

# THE FREQUENCY AND THE SHAPE OF DRIVING SIGNAL INFLUENCE IN MEASUREMENT OF THE ACTIVE POINTS

Marek KUKUCKA<sup>1</sup>, Zuzana KRAJCUSKOVA<sup>1</sup>

<sup>1</sup>Institute of Electronics and Photonics, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovicova 3, 812 19 Bratislava, Slovak Republic

marek.kukucka@stuba.sk, zuzana.krajcuskova@stuba.sk

**Abstract.** Our contribution deals with the human skin voltage chart measurement. The human skin has a certain impedance or resistance - it can be easily described and simulated using a substitute electric circuit. The skin also contains parts with measurably lower impedance and different electric properties – we can show them clearly by measurement of voltage chart. We have concentrated our effort on finding and following the measurement of active points on a certain part of the skin's surface, to acknowledge their existence and positions through a measuring process. The parameters of the measured voltage chart are influenced by the amplitude, frequency and the shape of the measuring electric signal. We focused our research effort in this paper to measure the frequency influence and then the influence of the shape of the driving signal.

## Keywords

Active point, acupuncture, frequency, human skin, impedance, meridian, sinusoidal and triangular signal, voltage chart, voltage measurement.

## 1. Introduction

The human skin has a certain impedance or resistance; it can be easily described and simulated using a substitute electric circuit. The skin also contains parts with measurably lower impedance and different electric properties – we can see them clearly by a measurement of voltage map. These small parts on the skin's surface are called active points (acupuncture points) and they are known and have been used in acupuncture centuries ago. For many years, a number of authors concentrated their efforts to measure them, to describe them and to learn about new properties of them. They are used in different new diagnostic and therapeutic medical devices nowadays.

## 2. The Electrical Model of Human Skin

The characteristic impedance of the skin and its capacity allows us to create an equivalent electric circuit of the human skin. The equivalent model of human skin impedance cannot be expressed using a simple passive circuit only because the properties of the skin are nonlinear and alternating in time [1]. The simplest model for skin impedance interpretation is a parallel circuit containing a capacitor and a resistor and a serial resistor (Fig. 1). The parallel connection of the capacitor  $C_p$  and the resistor  $R_p$  in this model represents the influence of the skin capacity and the serial resistor  $R_s$  represents the impedance of subcutaneous tissue [2]. For 0,8 cm<sup>2</sup> dry and clean skin, cleansed by ethanol and water values for resistors and capacitor were established as follows:  $R_s = 2 \text{ k}\Omega$  to  $200 \text{ k}\Omega$ ,  $R_p = 100 \text{ k}\Omega$  to  $500 \text{ k}\Omega$  and  $C_p = 50 \text{ pF}$  to  $1500 \text{ pF}$ .

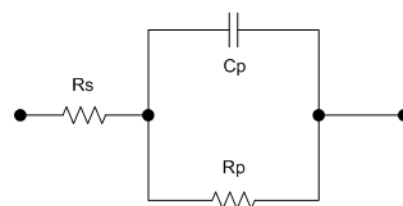


Fig. 1: The equivalent impedance model of the human skin [2].

## 3. Electro-Acupuncture and Physical Structures Called Meridians

Physical structures meridians are objectively measurable, identifiable and describable specific paths in the human body. They have special physical features and significance. They contain so called active points which are significant with: skin impedance between these points

(100-200 k $\Omega$ ) and surrounding skin (1 M $\Omega$ ) is different, the electric capacity of these points is greater – within the limits 0,1 to 0,5  $\mu$ F, in comparison with non active points where the capacity reaches only about 0,01  $\mu$ F. Various authors in their works consider meridians as channels that lead electric charge in the extracellular space. The blockage of the flow of these currents leads to a higher concentration of positive or negative charge and a physical manifestation of that can be pain or some disease symptoms. Named here are various qualitative indications on the skin's surface of significant meridian points, they are interesting from a technical point of view: high electric potential (to 300 mV), high electric capacity (0,1 to 0,5  $\mu$ F), low electric resistance, higher skin respiration, higher local temperature, generating of infrasonic waves (from 2 to 15 Hz). Some qualitative indications of deeper layer of the skin in significant meridian points: lower level of sensitivity for electric stimulation, higher electric capacity, higher conductivity of isotopic tracers. The measurement of electric parameters of the skin on meridians was described in various literal sources [3], [4]. Meridians have important information, energetic and regulative function in the human organism and are used since centuries in acupuncture prevention, diagnostics and therapy. Disorders in energy flow in the body then manifest in whole body form and state of the organism. The system of active points and meridians contains a multitude of information about the actual state of the organism. The problem is to find the appropriate key to evaluate this information. We have to respect the knowledge and laws of classic acupuncture when solving it. Literature and various web sources describe in wide range positions and properties of these physical body structures. Because of accessibility and position, we have chosen *Large Intestine Meridian (Li)*.

