Highly Sensitive Hardware Methods and Means of Determining Acupuncture Points

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Abstract

One of the problems that arises during electropuncture diagnostics is to correctly determine the position of acupuncture points on the human skin. Traditional methods of determining acupuncture points require the passage of an electric current through of the skin, which can affect the patient's condition. The authors have developed methods for measuring noise signals to determine acupuncture points using switching-modulation conversion of information signals, which provides high sensitivity for determining acupuncture points (AP). Functional schemes of devices concerning realization of algorithms are offered. The electrocontact method consists in use of own noise electric signals of the patient that allows to carry out researches without influence of external electric signals on a human body. Differential radiometric method for determining AP is non-contact measurement and comparison of microwave radiation of two parts of the patient's body. The original structures of devices with switching-modulation conversion of information signals provides not only high sensitivity, but also eliminate the influence of temperature and instability of the parameters of the circuit elements on the measurement result, which increases the accuracy of acupuncture points.

Keywords 1

Acupuncture points, electropuncture diagnostics, electrical resistance, thermal noise, commutation-modulation transformation.

1. Introduction

When conducting microwave, laser, thermal and other types of diagnostic and therapeutic procedures, methods are increasingly used that involve interaction with points of human acupuncture (electropuncture diagnostics, electropuncture therapy, reflexology, etc.) [1, 2] In some cases, electropuncture diagnostics (ED) provides a fairly high reliability of the results and can be used along with thermographic and ultrasound examinations of patients [3]. One of the problems that arises during ED is to correctly determine the position of acupuncture points on the human skin. The simplest method of finding AP is to measure the electrical resistance of the skin surface. Electrical measurements in AP confirm the minimum value of electrical resistance in relation to other areas of the skin [4]. At the same time, traditional methods of measuring the electrical resistance of the skin require the passage of electric current through the AP, which can change its parameters, as well as affect the patient's condition. This is especially true for people who use pacemakers. In addition, the

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measurement result significantly depends on the temperature and humidity of the skin surface, as well as the amount of current used in the measurements.

The aim of the study is to create devices for determining acupuncture points that do not change the electrical parameters of points, do not affect the patient and provide an increase in accuracy. Such methods include radiometric thermometry and switching-modulation conversion of information signals, which in combination provide high sensitivity and accuracy of measuring information signals, and have virtually no effect on the object of measurement [5, 6].

2. Physical fundamentals of the measurement method

Physical and biological bodies (dielectric or quasi-dielectric), including the human body, emit weak noise signals. The power of such radiation is determined by Nyquist's theorem, according to which the mean square (dispersion) of thermal noise voltage is proportional to the temperature and resistance of the studied part of the body, on the area of which thermal noise is measured [7]:

$$\bar{U}^2 = 4kT\Delta fR\,, \qquad (1)$$

where k - is the Boltzmann constant; T - thermodynamic temperature; Δf - frequency band in which thermal noise and radiation are measured; R - electrical resistance.

At a body temperature of 36° C, the level of human own radiation is very small and comparable to the level of own noise of the receiving equipment. Therefore, it is difficult to receive and analyze such signals. The implementation of such measurement is carried out by two-input (differential) radiometers based on the compensation, correlation, and most often the modulation method [5, 6].

Radiometric devices allow to measure and compare weak signals of parts of the human body in a non-contact way without disturbing the electromagnetic state of acupuncture points.

In [8, 9, 10] variants of two-electrode measuring devices are considered, which allow to obtain a voltage value proportional to the square of thermal noise and, accordingly, electrical resistance. The measurements use base and measuring electrodes, which are placed at symmetrical points of the object of study or acupuncture points. A significant limitation in the use of such a device is that you need to know in advance the location of the AP. In addition, the measurement result depends on the temperature of the skin, because by formula (1) the resistance and temperature affect the voltage level of thermal noise equally, and the signal level. Removed by the electrodes is very small and comparable to the own noise of the electronic elements of the measuring circuit of the device. As a result, even minor changes in the parameters of the elements of the conversion channel caused by time or temperature instability cause significant errors.

