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A New Acupuncture Point Detection Using the Impedance Measurement System Based on ANF and Phase-Space-Method

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Abstract— **In this study, a new method for acupuncture point detection using the impedance measurement system based on the PSM (Phase Space Method) is presented. The developed device has been developed as detectors for acupuncture points which are used for diagnosis and treatment in acupuncture. In this system, multi-frequency current injection and voltage measurements are both performed by the surface electrodes, which are controlled by a microcontroller. Also, the microcontroller process continuous time demodulation of the modulated signal by multi frequency components using the adaptive notch filter. After that, PSM is applied about each frequency using an acupuncture equivalent model which is proposed in the pre-study.**

I. Introduction

Electrical measurement of human skin, with the help of different impedance methods, are non-invasive and widely used for various clinical applications, such as bio-electrical impedance analysis, electrical impedance tomography, investigation of transdermal drug delivery and others.[1] It has been known that acupuncture points of human body have lower resistance and higher capacitance than that of the surrounding skin.[2-4] In all these impedance investigation methods, the difference in electrical characteristics between the acupuncture points and the surrounding human skin was reported. However, none of these papers showed the real-time measurement method to detect a few thousand acupuncture points.

Acupuncture points are not uniformly distributed across all parts of the human skin, and their resistance to direct current differs from the resistance of the surrounding skin. Therefore, accurate measurement of the resistance and capacitance of human skin should be performed. But it is difficult to measure the resistance and capacitance of human skin in real-time.

Typically, the time needed to take one point measurement, in the frequency range investigated, was 1.5-2.0 min. it was observed that, during this time, a measurement at a fixed frequency had variations in resistance and capacitance not exceeding 10-15%; these variations, are probably related to the drift of the electrical parameters of the point.[1]

Therefore, we propose a new method for detection acupuncture point using the equivalent circuit model and the impedance characteristics of acupuncture points which are different from the characteristics of the surrounding skin. In the proposed method, multi-frequency current injection and voltage measurements are both performed by the surface electrodes, which are controlled by a microcontroller. Also for determination of parameters in the equivalent circuit model, the microcontroller process continuous time demodulation of the modulated signal by multi frequency components using the Adaptive Notch Filter. And then the PSM is applied about each frequency.

II. Method and Experimental Setup

A. Experimental Setup and Data Acquisition

The reference electrode is made from brass with wide dimension and the active electrode is made from with yellow brass (3mm diameter).

The measurements were done especially for PC6 point of the Pericardium Meridian and TE5 point of Triple Energizer Meridian. We put the reference electrode either on the indifferent skin. The test electrode was applied with a light pressure on the skin. We made measurements using multiple sine waves. The Point position is selected carefully in the skin because the smallest deviation from the point position greatly changes the measured value of the impedance.

B. Design of Multi-Frequency Signal Generator

The current source composed using a microcontroller (Analog Device ADUC 7021 with A/D and D/A converter) and a low pass filter (LPF). The current source is used to generate a sinusoidal signal where the frequency can be selected between 3 Hz to 100Hz. The block diagram of the system is shown in Fig. 1. And then the generated current is passed by the human skin. Also, simultaneously the measured voltage is measured by digital-to-analog converter included in microcontroller.

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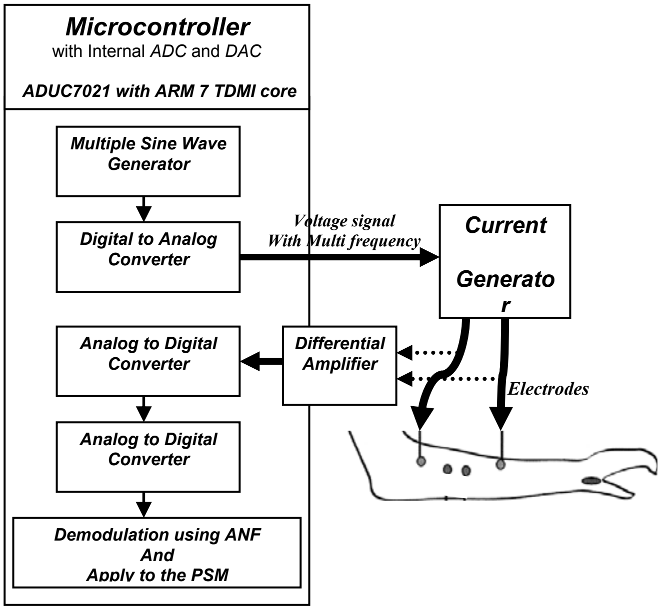

Fig. 1. The developed device for detection of acupuncture point

C. Equivalent Electrical Circuit Model for Skin and Acupuncture Point

The design and manufacture of frequency-scanning phase-sensitive impedance analyzer is more complex and expensive than that of analyzers operating at a single or few fixed frequencies.