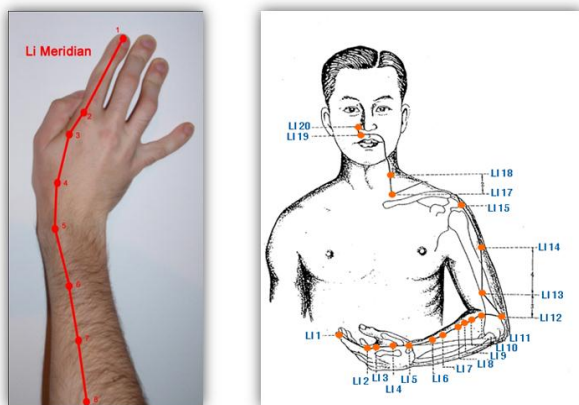


Fig. 2: Large intestine meridian path (Li Meridian).

#### 4. Experimental Measuring Device

The basic construction element of the designed and realized measuring device is a processor from Atmel - ATmega16 (Fig. 3). The processor contains one serial port, eight 10-bit A/D converters and one SPI - Serial

Peripheral Interface. For the controlled connection of measuring electrodes multiplexers DG406 were used. The device also contains a modified version of a peak detector. In addition, the device was extended by DDS - Direct Digital Synthesis generator from Analog Devices AD9833 which is controlled via a SPI bus by a microprocessor [5]. The communication with the PC covers the module DLP-USB232M which serves as a converter of the USB interface to UART - Universal Asynchronous Receiver / Transmitter. This module and the connected computer are separated from the measuring device by a two channel insulator ADUM1201 from Analog Devices, because of the safety of the patient. Supplying the device from accumulators is the way how to protect the human operator or the measured object from potential electric injury.

Our measurement was realized using needle electrodes [5], [6]. There are 64 electrodes placed into a 8x8 matrix on an isolative holding construction.

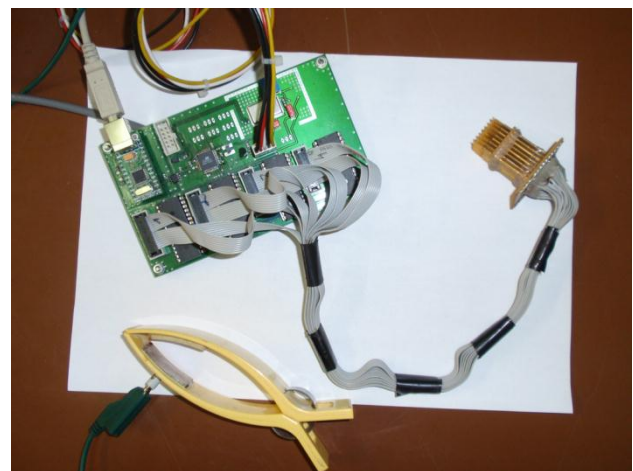


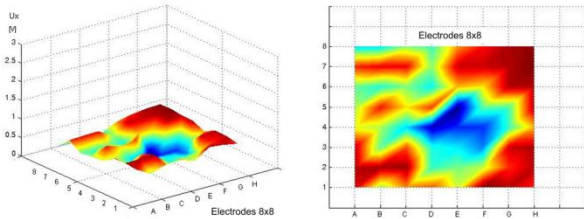
Fig. 3: Measuring device with connected electrodes.

Each of the electrodes is created by a brass needle located in a cavity shell with a nib which allows fitting each of the electrodes to the surface of the human body and make contact. All the electrodes measure the change of voltage with regard to a reference electrode placed on the chosen suitable position on the body. The distance of needle peaks is 2,5 mm. A similar method with a probe of 8x8 electrodes, but larger and differently constructed is used by authors in [9]. Mentioned construction of the probe is more flexible but too large for precious measurement. The way could be a construction of the measuring probe by a combination of conductive and isolative rubber combined in matrix into common contact material layer or use of special textile sensor [10].