3. Electro one-contact method and means of determination of acupuncture points

The authors of this work have developed a functional scheme and proposed an algorithm for its operation, which provides a measurement result independent of changes in the temperature of the studied area of human skin and the instability of the parameters of the electronic elements of the measuring device.

Figure 1 shows the functional scheme of the tool proposed by the authors to determine the points of acupuncture.

The device contains the following functional elements: 1, 2 - measuring electrodes; 3 - support electrode; 4 - common ground bus; 5, 13 - controlled switches; 6,7 - band high-frequency amplifiers; 8 - multiplier, 9 - low-pass filter; 10 - video pulse amplifier; 11 - logarithmic converter; 12 - smoothing resistor; 14, 15 - storage capacitors; 16 - voltmeter; 17 - multivibrator. Position 18 in the drawing indicates the area of the acupuncture point, and position 19 - the human skin.

Determining the position of the acupuncture point is as follows. A measuring electrode 1 is placed on the skin of the examined person in the area of the desired acupuncture point. A second measuring electrode 2 is placed outside the AP zone.

Due to the presence of thermal fluctuations of the elementary charge carriers between the measuring electrode 1 and the reference electrode 3 there is an electrical noise voltage. The greatest contribution to the noise voltage is made by the high-impedance section of the electrical circuit, which is the epidermis.

If we ignore the resistance of the subcutaneous tissues and the resistance of the skin in contact with the support electrode, the mean square of the voltage (dispersion) of thermal noise in this case is determined by the Nyquist formula:

$$\bar{U}_1^2 = 4kT_1\Delta fR_1, \tag{2}$$

where T_1 - the temperature in the area of AP R_1 - electrodermal resistance between electrodes 1 and 3.

By analogy between the measuring electrode 2 and the reference electrode 3 there is an electrical noise voltage:

$$\bar{U}_2^2 = 4kT_2\Delta fR_2, \tag{3}$$

where T_2 - temperature outside the zone AP; R_2 - electrodermal resistance between electrodes 2 and 3.

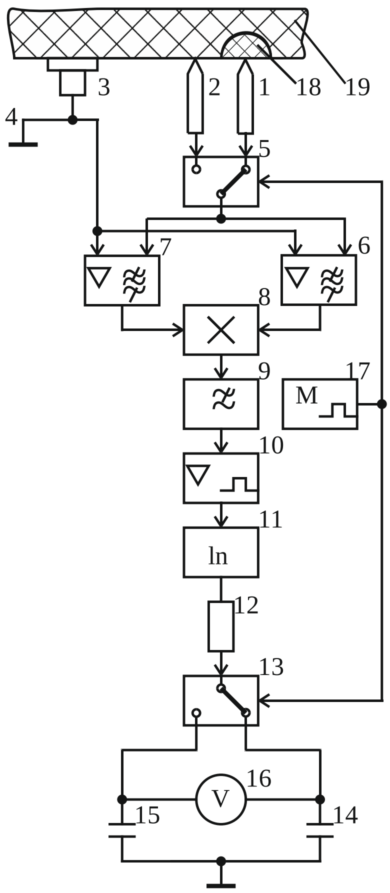

Figure 1: Functional diagram of the device for finding acupuncture points

Noise voltages (2) and (3) through the controlled switch 5 are sequentially applied to the potential inputs of the band high-frequency amplifiers 6 and 7. The switching frequency of the controlled switch 5 is set by the multivibrator 17 and selected within 1 kHz. The bandwidth of the amplifiers is chosen in the region of high-frequency thermal fluctuations (0,5…1 MHz). This choice of parameters of the measuring device avoids the influence of signals of man-made origin and low-frequency flicker noise.

