signal, the calculation of the *spectral power density* (with FFT), of the crossed spectrum, calculation of the coherence and of the phase relations. [7]

In order to send the remote control and command by means of an EEG signal structure, to manage it in the experience base, the *spectral power density* is determined, which will indicate quantitative information about the signal frequency distribution. Hence, the frequency distribution can be constituted in a pattern (***Figure 2***) that can be stored and managed.

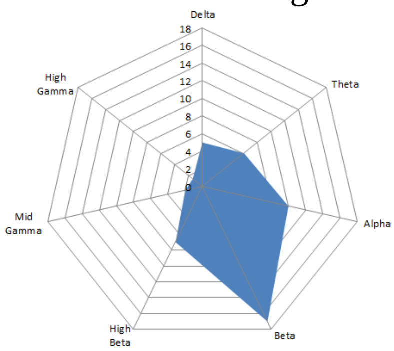



***Figure 2.*** *EEG pattern form - spectral power density*

### 1.2. GSR signals

The terminology used in the technique of electrodermal activity establishes that, for a SCR signal, the following parameters can be recorded: amplitude (given in microSiemens), latency, duration of conductance increase after stimulus application and the half of SCL restoration time. Amplitude is given by the difference between the maximum level of the SCR response and the

SCL level from the moment when the external stimulus is applied. The latency (about 3 seconds) is the duration between the moment when the stimulus is applied and the moment when the SCR response occurs. The duration of conductance increase is the duration for crossing the upslope up to the SCR maximum (between 1-3 seconds). The semi-time of restoration is recorded from the moment when the SCR peak is reached up to 50% from the amplitude (between 2 and 10 seconds).

A practical way to evidence the GSR neurosignals is electrical stimulation of the epidermis, i.e. to maintain it in a stimulation condition within a time range calibrated on the phase conductance level. Due to this manner of stimulation, according to the principle of self-adjustability by reverse connection installed between the system outputs and the sensitive input area, the response in phase conductance perceived through the epidermis will be in a projective correspondence with the bioelectric events taking place in the body, generated in the self-adjustment processes whereby the mental-physiological functions are manifested.

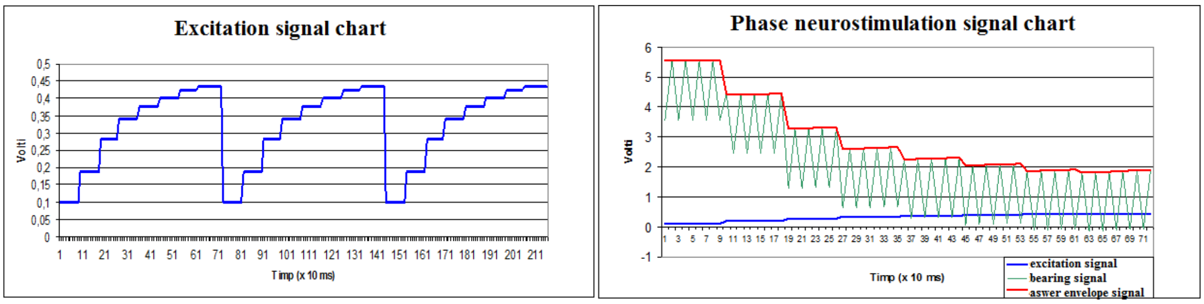
The opening of a neurostimulating canal will align the measurement area with the targeted mental-physiological function, and the neurosignals collected from the sensors will contain the information on the response pattern for the applied stimulus.

The neurostimulation process will be tackled in terms of the assembly of applied signals: the excitation step signal, the response step signal and the bearing, sinusoidal signal.

a. *The excitation signal.* It is a step signal (***Figure 3.****a*), of which form can be given as follows:

$$x(t) = \sum_{k=1}^{N} A_k \left[ \sigma(t - kT) - \sigma(t - (k+1)T) \right] \qquad (7)$$

Where $\sigma(x - x_0) = 1$ ; $x \geq x_0$ ; $\sigma(x - x_0) = 0$ ; $x \leq x_0$ is the Heaviside function; A - it is the amplitude of the step signal; T - it is the period of the step signal;




a b

***Figure 3.*** *a. the diagram of the excitation signal; b. the diagram of the signals involved in the phase neurostimulation on a single step impulse*

b. The *bearing signal* can be also described as follows:

$$x(t) = A_S \cos\left(\frac{2\pi t}{T}\right) \qquad \textbf{(8)}$$

where $A_S$ is the signal amplitude and $T_0$ is its period.

c. *The response signal*. ***Figure 3.b*** provides all the three signals involved in the phase neurostimulation of the epidermis.

The response time is a signal made of the step signal and the bearing signal, of which envelope contains critical information about the mental-physiological processes on which we intend to apply an interference. The mathematical description of the composed signal is as follows:

$$x_{Total}(t) = A_S \cos\left(\frac{2\pi t}{T_0}\right) + A_t \sum_{k=1}^{N} k\left[\sigma(t-3kT) - \sigma(t-3(k+1)T)\right] \qquad \textbf{(9)}$$

By expanding the diagram shape to the level of the seven stimulation cycles, we acquire the form of the seven functions that form the GSR pattern. These will be simultaneously evaluated to intercept by their variability, their response in the cognitive pattern coordinates to the applied stimulus.