#### 5. Searching for Active Point Position

During the measurement process on the large intestine meridian we found a point which showed a significant

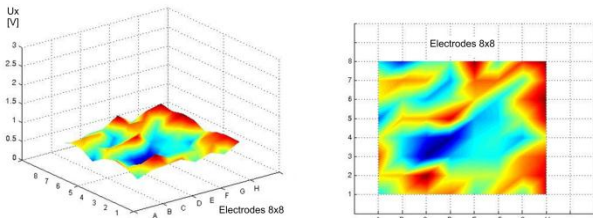
change in comparison with previous measurements. It was the active point No. 4 on the large intestine LI meridian (Fig. 2, left side) [7]. The point was measured repeatedly, each measurement was performed in a different time and all the measurements proved the existence of that active point (see Fig. 4).



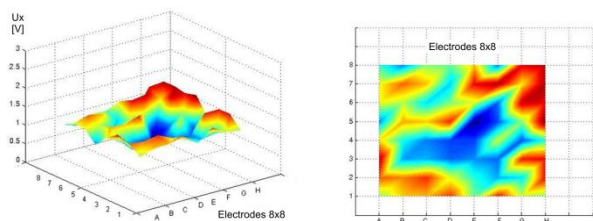
**Fig. 4:** Voltage chart measured on position of active point no. 4 on Li meridian in 3D visualization and 2D visualization.

## 6. The Influence of the Frequency on the Voltage Map Measurement

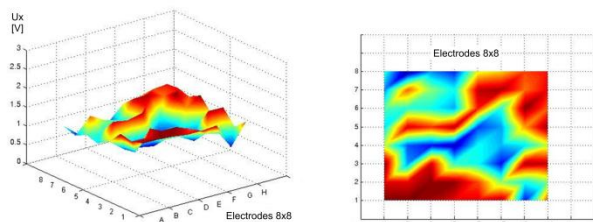
Various published sources (e.g. [8]) insist that the higher frequency of measuring electric signal causes that the lower impedance of skin is measured. Our own measurements confirmed this proposition (Fig. 5 - 17).



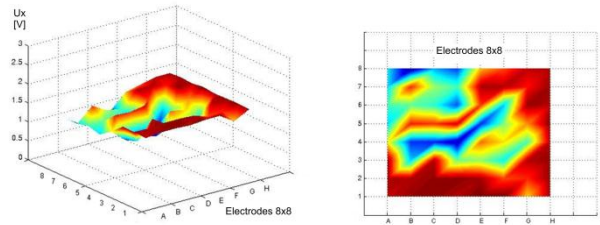
**Fig. 5:** Voltage chart measured with signal  $f = 10$  Hz.



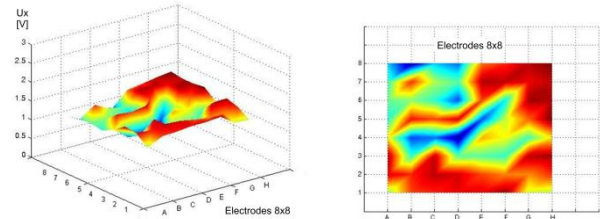
**Fig. 6:** Voltage chart measured with signal  $f = 20$  Hz.



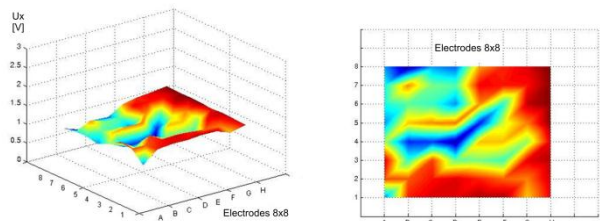
**Fig. 7:** Voltage chart measured with signal  $f = 50$  Hz.



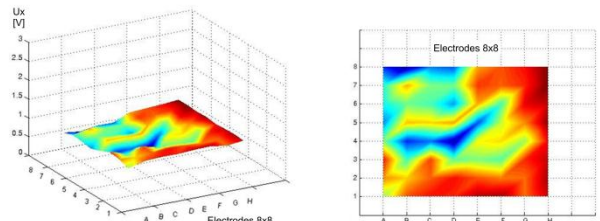
**Fig. 8:** Voltage chart measured with signal  $f = 100$  Hz.