Electric noise voltages after amplification are multiplied, and their value, proportional to the product of voltages is averaged by the filter 9 lower frequencies. At the output of the filter, a constant voltage component is formed, the value of which is proportional to the value of the mean square of the measured noise voltage.

At the output of the low-pass filter 9 at different positions of the switch 5 is formed two values of DC voltage:

$$U_3 = K_1^2 S_1 K_2 \bar{U}_1^2, \tag{4}$$

$$U_4 = K_1^2 S_1 K_2 \bar{U}_2^2, \tag{5}$$

where K_1 - is the gain of the band high-frequency amplifiers 6 and 7; S_1 - the steepness of the multiplication transformation; K_2 - the transfer factor of the filter 9 low frequencies.

By multiplying the output signals of amplifiers 6 and 7, their own noise components are compensated. This is because their own noises are uncorrelated. Therefore, the product of uncorrelated noise signals when averaging is close to zero. That is why in formula (4) and (5) there are no components that are due to the own noise of the amplifiers.

Thus, during the periodic operation of the switch 5, controlled by the pulses of the multivibrator 17, the output of the filter 9 forms a sequence of rectangular video pulses, the value of the amplitude of which is determined by formula (4) and (5). The output signal of the filter after amplification is subjected to logarithmic transformation. As a result, the output of the logarithmic converter 11 at different positions of the switch 5 signals are formed:

$$U_5 = S_2 \,\mathbf{ln}\, K_3 U_3, \tag{6}$$

$$U_6 = S_2 \,\mathbf{ln}\, K_3 U_4, \tag{7}$$

where S_2 - is the steepness of the logarithmic converter 11; K_3 - is the gain of the video pulse amplifier 10.

Signals (6) and (7) through the smoothing resistor 12 are fed to the input of the second controlled switch 13. It, like switch 5, is controlled by signals of the multivibrator 17. As a result, during periodic synchronous operation of switches 5 and 13 pulses with amplitude (6) the storage capacitor 14, and the pulses with amplitude (7) - on the storage capacitor 15. There is a separate accumulation of charges by the capacitors 14 and 15.

The smoothing resistor 12 forms with the storage capacitors 14 and 15 integrating circuits, which from the sequence of pulses (6) and (7) emit constant voltage components:

$$U_7 = K_4 U_5 = K_4 S_2 \,\mathbf{ln}\, K_3 U_3, \tag{8}$$

$$U_8 = K_4 U_6 = K_4 S_2 \,\mathbf{ln}\, K_3 U_4, \tag{9}$$

where K_4 - is the transmission (averaging) of the integrating circuits.

The difference between the DC voltage components (8) and (9) is measured by a voltmeter 16

$$U_9 = U_8 - U_7 = K_4 S_2 \left(\mathbf{ln}\, K_3 U_4 - \mathbf{ln}\, K_3 U_3\right). \tag{10}$$

Given that the difference of logarithms is equal to the logarithm of the relation, the formula (10) takes the form

$$U_9 = K_4 S_2 \,\mathbf{ln}\, \frac{U_4}{U_3}. \tag{11}$$

After substituting in (11) the values of voltage and c (5) and (4), as well as the values of dispersion from (3) and (2), we finally obtain

$$U_{10} = K_4 S_2 \,\mathbf{ln}\, \frac{T_2 R_2}{T_1 R_1}. \tag{12}$$

Since the temperature in the zone AP and the temperature near this zone are almost the same, so we can assume $T_2 = T_1$. Then the measured voltage is determined by the formula.

$$U_{10} = K_4 S_2 \,\mathbf{ln}\, \frac{R_2}{R_1}. \tag{13}$$

From formula (13) it follows that the measured electric noise voltage is proportional to the logarithm of the ratio of resistances outside the zone AP and in the zone AP.

To determine the position of the AP, you need to move the measuring electrode 1 in the area of the AP at a fixed position of the measuring electrode 2.

The maximum readings of the voltmeter indicate that the measuring electrode 1 is at the point of acupuncture.

