

# COMPUTATIONAL TECHNIQUES FOR EMPHASIZING EQUIVALENT PARAMETERS OF ACUPUNCTURE POINTS

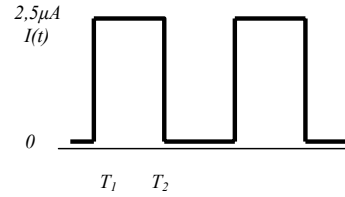
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*Abstract: Targeting of the phenomena which arises when the electric current is passing through the human body leads to the definition of some equivalent electric circuits. The parameters of the passing segment of the current through the skin were studied. For this, an original measuring device was conceived and built [1], and a original computational method was defined. The obtained results showed particular electric properties on the body surface points that coincide with the acupuncture centers.*

By switching on and off the key K, the circuit is fed discontinuously, with current pulses having a filling factor  $\theta = 0.5$



(a)

## 1. METHODS AND TECHNIQUES

In order to describe the properties of the circuit segment between the active electrode and the body internal tissues, a model circuit is adopted [2], with a simple equivalent electric scheme as shown in figure 1.

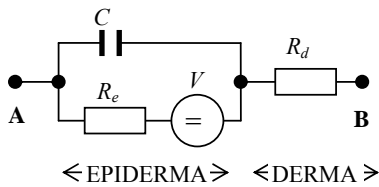


Fig. 1 The electrodermal center equivalent scheme,  $Z_p$

The resistance  $R_e$  and the capacity  $C$  reflect the electric properties of the epidermis. The derma, more profound, series the resistance  $R_d$  [3].

### 1.1. THE ADOPTED EXPERIMENTAL METHOD

The pulsating current method used hereby, leads not only to the  $R_e$ ,  $R_d$  values, but also to the determination of the reactive parameter,  $C$ . In order to do this, the exit voltage time function,  $U(t)$ , is analyzed, when the measuring circuit is in a switching out supply state (Figure 2).

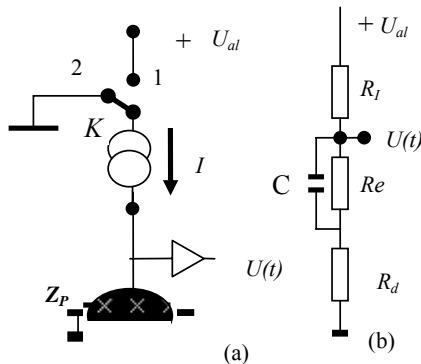


Fig. 2

a – the principle for measuring the impedance  $Z_p$  in constant current

b – the equivalent measuring circuit

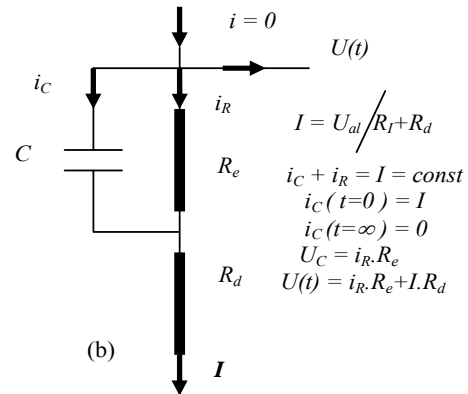


Fig.3

a – waveform applied; b – equivalent circuit

Above (figure 3) are presented the equations for the charging process. In the initial moment,  $t = 0$ , the capacity  $C$  starts charging from zero, so  $U_C(0) = 0$ . Therefore, the measured voltage is:

$$U(0) = R_d \cdot I$$

At the end of the period  $T_1$ , the capacity is loaded, the currents are  $i_C = 0$ ,  $i_R = I$  and the final voltage on the capacity is  $U_C = I \cdot R_e$ . Thus:

$$U(\infty) = I(R_e + R_d)$$

Having these data, the analytic solution of the transitory operation mode for constant current charging of the circuit during  $T_1$  leads to the following measured voltage time function:

$$U(t) = I \cdot \left[ R_d + R_e \cdot \left( 1 - e^{-\frac{t}{R_e C}} \right) \right]$$

The durations of the two sequences is chosen long enough for the charging and discharging processes to be complete. Below, in figure 4 is represented the charging sequence characteristic for the capacity from 0 to  $T_1$ .

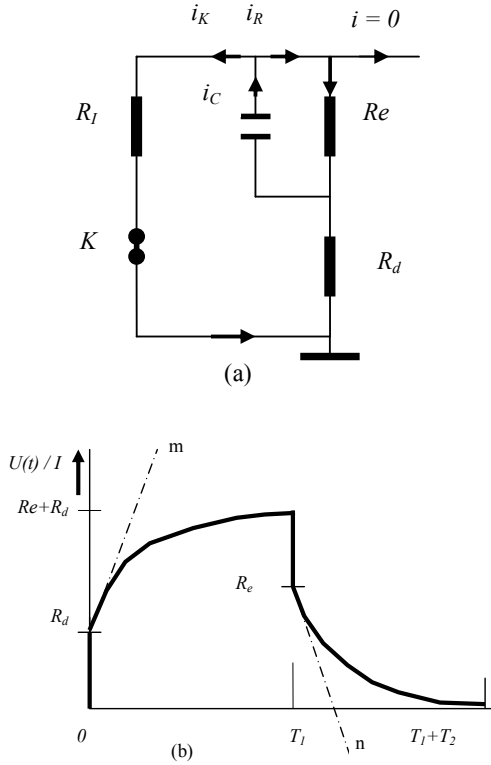


Fig. 4

a – the equivalent circuit scheme during the discharging sequence  
b – the exit function diagram during the charging sequence, from 0 to  $T_1$ , and during the discharging sequence, from  $T_1$  to  $(T_1 + T_2)$