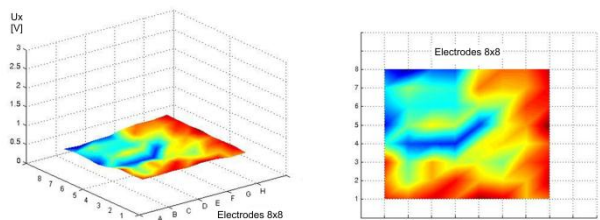
**Fig. 9:** Voltage chart measured with signal  $f = 200$  Hz.



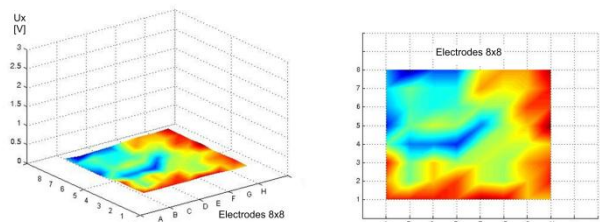
**Fig. 10:** Voltage chart measured with signal  $f = 500$  Hz.



**Fig. 11:** Voltage chart measured with signal  $f = 1$  kHz.



**Fig. 12:** Voltage chart measured with signal  $f = 2$  kHz.



**Fig. 13:** Voltage chart measured with signal  $f = 5$  kHz.

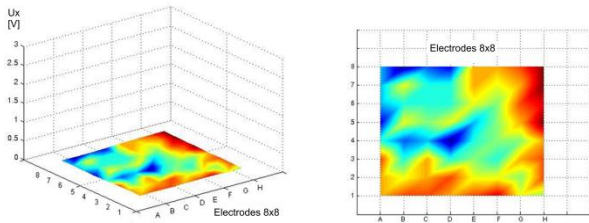


Fig. 14: Voltage chart measured with signal  $f = 10$  kHz.

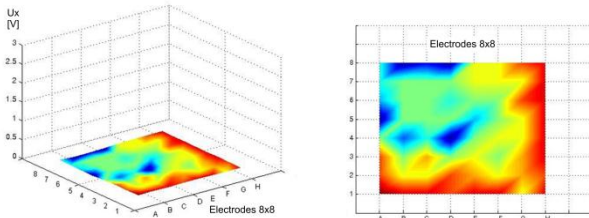


Fig. 15: Voltage chart measured with signal  $f = 12$  kHz.

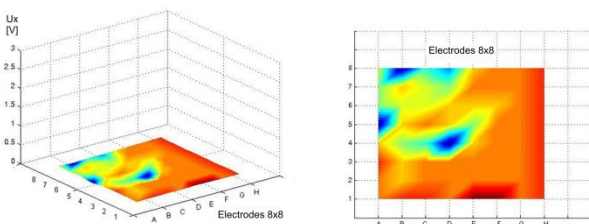


Fig. 16: Voltage chart measured with signal  $f = 15$  kHz.

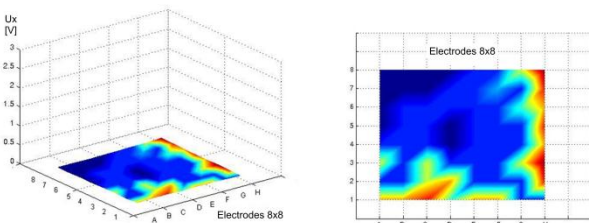


Fig. 17: Voltage chart measured with signal  $f = 20$  kHz.

A table of voltage values for all the 64 probe electrodes was measured and recorded for each chosen frequency from range 10 Hz to 20 kHz. For easier evaluation of each of these measurements (graphically described above), considering the achieved voltage scale and dynamic range of values, therefore were calculated mean values of the voltage  $U_{xs}$  for every chosen frequency (described in Tab. 1).

Tab.1: Table of mean values of the voltage  $U_{xs}$  for various frequencies.