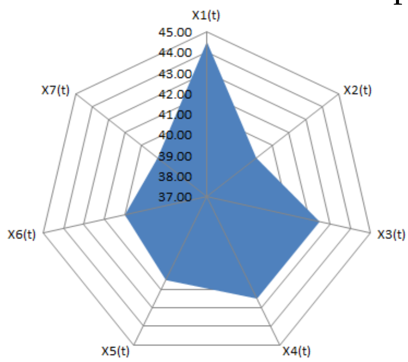



***Figure 4.*** *GSR pattern form - the functions of response to neurostimulation*

Because in the following we will use the functions $X_3(t)$, $X_6(t)$ și $X_7(t)$ to study the correlations, we specify that $X_3(t)$ is specific to affectivity, $X_6(t)$ is specific to the *cognitive activity*, and $X_7(t)$ is relevant for the *relaxation status*.

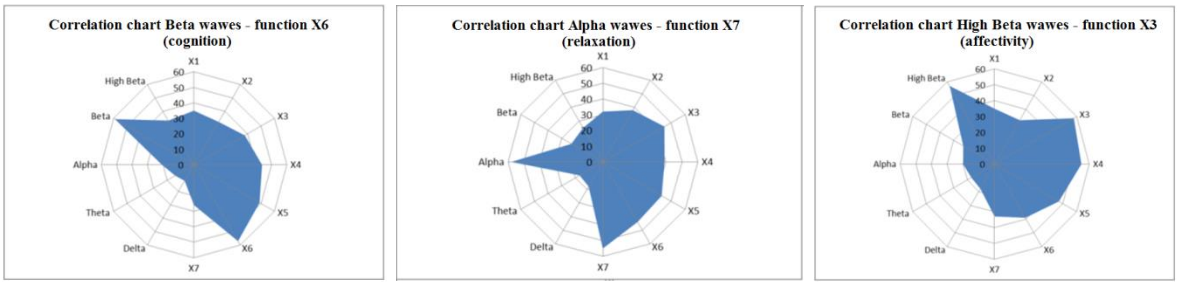
## 2. The research methodology

*3.1. Assumption*: there is a multiple correlation between the pattern of the *spectral power density* of an EEG signal taken from the scalp level and the pattern of the *response functions* by the GSR signal taken from the palm of the same individual, by the *phase neurostimulation* procedure.

*3.2. Equipment and software: for the GSR signals, the phase neurostimulator* MindSpring™ manufactured by Canadian Psychometric Systems LLP was used, and for the EEG signals, the device MindWave from NeuroSky, Inc. was used, by means of which simultaneous determinations were made with the ones from palm level. The statistic analysis was made with SPSS 18.

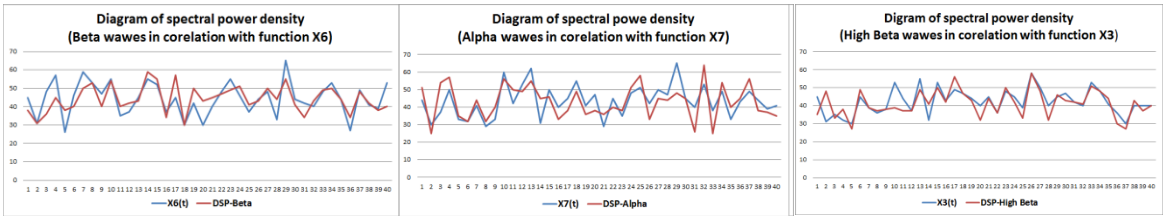
*3.3. Participants and methodology.* The tests targeted a number of N=40 individuals in three stages: *cognitive* for the correlation between the spectral power density of the Beta waves *(DSP-Beta) and the projective function* $X_6(t)$; *relaxation* for the correlation between the spectral power density of the Alpha waves *(DSP-Alpha)* and the projective function $X_7(t)$; *emoțional* for the correlation between the spectral power density of the High Beta Waves *(DSP-High Beta)* and the projective function $X_3$ (t).

## 3. Results




a b c

***Figure 5.*** *a. eg. Beta correlation-$X_6$; b. eg. Alpha correlation-$X_7$; c. eg. High Beta correlation-$X_3$*




| | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item-Total Correlation | Squared Multiple Correlation | Cronbach's Alpha |
|---|---|---|---|---|---|
| X6 | 44,15 | 51,721 | ,682 | ,465 | ,798 |
| DSP_Beta | 44,28 | 82,256 | ,682 | ,465 | |
| X7 | 42,95 | 91,998 | ,657 | ,432 | ,791 |
| DSP_Alpha | 43,56 | 78,052 | ,657 | ,432 | |
| X3 DSP_ | 41,22 | 52,676 | ,716 | ,512 | ,834 |
| High_Beta | 42,34 | 48,280 | ,716 | ,512 | |

***Figure 6.*** *The diagrams and statistics of the correlation between the spectral power density and the X(t) functions*

## 4. Conclusions

The results obtained in this benchmarking experiment confirms the assumption that there is a significant correlation between the pattern of the *spectral power density* of an EEG signal taken from the scalp level and the pattern of the *response functions* by the GSR signal taken from the palm of the same individual, by the *phase neurostimulation* procedure.

We mention here the difference between the EEG signals, which we consider predominantly signals of clinical interest, them being connected to subsystems having a strictly specialised brain activity, and the GSR signals - stimulated, which are signals of psychological interest, them being correlable with the subsystems with integrated mental activity.

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