In our measurements, we used a model proposed in reference.[1] The model is shown in Fig. 2. It includes the additional resistance Rp and capacitance Cp in the equivalent circuit for the acupuncture points. The physical interpretation of these elements means the change of the capacitance and resistance in the acupuncture areas.

In our measurements, one electrode is kept by the patient in one hand, and the second is placed on the acupuncture areas or on the skin of the other hand, or on the body.

As can be seen from reference [1], a major portion of the impedance spectrum of human skin lies in the frequency range of 3-100 Hz.

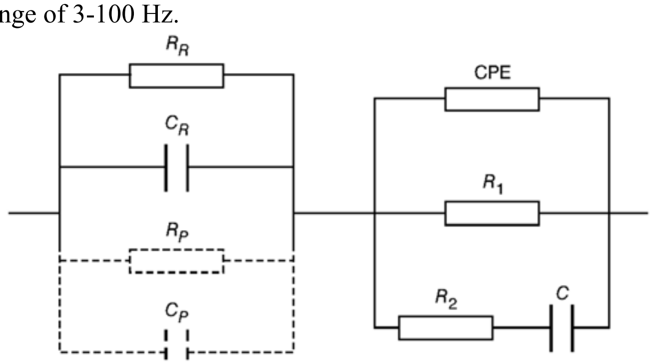

Fig. 2. Equivalent electrical circuit for skin and acupuncture point

D. The Structure of Adaptive Notch Filter

We performed the continuous time demodulation of the modulated signal by multi frequency components using the ANF (Adaptive Notch Filter).

To design the filter, we need to estimate the precise frequency of the concerned signal. A very narrow notch is usually desired in order to filter out the unconcerned interference. The advantages of the adaptive notch filter are that it offers an infinite null, and the capability to adaptively track the frequency of the interference. The adaptive notch filter is especially useful when the interfering sinusoid drifts slowly in frequency.

The adaptive structure is shown in Fig.3.

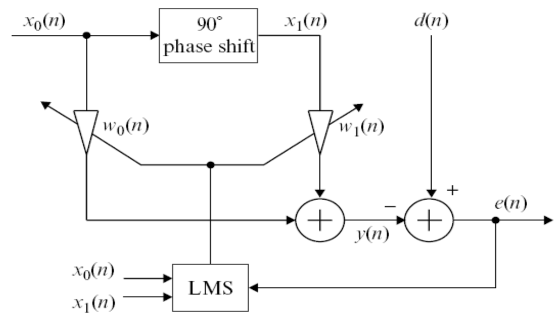

Fig. 3. The structure of adaptive notch filter

The adaptive system between the input x(n) and the output e(n) is an adaptive notch filter, which forms several notch filters centered at frequency of the sinusoidal components.

A sinusoidal can be used as a reference signal for canceling each component of narrowband noise. When a sinewave is employed as the reference input, the LMS algorithm becomes an adaptive notch filter, which removes the primary spectral components within a narrowband centered about the reference frequency. A single-frequency adaptive notch filter with two adaptive weights is illustrated in fig.3. The reference input is a cosine signal;

$$x(n) = x_0(n) = A\cos(\omega_0 n) \qquad (1)$$

A 90 phase shift is used to produce the quadrature reference signal;

$$x_1(n) = A\sin(\omega_0 n) \qquad (2)$$

Digital Hilbert transform filter can be employed for this purpose. Instead of using cosine generator and a phase shifter, the recursive quadrature oscillator given in fig.3 can be used to generate both sine and cosine signals simultaneously. For a reference sinusoidal signal, two filter coefficients are needed.

The LMS algorithm is summarized as follows;

$$y(n) = w_0(n)\cdot x_0(n) + w_1(n)\cdot x_1(n) \qquad (3)$$

$$e(n) = d(n) - y(n) \qquad (4)$$

$$w_l(n+1) = w_l(n) + \mu\cdot x_l(n)\cdot e(n), \quad l = 0,1 \qquad (5)$$

Note that the two-weight adaptive filter W(z) shown in fig.3 can be replaced with a general L-weight adaptive FIR filter for a multiple sinusoid reference input x(n). The reference input supplies a correlated version of the sinusoidal interference that is used to estimate the composite sinusoidal interfering signal contained in the primary input d(n). The single-frequency adaptive notch filter has the property of a tunable notch filter. The center frequency of the notch filter depends on the sinusoidal reference signal, whose frequency is equal to the frequency of the primary sinusoidal noise.