<b>f [kHz]</b>	0,01	0,02	0,05	0,1	0,2	0,5	1
<b><math>U_{xs}</math> [V]</b>	0,723	1,301	1,339	1,525	1,478	1,257	0,976
<b>f [kHz]</b>	2	5	10	12	15	20	
<b><math>U_{xs}</math> [V]</b>	0,647	0,318	0,169	0,146	0,113	0,083	

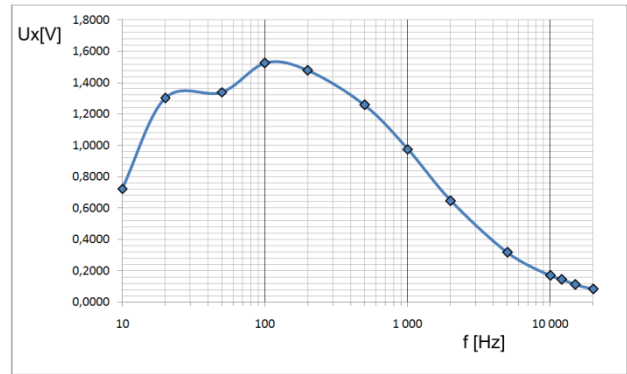


Fig. 18: The relation between measured amplitude of voltage on skin and the frequency of excitation measuring signal.

Authors of papers [4] and [8] performed similar measurements trying to unfold the influence of the frequency of measuring signal on the impedance of active or non-active point on the skin. They found out the higher value of input frequency of signal causes that the lower skin impedance on the same point was measured. Recognized impedance drop measured on active point on skin was relatively small. The difference of the impedance, measuring at 10 Hz and 10 kHz was about 800 k $\Omega$  [8]. Recognized impedance drop measured on non-active point on skin was higher, it was about 3400 k $\Omega$ . Their research proved that the best results and differences in impedance of active/non-active point measurement are achievable in low frequency area (see Fig. 19).

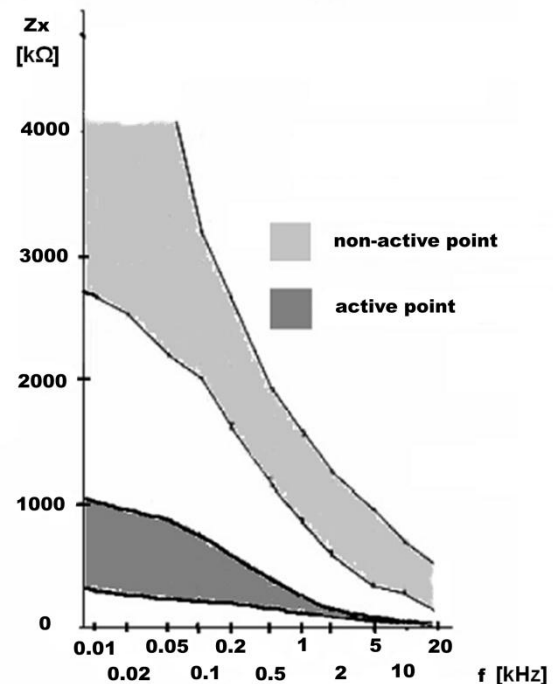


Fig. 19: Influence of the frequency of el. current on human skin impedance, according to authors in [8].

The results in our measurement were similar, in general, but even more interesting than previously

mentioned results in [8]. The optimum level of the measured voltage on the skin was achieved with a signal frequency of approximately 100 Hz (the maximal amplitude of measured voltage, see the curve extreme on Fig. 18).

### 7. The Influence of the Shape of Driving Signal on the Voltage Map Measurement

To unfold the influence of the shape of the driving signal on the voltage map measurement we changed settings of built in DDS generator of the measuring device. This change was made via software settings in control Matlab program environment in PC. We changed the sinusoidal signal to triangular signal of the same amplitude and frequency as well. We used an oscilloscope to check a drive signal coming to measuring probe electrodes. Our measurement was performed in sequence by two driving signals of frequency 1 kHz (both triangular and sinusoidal shape of signal) in the exactly same position of measuring matrix probe on the skin. We set frequency of generator on 1 kHz and changed the shape of signal for triangular. We can see a measured voltage on each of the electrodes of measuring probe, as voltage bar chart on Fig. 22 displays. Precisely considering the amplitude of measured signals on each of the electrode we can say in general, that we measured higher amplitudes of voltage on most of the electrodes. It means that this measurement has better dynamical range of amplitudes and it gives a better possibility to precisely distinguish an active point on the skin surface. A verification measurement, using sinusoidal and triangular driving signal of frequency  $f=100$  Hz, showed that the output voltage charts measured on position of active point, are relatively similar. One most significant difference between these two measurements was a dynamic range of measured values of voltage  $U_x$ . When we used a sinusoidal driving signal of frequency  $f=1$  kHz then we have gotten even greater dynamic range of measured values - measuring on active point on the skin and its passive surroundings (Fig. 20), comparing with results from measurement with triangular driving signal (Fig. 21).

