Biosignals from a biophysics perspective

Introduction

We can refer to all signals whose existence can be detected in living organisms as **biosignals**. These can be electrical voltage waveforms, changing magnetic fields, changes in chemical concentrations, mechanical movements, sounds, temperature changes, etc. They can be registered as a result of **spontaneous activity** of a biological system (**native signals**) or as a result of some intentional **stimuli (evoked signals, provocations**, etc.).

In spite of the wide spectrum of physical character (in terms of quality and quantity) of biosignals, we can observe and investigate a large number of common features. Therefore, in the immediately following theoretical section we will mostly **abstract** from their biophysical nature and concentrate on describing what all signals have in common. In this way, we will gradually get to the most common reason why we deal with the investigation of biosignals, i.e. the **diagnostic methods** that use the examination of different biosignals. Virtually all of these diagnostics have some antecedent in the previously used technical and industrial methods from which they were derived and applied in biology and medicine and from which they also took their terminology. We therefore expect some tolerance and forbearance from medical students if they find the use of, for example, electrical terminology beyond their expectations. It should be noted that whatever the origin of one or another biosignal, its subsequent conversion into an electrical signal is inevitable nowadays. For the same reason, a basic knowledge of electrical circuit theory is inevitable, as is a knowledge of basic mathematical apparatus.

Signal

Signal concept

The term "**signal**" is derived from Lat. Signum, which is most often translated as "sign" - in Roman times, for example, a sign to fight, given by a trumpet as a sound signal. It can also be understood in the sense of "sign" (of an activity, a process). It means that the signal carries some meaning, has an informational value that is encoded in it in some way (e.g. traffic light = traffic signal).

Time dimension

What is important for us here is the temporal dimension of the signal, its **dynamic character** - e.g. a traffic light changes colours over time - unlike "signals" which can also be static.

Physical nature of the signal vs. abstract information

The signal carries some information, but it is always itself carried by some **carrier**, it has a **physical character**. That is why we talk about the way the signal is transmitted. It is interesting that during the transmission different **carriers can be changed** without changing the actual character of the signal, i.e. the signal still carries the same information - e.g. the signal of a trumpet from a physical point of view is propagated in the form of acoustic waves progressing through the sound, but if the ancient Romans had known how to use electricity, they could have transmitted their battle signals in this advanced way without disturbing the informational value of the transmitted message.

In the end, we can therefore **abstract** from the physical nature of the signal and deal only with its mathematical expression or its information value. And since various signals are used everywhere around us in our time, especially in communication technology, we can use the rich mathematical apparatus that has been developed to process them in their analysis. (Later we will recall that in practice, due to imperfect transmission, the transmitted signals are distorted and thus the content of the transmitted information can be **distorted** - which can be **used, for example, to diagnose** various functional disorders. However, this fact does not prevent us from abstracting from the physical signal carrier wherever it is convenient and possible).

Signal representation using a function

The fact that the signal runs in time means that it takes on a certain value at each instant. And since the passage of time is considered an independent variable in classical physics, we can think of any signal as a **function of time** and represent it by a **graph** of that function, with time as the independent variable and the dependent variable being the appropriate physical quantity corresponding to the physical nature of the transmission channel. We must not forget that in this physical representation, both variables correspond to **physical quantities** that we measure in **certain units**, which, when represented graphically, will be reflected in the respective scales of all axes: while on the horizontal axis we usually plot time in seconds (milliseconds, minutes, hours, etc.), on the horizontal axis we plot time in seconds (milliseconds, minutes, hours, etc.).), on the vertical axis we will read the magnitude of the signal in the appropriate unit according to its actual physical nature (e.g. for a pipe sound signal this will be the measured sound pressure, given in pascals).

Signal waveform measurement and registration

Measurement of any **physical quantity**, as we know, essentially means **comparing** the magnitude of that quantity with some **standard** and expressing that ratio in some rational number. However, measuring a quantity that is constantly changing "under our hands" can be very difficult, if not impossible, if its value at the next instant is different again from what we have just measured.

One of the ways to capture such constantly changing quantities is to **register them continuously**, for example by converting the observed quantity into a mechanical movement of a stylus drawing a curve on a moving strip of millimetre paper (paper with a printed square or other grid). In this way we convert the independent variable (time) into a coordinate given by the product of the **time elapsed** since the beginning of the registration and **the speed of the paper movement**, while the product of the magnitude of the dependent variable and some constant of proportionality given by the design and setting of the recording device gives us the value of the coordinate of the dependent variable. The result of the process is directly a **graph** of the monitored variable, from which we can later read the measured values at any point in time using a pre-printed grid.

For example, thermobarographs at meteorological stations worked in the purely mechanical way described above. Edison's roller phonograph worked on the same principle: here the sound waves were transferred from the air to the oscillation of a stylus, which was used to carve a groove in the supporting material, the shape of which, visible to the naked eye or magnifying glass, corresponded to the graphic recording of the sound waves.

The gramophone records that we can still encounter were made in a similar way, and, leaving aside the mechanism of their mass reproduction, the main advance was the inclusion of electronic amplification stages between the transducer of the original quantity (the microphone) and the recording device (the stylus). The development of other recording devices, including those such as the ECG or EEG machine, has been carried out in a completely similar way. Different methods of recording curves on a carrier medium were tried, and can still be encountered today - ink on paper, stylus on waxed paper, hot pens on waxed or thermosensitive paper, light beam on photographic film - but the basic idea of all such methods remains the same: to fix the temporal dimension of the variable quantity in the spatial dimension and thus enable its subsequent reproduction.

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- HERMAN, Peter. *Biosignals from the point of view of biophysics.* 1. edition. Prague : Dúlos, 2006. 63 pp. ISBN 80-902899-7-5.

Recommended literature

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- NAVRÁTIL, Leoš. *Biophysics in Medicine.* 1. edition. Prague : Manus, 2003. 398 pp. ISBN 8086571033.
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