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Metrological traceability of a system for measuring electrodermal activity

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ABSTRACT

The paper presents a procedure for evaluation of system for measuring electrodermal activity of the skin. The proposed procedure was tested within a metrological evaluation of a low-cost wireless system. The procedure consists of static calibration by comparison, dynamic evaluation by means of generated sine signals and testing for functionality using of a simple psychophysiological experiment. Additionally, the quality and reliability of measured data transmission is evaluated. A low cost, low weight, ergonomically shaped and battery powered wireless (ZigBee protocol) portable wrist-type measuring system was designed and built and the proposed procedure used to evaluate it. Based on the results of the evaluation acceptance criteria for a reliable skin conductance meter used for skin conductance levels studies could be proposed. Devices conforming to these criteria would be reliable and sufficiently accurate for skin conductance level measurements, with an established metrological traceability and readings linked to the basic units of the international system of units SI.

1. Introduction

In general, the physiological parameters of a participant in psychophysiological experiments are related to the emotional state of the participant and the cognitive level of difficulty of her/his task. Psychophysiological experiments can be defined as experiments of observing changes in person's physiology (hart rate, sweat, temperature, blood pressure, respiration, etc.) that were induced by a psychological stimulus (mental and cognitive tasks, physical tasks, psychological tasks, etc.). The relationship between psychophysiological parameters and complexity of the tasks is not always unique and is actually very complex [1–4], because the physiological response is also subject to large interpersonal differences [5,6].

Electrical activity of the skin is a physiological parameter associated with the sweat glands function. Sweat glands are controlled by the autonomic nervous system. In general, the psychological activity of a person is a cause for a change in skin electrical properties, i.e. electrodermal activity (EDA) of the skin [7,8]. The two major skin conductance components are skin conductance level (SCL), describing the tonic activity, and skin conductance response (SCR) describing the phasic activity of the autonomous nervous system. Low frequency SCL signal has amplitudes of up to 30 μs, and higher frequency SCR magnitudes of up to 0.05 μs. SCL in general reflects the overall level of sympathetic arousal whereas SCR reflect transient sympathetic arousal, either spontaneous or in response to events [7,9].

For EDA measurement two electrodes are attached to the skin surface, allowing current to run through the skin tissue, causing a voltage drop. Conductance of the skin tissue is the ratio between current and voltage drop. Problems in measurement of the skin conductance are:

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(i) selecting the measurement sites and electrodes, (ii) electrical contact between the electrodes and the skin, (iii) the amplitude of the DC power supply of the measurement system [7,8,10,11].

Commonly biomedical devices, like EDA measurement systems, are rarely metrologically evaluated in the sense of determining their accuracy, measuring error and uncertainty [11]. Therefore the establishment of metrological traceability to higher standards is non-existing. Traceability of measurement is defined as the property of the result of a measurement whereby the result can be related to stated references, usually national or international standards, through an unbroken chain of comparisons, all having stated uncertainties [10]. Traceability enables accuracy, reliability and above all comparability of skin conductance measurements of various laboratories, using various instrumentations throughout the world.

Based on our experience from our previous work [11] in this paper we are proposing an evaluation procedure with acceptance criteria for a reliable and accurate EDA measurements of SCL. The paper describes the procedure used for evaluation of a SCL measuring device in order to ensure estimation of its measurement accuracy (error and uncertainty) in both static and dynamic conditions, thus establishing its metrological traceability to higher level standards of electrical resistance.

2. Measuring system under test

For the purpose of evaluating the proposed protocol and due to the lack of affordable inexpensive commercial systems with wireless transmissions, which could be easily connected to an analogue sensor and wirelessly transmit data to a remote computer, we decided to design, develop and build our own modular system for SCL recording.

The wireless skin conductance (SC) measuring system was composed of two parts: (i) the SC measuring circuit, based on the non-inverting amplifier and (ii) the module for the wireless transmission of the measured values (Fig. 1).

SC meter was based on commercial low cost ATmega328 microprocessor-based system Arduino Nano (by Gravitech) with 10-bit AD converter. AD converter was acquiring analogue output U_{out} proportional to the conductance of the skin G_{skin}. The method shown in Fig. 2 was selected as optimal for measuring skin conductance because it provided a constant (and electrically safe) voltage of appropriate amplitude (about 0.5 V) across the two electrodes on the skin [12,13]. To avoid issues due to electrical contact with the skin wet single use Ag/AgCl electrodes were used. The value of the resistor R_{ref} could be selected to enable the use of the full measuring range of AD converters. For U_{in} we used 5 V which was generated by a step-up regulator powered by lithium battery cells.

The virtual instrument developed in LabVIEW graphical program environment (by National Instruments) was the second part of the SC meter. Main tasks of the software part were: (i) instrument settings, (ii) data, communication and transmission between the local and remote devices, (iii) plotting real time acquisition and (iv) saving the

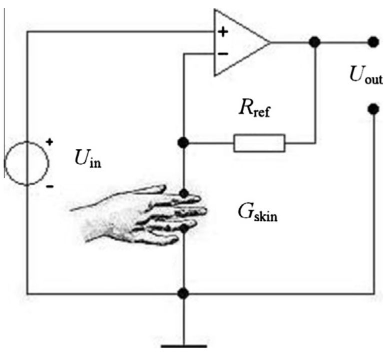

Fig. 2. Measuring the conductance of the skin by means of a non-inverting amplifier system.

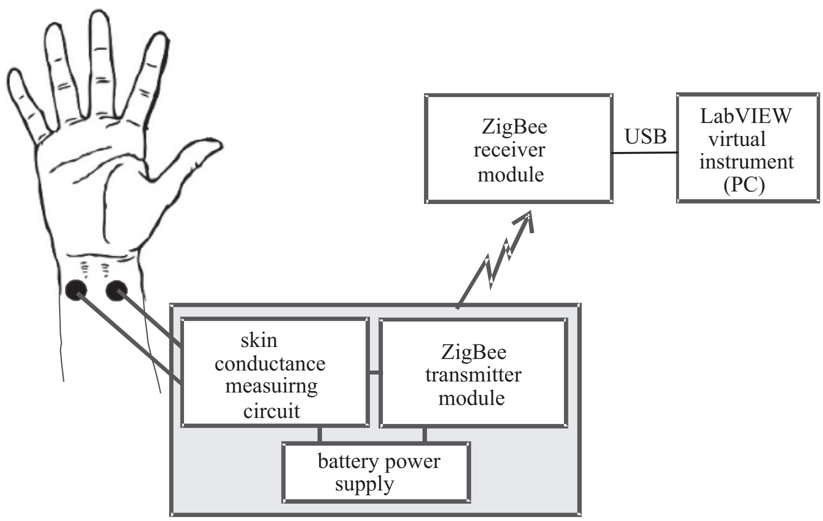

Fig. 1. Schematics of the wireless skin conductance measuring system.