Electrical characteristics of Human Skin of Including at Biological Active Points using Noninvasive measurement method

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Abstract—**Electrical impedance measurement methods have been proposed to study a large number of physiological events, especially due to the simplicity, low-cost and noninvasiveness of the technique.**

Acupuncture (Biological active points: BAPs) research has since become a very broad active area both in Asia and the West. These points are not uniformly distributed across all parts of the human skin and investigated in various ways for the purpose of scientifically establishing their existence.

This paper describes a system to measure the characteristic frequency and reactance of BAPs and surrounding skin. The method uses the three-electrode technique with a constant sinusoidal current.

The measurements were taken at 50 different frequencies between 1 Hz to 1 kHz. The input peak current value was set to below 5 μA maximum in order to reduce the electrical stimulus as much as possible. We show the dependence of the reactance on frequency, measured at PC-3, PC-4, PC-7 and the surroundings skin.

The BAPs measuring method is well illustrated by a simple model of an equivalent electrical circuit that correlates well with experimental results. The values of the chosen components were determined to fit the equivalent circuit using the simulation.

A new BAPs measurement system has the superior characteristics of noninvasiveness measurement and easy operation. The characteristic frequencies of BAPs are 20-30 Hz higher than that of the surrounding skin, and the reactances are about 45-50 KΩ smaller than that of the surrounding skin. The reactance and characteristic frequency of BAPs and surrounding skins can be observed simultaneously, which enables objective analysis. This system has the advantage of being able to instantaneously observe the characteristic frequency and reactance of BAPs.

Keywords—**Biological Active Points(BAPs), Noninvasiveness, Characteristic frequency, Reactance**

I. Introduction

Electrical impedance analysis technique for human skin is a promising tool for transdermal drug delivery analysis and impedance tomography, etc.

To analyze skin impedance effectively, it is very desirable to introduce the skin impedance model. Skin impedance models can be applicable for diagnosis of the skin disease, the clinical systems related to the skin impedance, and skin impedance simulators.

BAPs, which are essential features of traditional Chinese medicine, have been investigated in various ways for the purpose of establishing their existence by scientific methode**[1]**. Since the 1950s the electrical characteristics of the BAPs have been extensively studied, first by Nakatani**[2]** and followed by Niboyet**[3]**, Zhu**[4]**, Voll**[5]**, Reichmanis et al.**[6]**. Reinhold Voll**[7]** designed an instrument called the Dermatron to measure these properties, and he has continued using it to supplement his clinical diagnosis and therapy since the early 1950s. Now, this testing method has advanced to the electrodermal screening test(EDST). The scientific basis of EDST was presented by Chen**[8]** in 1999.

Electrical resistance at BAPs is normally smaller than that of the surrounding skin. The electrical characteristics of the BAPs have also been extensively studied using alternating current impedance measurements**[9]**. These publications report that the capacitance of the BAP is large and the resistance smaller than that of the surrounding skin.

The BAPs measurement system is constructed of a synchronous rectifier with a phase sensitive detector, has been proposed. It can be utilized to measure automatically and continuously the resistive component and the reactive component of the impedance.

A new equivalent circuit model is proposed, which accurately describes the experimental results. This method can measure the skin impedance of a point more exactly.

The aim of this work is to report the difference in electrical characteristics between the BAPs and the surrounding skin found in the non-invasiveness experiments. The reactance and characteristic frequency of BAPs and surrounding skins can be observed simultaneously, which enables objective analysis.

II. Measurement method

Skin impedance changes due to various factor inside and outside the body and also according to time. We must rapidly measure skin impedance under constants for obtaining the most reliable data. It can be utilized to measure automatically and continuously the resistive component and the reactive component of the impedance. A sine wave voltage from a current source is converted by a voltage to a current converter to the impedance.

The method uses the three-electrode technique with a constant sinusoidal current. Impedance is determined by the ratio of applied voltage and current. The three electrode method in Fig. 1 has the advantage of measuring the impedance of the BAPs under the skin. In this method, one electrode is used to apply current and to measure the voltage(Electrode1 in Fig. 1). It is attached to the skin at the point to the be measured. The reference electrode (Electrode 2 in Fig. 1) is attached near the measurement electrode. Finally, the ground electrode (Electrode 3 in Fig. 1) is attached at least 10 ㎝ away from the measurement electrode. Current flows through the skin via electrodes 1 and electrode 3. The voltage drop, which is output response, of the impedance of the skin under electrode1 is amplified by a differential amplifier.