4. Radiometric contactless method and means of determination of acupuncture points

The radiometric non-contact method and device are implemented on the basis of a two-channel differential radiometric system for recording the difference in the values of radiation intensity in the microwave range. To study the gradients of the electromagnetic field of biological objects, you can use differential radiometers that measure the difference in radiation intensities from neighboring or remote biologically active points (BAP), as well as various (for example, symmetrical) parts of a patient's body to compare the radiation of two patients.

To increase the sensitivity of differential radiometers, it is reasonably to use power feedback to small difference intensities, which provides a deep modulation. In Fig. 2, a functional diagram of a differential radiometers positive feedback [11] is presented, which consists of two microwave antennas X1 and X2, attached to matching elements A1 and A2 that are connected to two inputs of the microwave switch S1.

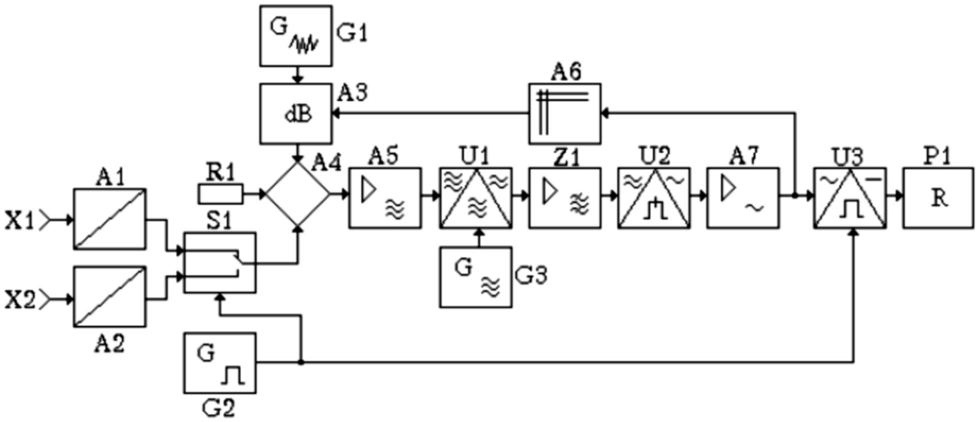

Figure 2: Differential radiometers for recording the difference in radiation intensities

A hybrid tee A4 is connected to the output of a microwave switch, and the matched load R1 and the controlled attenuator A3 are connected to its inputs, too. A microwave amplifier A5, a microwave mixer U1, an intermediate frequency amplifier (IFA) with a filter Z1, a quadratic detector U2, a low-frequency amplifier (LFA) A7, a synchronous detector U3, and a recorder P1 are connected tandem to the output of a hybrid tee A4.

The switching generator G2 is connected to the control inputs of the microwave switch S1 and the synchronous detector U3. A noise generator G1 is connected to the first input of the controlled attenuator A3. A control unit A6 is connected to the second input, the control module of which is connected to the output of the low-frequency amplifier A7.

Microwave antennas X1 and X2 receive the thermal radiation from the surface of an object. The output signals of an antenna can be represented as dispersions of random signals:

$$\bar{U}_1^2 = ST_1, \tag{14}$$

$$\bar{U}_2^2 = ST_2, \tag{15}$$

where S – the antennas sensitivity; T_1 and T_2 – a temperature of controlled areas of an object surface.

The signals $U_1(t)$ and $U_2(t)$ through matching elements A1 and A2, for example, flexible dielectric (fluoroplastic) waveguides, and the arms of the microwave switch S1 periodically arrive at one input of a hybrid tee A4.

The signal from the noise generator G1 is fed to the second input of the tee through the attenuator A3, controlled by an electrical voltage of only one polarity - negative or positive one.