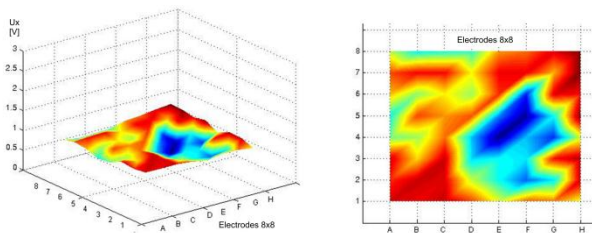


Fig. 20: Voltage chart measured on position of active point No. 4 on Li meridian in 3D visualization and 2D visualization, using sinusoidal driving signal  $f=1$  kHz.

Voltage bar chart of measured values  $U_x$  on

electrodes of probe, using driving signals of frequency  $f=1$  kHz shows us the fact that the dynamic range of measured voltage values, using triangular driving signal is smaller than range obtained using sinusoidal driving signal (Fig. 22).

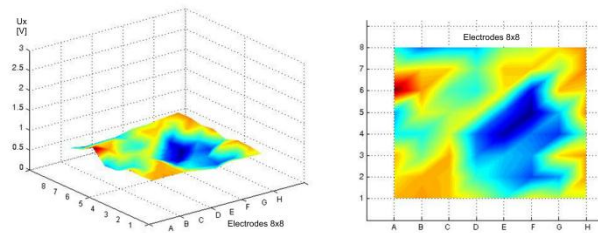


Fig. 21: Voltage chart measured on position of active point No. 4 on Li meridian in 3D visualization and 2D visualization, using triangular driving signal  $f=1$  kHz.

Almost every measured value of  $U_{xt}$  voltage on electrodes is smaller (used triangular driving signal) than measured value of  $U_{xs}$  voltage on electrodes (used sinusoidal driving signal).

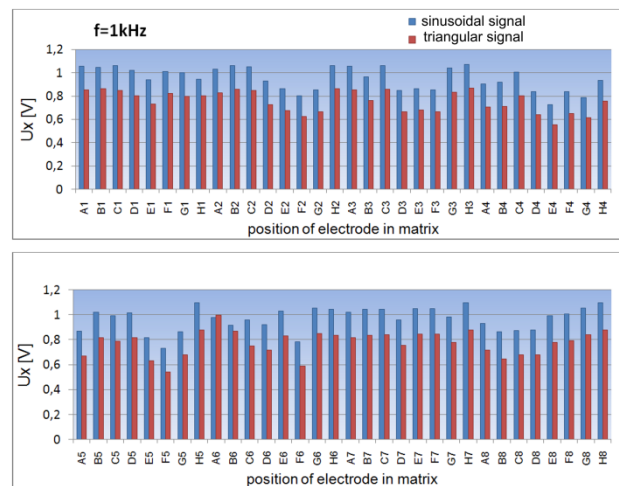


Fig. 22: Voltage bar chart of measured values  $U_x$  on electrodes of probe, using sinusoidal and triangular driving signal  $f=1$  kHz.

Measurements of the active point shape and position and also measurements considering the influence of the frequency of the driving signal to the ability of discovering an active point on the skin were made on a group of enthusiastic volunteers and also ourselves. In measurements considering the influence of the shape of driving sinusoidal and triangular signals, mentioned above, it was essential to keep the exact position of measuring matrix probe on the selected area of skin, therefore these sets of measurements were necessary to perform with the same person, patiently, keeping the position of electrodes on his or her body and changing only the parameters of measuring signals.

## 8. Conclusion

Our automatized measuring device provided us the opportunity to unfold position and the shape of certain active points on the human skin surface and measure their voltage maps. A set of frequency measurements was made on active point No. 4 on Li meridian. Achieved results confirmed the drop of impedance/voltage on active point in higher frequency area as authors of papers [4] and [8] published. We have found even more. In very low frequency area we measured similar drop of voltage amplitude as in the area of higher frequencies. The optimum was achieved using a signal frequency of approximately 100 Hz. We have also found, thanks to our measurements that the sinusoidal driving signal is more suitable for unfolding of the active points on the human skin surface and for the measurement of voltage/impedance map on the skin, than the triangular driving signal (a greater dynamic range of measured values). In general, methods and electronic measuring devices used for measuring of 3D voltage charts of the human body surface offer a wide space for following practical research and can be useful in medicine, diagnostics and therapeutic process as well.