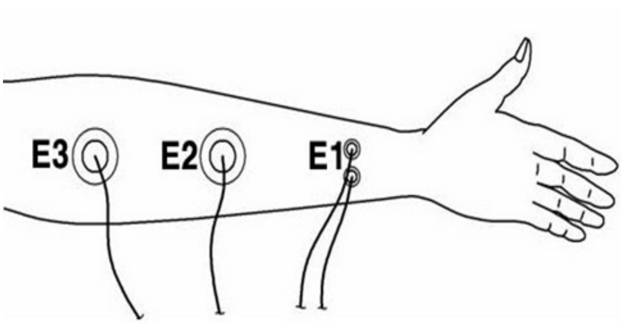

Fig. 1 Construction of electrode system in impedance measurement by constant current method. Electrode1 is the measurement electrode and current source. Electrode2 is the reference electrode and Electrode3 is the ground electrode.

The impedance measurements at BAPs and the surrounding skin were carried out on healthy young man. Ag-AgCl electrodes(EL 258H Biopac system Inc), which were unpolarizable and 8mm in diameter, were used as measurement and reference electrode. The electrode paste used was a cream (EC 33 skin conductance). The ground electrode was an ECG electrode (Biopac EL 503) with a diameter of 10mm.

Examinee lay down on a bed and waited for 20 minutes at a constant temperature(20-25℃). Before the electrodes were attached, the skin was wiped with ethanol to avoid the influence of sweat.

Measurements were taken at three BAPs: PC 3, PC 4 and PC 7 on the left and right forearm. At constant pressure, the measurement electrode was attached directly on the BAPs, or at a distance of 5-10 mm from the BAPs, and the reference electrode was placed a distance of 20 mm from the measurement electrode.

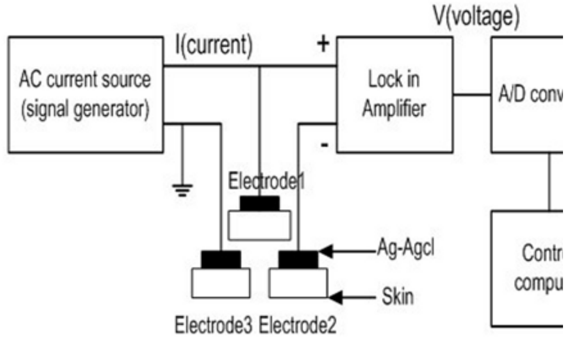

Fig. 2 The black diagram of the BAPs measurement system

The BAPs measuring system is shown in Fig. 2. This measurement system consists of a digital lock-in amplifier (SR 830, Standard Research Systems), AC current source (Keithley 6221) and Control system (National Instrument PXI). It measures the components of reactance and characteristic frequency of the skin in the frequency range of 1 Hz-1 kHz. The measurements were taken at 50 different frequencies between 1 Hz to 1 kHz. The input peak current value was set to below 10 ㎂ maximum in order to reduce the electrical stimulus as much as possible. The total required time for the frequency sweep measurement was about 10minutes. We measured twice, and the two sets of data were processed by the linear interpolation in time because the skin was hydrated by wet gel, which decreases the skin impedance.

III. Result of BAPs measurement experimental

We show the dependence of the reactance on frequency, measured at PC 3, PC 4, PC 7 and the surroundings skin in Fig. 3. The characteristic frequencies of BAPs, which have maximum reactance, are about 20-30 Hz higher than that of the surrounding skin. Also, reactance values of PC 3 are about 45-50 kΩ lower than those of the surrounding skin in Fig. 3. The characteristic frequency PC4 is about 20Hz higher than the surrounding skin. The characteristic frequency of PC 7 is about 30 Hz higher than that of the surrounding skin, the maximum reactance was 50 kΩ.

Based on our experimental results, we propose the following equivalent electrical for the surrounding skin and BAPs. The simple equivalent circuit that we propose is shown in Fig. 4. The model consists of the equivalent circuit of the skin described in Kontturi and Murtomaki**[10]**, in series with the resistance R_1 and the capacitance C_1 of

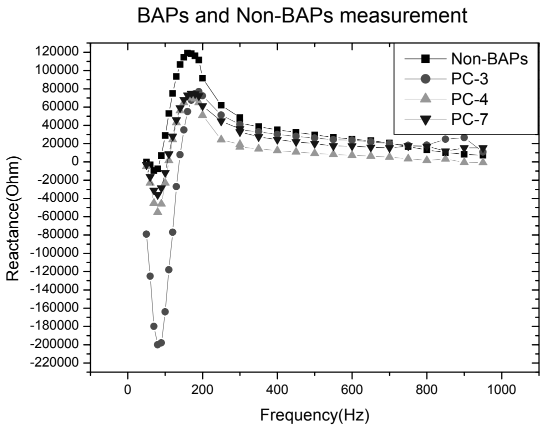

Fig. 3 The comparison results of reactance and characteristic frequency for BAPs and the surrounding skins.

the body. We have chosen the model of skin proposed in a previous report (Kontturi and Murtomaki). In the case of the skin, the parameters R_1 and C_1 of the body are such that the low-frequency depressed semicircle. In the BAPs reading, the additional resistance R_2 and CPE_1 are due to the appearance, in the impedance spectrum of the BAPs, of the low and high frequency semi-circuit arcs.