Since the controlled input of the attenuator is connected through the control unit A6, which is a rectangular voltage generator and a power amplifier that is connected to the output of the LF- amplifier A7, the attenuator opens for a time equal to the half-period of a low-frequency voltage, which is the envelope of the modulated microwave signal. In this case, the half-cycle of the low frequency is equal to the half-cycle of the switching frequency of the microwave switch S1.

In the first switching half-period, when a signal $U_1(t)>U_2(t)$ is fed to the input of the microwave switch, the attenuator A3 opens.

Independent noise signals are summed in a hybrid tee, the sum dispersion of which can be represented in the following way:

$$\bar{U}_4'^2 = K_1\left(\bar{U}_1^2 + K_2\bar{U}_3^2 + \bar{U}_5^2\right), \quad (16)$$

where K_1 – the power transmission coefficient of the hybrid tee A4; K_2 – the attenuator power transfer coefficient A3; $U_3(t)$ – the noise generator G1; $U_5(t)$ –the intrinsic noise of a one-link path of a differential radiometer, brought to the input of the amplifier A5.

In the second switching half-cycle, the signal $U_2(t)<U_1(t)$ is supplied to the input of the microwave switch S1, the attenuator A3 is closed by a low-frequency voltage of the opposite polarity (K_2=0). Therefore, the total noise signal can be represented by the dispersion:

$$\bar{U}''^2_4 = K_1\left(\bar{U}_2^2 + \bar{U}_5^2\right). \quad (17)$$

Signals $U_4'(t)$ and $U_4''(t)$, that create one modulated signal, are periodically fed to mixer U1. An amplifier with a filter Z1 selects a signal of difference frequency, the spectrum of which is determined by the passband of the filter.

The quadratic detector U2 receives packets of noise signals of an intermediate frequency, which can be represented as a dispersion:

$$\bar{U}'^2_6 = K_3K_1\left(\bar{U}_1^2 + K_2\bar{U}_3^2 + \bar{U}_5^2\right), \quad (18)$$

$$\bar{U}''^2_6 = K_3K_1\left(\bar{U}_2^2 + \bar{U}_5^2\right), \quad (19)$$

where K_3 – a gain of the amplifier Z1 in the filter bandpass.

The voltage of the envelope of the switching frequency with the amplitude is allocated at the output of the quadratic detector U2:

$$U_7 = K_1K_3K_4\left(\bar{U}_1^2 + K_2\bar{U}_3^2 - \bar{U}_2^2\right), \quad (20)$$

where K_4 – a conversion coefficient of the quadratic detector U2.

An alternating voltage with an amplitude $U_7(t)$ controls the operation of an attenuator A3 and is simultaneously rectified by a synchronous detector U3. The rectified voltage, which is fixed by a indicator P1, can be written as follows:

$$U_8 = K_1K_3K_5K_6\left(\bar{U}_1^2 - \bar{U}_2^2 + K_2\bar{U}_3^2\right) = \alpha\left(\bar{U}_1^2 - \bar{U}_2^2 + K_2\bar{U}_3^2\right), \quad (21)$$

where K_5 – the gain of amplifier A7; K_6 – a conversion coefficient of asynchronous detector U3; $\alpha = K_1K_3K_5K_6$ – a resulting coefficient of a direct conversion of RS.

The gain of the controlled attenuator A3 is proportional to the amplitude of the low-frequency voltage $U_7(t)$:

$$K_2 = K_7U_7, \quad (22)$$

where K_7 – the gear ratio of a control unit A6.

If a control voltage $U_7(t)$ is expressed through the output voltage $U_8(t)$, then:

$$K_2 = \frac{K_7}{K_6}U_8 = \beta U_8, \quad (23)$$

where $\beta = \frac{K_7}{K_6}$ – a coefficient of the inverse transformation of a RS output voltage.