III. RESULT

A. *Generation of Multi Frequency Voltage Signal*

Multi frequency voltage signal to pass to human skin are presented in this section.

Fig.4(a), (b), (c) and (d) show each sine wave signal with 20 Hz, 50 Hz, 70 Hz and 90 Hz frequency. And Fig.4(e) shows the modulated signal by summation of four signals. The modulated signal is entered in human skin.

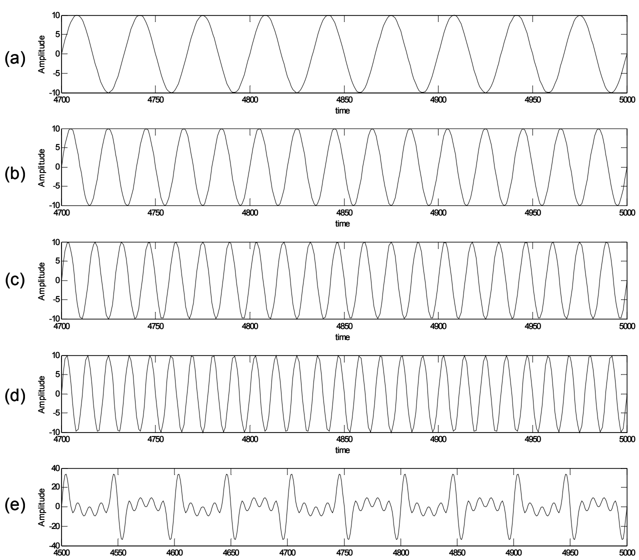

Fig. 4. The generated Multi frequency voltage signal

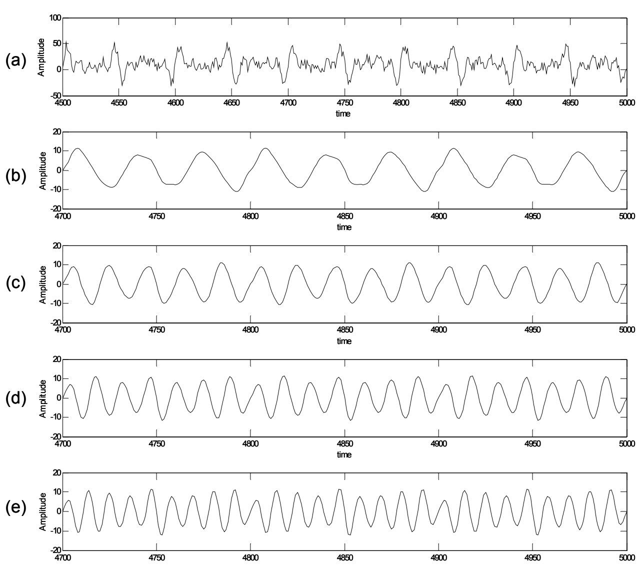

Fig. 5. The results of adaptive notch filter for demodulation

B. *Evaluation of Performance for the proposed Method*

To evaluate quantitatively if the proposed filter works well enough, performance analysis is performed. Demodulation process is performed by using the ANF.

Fig.4(a) shows multi frequency voltage signal which is measured in human skin. Fig.4(b), (c), (d) and (e) show each sine wave signal which are estimated by the proposed filter.

For detection of acupuncture point, the estimated signal about each frequency is applied in the PSM. The PSM (Phase-Space-Method) is an algorithm that can detect points from a characteristic form of signal happening in real-time. The result is shown in Fig. 6. As shown in the result, the transition of phase was induced in acupuncture point. Therefore if the areas of the transition of phase are searched, acupuncture point can be detected easily and simply.

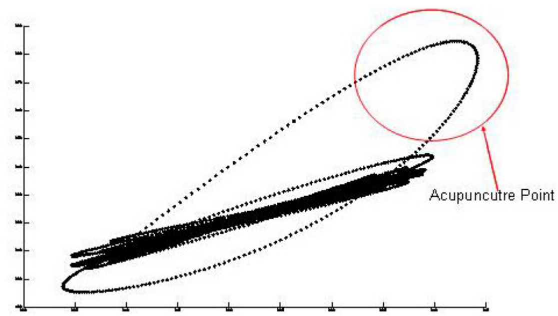

Fig. 6. The detection of acupuncture point using the PSM

IV. DISCUSSIONS AND CONCLUSIONS

In this study, a microcontroller controlled programmable Multi frequency electrical impedance data acquisition system is designed for detection of acupuncture points.

The microcontroller processes continuous demodulation by multi frequency components using the ANF. The proposed method showed good performance. Therefore this method can be used in real time application because the transition of phase in acupuncture point is only detected.

Also this method is simpler than previous methods. Minimum hardware circuit is acquired.

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