The equivalent circuit that describes the impedance of skin consists of :

1. a constant phase element(CPE) with $Z_{CPE} = Y^{-1}(j\omega)^{-▯}$, where ▯ is related to the fractal dimension of the skin's surface and can be considered as a measure of the roughness of the skin's surface, ω is the angular frequency, and Y is the admittance of the CPE.

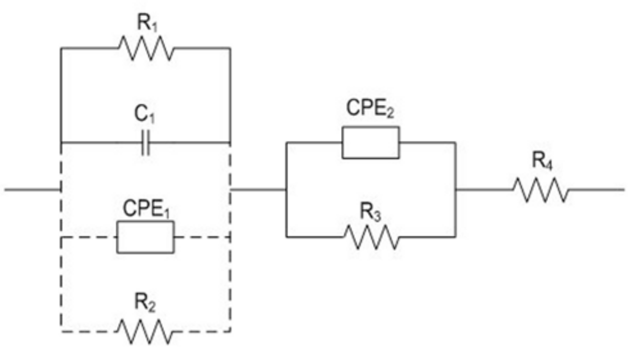

Fig. 4 The proposed equivalent electrical circuit model for BAPs and surrounding skin.

The impedance locus has the well-known form of a depressed semicircular arc. The values of the chosen components were determined via a non-linear least-squares fit to the equivalent circuit using the Z-view program. The results of this fit are shown in Fig.5, Fig.6 and Table 1

The impedance spectrum for the BAPs differs from that obtained for the skin, shown Fig. 5.

Then, using the values found, the BAP simulation was carried out, taking into account the presence in the circuit of the additional elements R_2 and CPE_1. Such an approach seems to be appropriate, as the results of the simulation and the experiment measurements show good agreement(Fig. 6)

We could get the best result for BAPs Resistor R_2 (90kΩ) and BAPs CPE_1(**0.9×10^{-9}**) shown in Fig. 6.

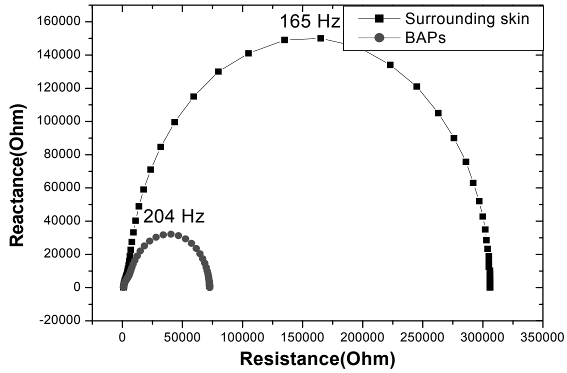

Fig. 5 Result of fit with help of equivalent electrical circuit shown in Fig. 3

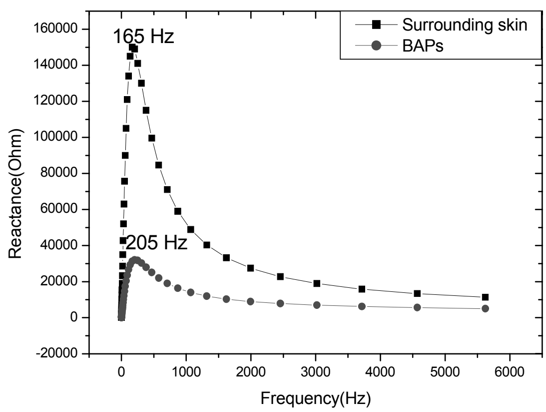

Fig. 6 Simulated result of the equivalent electrical circuit shown in Fig. 4. Characteristic frequency values of reactance when variable resistance R2 and CPE1.

Table 1 Components of parameters for the equivalent electrical circuits used for simulation of surrounding skin and BAPs

Component	R(kΩ)	C_1(nF)	CPE_1 CPE_2	α (CPE_1) α (CPE_2)
BAPs	R_1=300 R_2=90 R_3=5 R_4=1	3	$CPE_1=0.9\times10^{-9}$ $CPE_2=0.1\times10^{-9}$	α (CPE_1)=0.90 α (CPE_2)=0.93
Skin surrounding	R_1=300 R_3=5 R_4=1	3	$CPE_2=0.1\times10^{-9}$	α (CPE_2)=0.93

IV. Conclusions

A new BAPs measurement system has the superior characteristics of noninvasiveness measurement and easy operation.

The three electrode method has the advantage of measuring the impedance of the BAPs under the skin. The experimental results are well described by a simple model of an equivalent circuit. The reactance and characteristic frequency of BAPs and surrounding skins can be observed simultaneously, which enables objective analysis.

From the results obtained, we propose that the observed reports in the literature about the large dispersion of the non-invasiveness impedance characteristics of the human body.

Another conclusion that can be deduced from these measurements is that, to locate better the exact position of a BAP low-frequency measurements in the range of 1 Hz-1 kHz offer a better opportunity.

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