Substituting the value a transmission coefficient K_2 of the controlled attenuator A3 from expression (23) into the expression (21), we get:

$$U_8 = \frac{\alpha}{1-\alpha\beta\bar{U}_3^2}\left(\bar{U}_1^2 - \bar{U}_2^2\right). \quad (24)$$

Using expressions (24), (14) and (15), which take into account the temperature of controlled areas of an object, we finally get:

$$U_8' = \frac{\alpha S}{1-\alpha\beta\bar{U}_3^2}\left(T_1 - T_2\right). \quad (25)$$

A change in the sign of the measured temperature difference $\left(T_1 < T_2\right)$ leads to a change in the phase of the low-frequency voltage at the output of the A7 amplifier by 180°.

As a result, the switching half-period changes, in which the controlled attenuator A3 opens, and the noise signal from the generator G1 is summed not with the signal $U_1(t)$, but with the signal $U_2(t)$ (with higher power). Thus, the operation of differential RS is not disturbed, and its indications will be equal to:

$$U_8'' = \frac{\alpha S}{1-\alpha\beta\bar{U}_3^2}\left(T_2 - T_1\right). \qquad (26)$$

The rectified voltage can be written in the following form because when thephase of the voltage of a switching frequency changes by 180°, the polarity of a rectified voltage changes at the output of a synchronous detector U3:

$$U_8 = \pm\frac{\alpha S}{1-\alpha\beta\bar{U}_3^2}\left(T_1 - T_2\right). \qquad (27)$$

Thus, the considered differential RS works consistently at any temperature ratio of the controlled object ($T_1 < T_2$ or $T_1 > T_2$), and the polarity of the measured voltage determines the sign of the controlled temperature difference. If the feedback coupling is absent in differential RS ($\beta = 0$), then the output voltage has the form:

$$U_9 = \alpha S\left(T_1 - T_2\right). \qquad (28)$$

The introduction of positive feedback ($\beta > 0$) leads to the appearance of an output voltage, which is described by expression (27), and an increase in the sensitivity of the differential radiometer by a factor equal to:

$$\gamma = \frac{U_8}{U_9} = \frac{1}{1-\alpha\beta\bar{U}_3^2}. \qquad (29)$$

If a denominator of expression (29), for example, is equal to 0,01, then the sensitivity of differential RS will increase 100 times due to the feedback coupling.

The maximum gain in sensitivity with the condition $\left(\left[1-\alpha\beta\,\bar{U}_3^2\right]\to 0\right)$ is limited by the possibility of auto-oscillations in the positive feedback circuit. Phase compensation chains and amplitude limiting elements are introduced to suppress auto-oscillations in control unit A6.

In practice, the fluctuation threshold of sensitivity of a differential radiometer can be reduced to $10^{-22}...10^{-23}$ W/Hz by introducing feedback coupling, which corresponds to sensitivity by temperature difference $10^{-4}...10^{-5}$ K.

The usage of the considered differential RS allows to study the gradients of the temperature fields of biological objects in the range of their electromagnetic radiation and to compare the field intensities in biological active points of these objects.

5. Conclusion

The commutation - modulation method and means of contact and non - contact determination of acupuncture points proposed by the authors are based on the use of anomalous values of electrical resistance and microwave radiation from the surface of human skin in the areas of TA.

Internal information fluctuations of electric charges which intensity is proportional to resistance and temperature of the investigated site of a skin of the person are used as information signals.

Algorithms for measuring noise signals and their conversion are based on the comparison of signals at the point of acupuncture with the adjacent part of the human body and the reference point.

The use of the proposed method and means of determining the points of acupuncture provides complete safety when performing diagnostic procedures.

The result of determining the location of the TA is not affected by the temperature of the studied area of the skin, the variability of the gain of the measuring channel of the device and the change of the conversion factors of the passive elements.

These advantages provide an increase in the accuracy of determining the points of acupuncture and, accordingly, increase the effectiveness of treatment.

Scientific novelty lies in the creation of a method and devices for taking characteristics and parameters of the human body without affecting the measurement zones, which in our case increases the sensitivity and accuracy of determining acupuncture points.

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