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## References

- [1] TEPLAN, Michal. Fundamentals of EEG measurement. *Measurement Science Review*. 2002, vol. 2, no. 2, pp. 1-11. ISSN 1535-3893.
- [2] REILLY, J. P. *Electrical stimulation and electropathology*. Cambridge: Cambridge University Press, 1992. ISBN 978-0521417914.
- [3] ROSELL, J., J. COLOMINAS, P. RIU, R. PALLAS-ARENY and J. G. WEBSTER. Skin Impedance from 1 Hz to 1 MHz. *IEEE Transactions on Biomedical Engineering*. 1988, vol. 35, iss. 8, pp. 649-651. ISSN 0018-9294. DOI: 10.1109/10.4599.
- [4] BECKER, R. O., M. REICHMANIS, A. MARINO and J. A. SPADARO. Electrophysiological Correlates of Acu-puncture Points and Meridians. *Psychoenergetic Systems*. 1979, vol. 1, pp.105-112. ISSN 0305-7224.
- [5] ONDREIOV, I. M. *Experimental Impedance Chart Meter of Skin*. Bratislava, 2010. Graduation theses. FEI SUT.
- [6] GOGOLA, D., et al. *Design and realization of USB interface for experimental scanner of impedance chart from surface of human body*. Bratislava, 2009. Team project, FEI SUT.
- [7] KUKUCKA M. and Z. KRAJCUSKOVA. Voltage Chart of Human Skin Measurement. In: *33rd International Conference on Telecommunications and Signal Processing – TSP 2010*. Baden, Austria: VUT Brno, 2010, pp. 108-113. ISBN 978-963-88981-0-4.
- [8] ZHANG, C. L. Skin Resistance vs. Body Conductivity: On the Background of Electronic Measurement on Skin. *Subtle energies and energy medicine*. 2003, vol. 14; part 2, pp. 151-174. ISSN 1099-6591.
- [9] KRAMER S., D. ZAPS, B. WIEGELE and D. IRNICH. Changes in electrical skin resistance at gallbladder 34 (GB34). *JAMS Journal of Acupuncture and Meridian Studies*. 2008, vol. 1, iss. 2, pp. 91-96. ISSN 2005-2901.
- [10] CERNY, M., L. MARTINAK, M. PENHAKER and M. ROSULEK. Design and implementation of textile sensors for biotelemetry applications. In: *14th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics*. Riga: 2008, vol 20. ISSN 1680-0737, ISBN 9783540693666, DOI: 10.1007/978-3-540-69367-3-53.

## About Authors

**Marek KUKUCKA** was born in Bratislava, Slovakia, November 8th 1975. In 2000 he finished masters' study at Faculty of Electrical Engineering and Information Technology at Slovak University of Technology in Bratislava and became M.Sc. He worked as researcher at Department of Radio and Electronics. In 2005 defended dissertation thesis "Diagnostic processing of medical signals" and obtained Ph.D. in Electronics. He has been working as assistant lecturer at Slovak University of Technology, Faculty of Electrical Engineering and Information Technology. He is interested in medical signal processing, measurement, biomedical sensors, diagnostic methods and systems and research in biomedical electronics. Dr. Kukucka is scientific secretary of Society for Biomedical Engineering and Medical Informatics of Slovak Medical Association. He is member of International Federation for Medical and Biological Engineering. Dr. Kukucka was also solutionist of many scientific projects and coorganiser of various scientific conferences.

**Zuzana KRAJCUSKOVA** was born in 1952 in Bratislava, Czechoslovakia. She received M.Sc. degree in Radioelectronics from the Slovak University of Technology in 1976, Ph.D. degree in Electronics from the Slovak University of Technology in 2008. Since 1976 she has been working as a university teacher at the Department of Radio and Electronics, Faculty of Electrical Engineering and Information Technology, SUT in Bratislava. Her research interests are digital signal processing, time-frequency representations of signals, reliability theory, reliability growth models (hardware, software), biomedical engineering, and telemedicine technology. Dr. Krajcuskova is member of Society for Biomedical Engineering and Medical Informatics of Slovak Medical Association, member of Society for Medical Informatics of Slovak Medical Association. She is member of International Federation for Medical and Biological Engineering. Dr. Krajcuskova was also solutionist of many scientific projects and coorganiser of various scientific conferences.