Neglecting the  $i_k$  current (because  $R_l \gg R_e$ ), we can obtain the output voltage:

$$U(t) = i_C \cdot R_e = I \cdot R_e \exp\left\{ -(t - T_1)/\tau \right\}$$

where

$$\tau = R_e \cdot C$$

$$T_1 < t < \infty$$

The tangent to the exponential curve of charging, (m) and to the discharging curve (n) permits the determination of the capacitance  $C$  by computation, after evaluating the derivative of the exponential function  $U(t)$  in those moments, knowing that

$$\left| \frac{dU(t)}{dt} \right|_{t=0}$$

has an absolute value of  $I/(R_e C)$ .

For the measuring of the potential  $V$  in the electrodermal point [4] (tenth of millivolts) we interrupt the current driven in the circuit ( $U_{a1}=0$ ) and the output voltage is amplified as necessary.

## 2. COMPUTATIONAL TECHNIQUES

At a given pulsation,  $\omega$ , the impedance is a complex value, defined as  $Z = X - jY$  with the real component  $X$  between  $R_d$  and  $(R_e + R_d)$ . The imaginary component,  $jY$  takes values according to the pulsation  $\omega = 2\pi f$ . Then we can write:

$$\underline{Z} = R_d + \frac{R_e(1 - jR_e\omega C)}{1 + \omega^2 C^2 R_e^2} \quad (I)$$

Splitting (I) into the two terms,  $\text{Re}(Z)$  and  $\text{Im}(Z)$  we obtain:

$$\text{Re}(Z) = X = R_d + \frac{R_e}{1 + \omega^2 C^2 R_e^2} \quad (II)$$

and

$$\text{Im}(Z) = jY = j \frac{R_e^2 \omega C}{1 + \omega^2 C^2 R_e^2} \quad (III)$$

By substituting  $\omega = 0$ , the value of impedance  $Z$  reduces to  $\underline{Z}(0) = R_e + R_d$ . Also, we can prove that if  $\omega = \infty$  then  $\underline{Z}(\infty) = R_d$ .

Computing (I), (II) and (III) finally we obtain:

$$\left[ X - \left( R_d + \frac{R_e}{2} \right) \right]^2 + Y^2 = \frac{R_e^2}{4} \quad (V)$$

which is the equation of a circle of radius  $R_e/2$ , with its center on the real axis in a point  $P$ , where  $X$  is equal to  $(R_d + R_e/2)$ . Since the reactance is capacitive and  $\omega > 0$ , the representation has physical sense on a semicircle's arc, in the fourth plane.

The experimental measurements are made at different pulsation ( $\omega_1, \omega_2, \dots, \omega_6$ ) and at various current intensities (peak to peak,  $I_{S1}, I_{S2}, I_{S3}$ ).

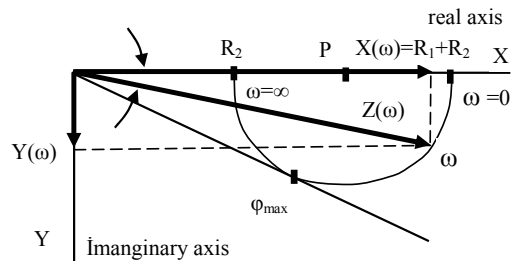


Fig. 5 Real and imaginary components of  $\underline{Z}$

Figure 5 shows the graphical relation between the circuit's impedance at  $\omega$  pulsation,  $Z(\omega)$  and its components  $X(\omega)$  and  $Y(\omega)$ . Knowing the values  $\phi(\omega)$

and  $|Z(\omega)|$ , the components  $X(\omega)$  and  $Y(\omega)$  can be obtained using the trigonometric relations:

$$\cos \varphi(\omega) = \frac{X(\omega)}{|Z(\omega)|} \quad \text{and} \quad \sin \varphi(\omega) = \frac{Y(\omega)}{|Z(\omega)|}$$

therefore:

$$X(\omega) = |Z(\omega)| \cos \varphi(\omega) \quad \text{and} \quad Y(\omega) = |Z(\omega)| \sin \varphi(\omega)$$

The measuring procedure of  $|Z|$  and  $\varphi$  is repeated six times for the six values of pulsation  $\omega$  defined above and then we write a table with the computed values, shown below (Table 1)

Pulsation	$ Z(\omega) $	$\varphi(\omega)$	$\cos \varphi(\omega)$	$\sin \varphi(\omega)$	$X(\omega)$	$Y(\omega)$
$\omega_1$	→	→	→	→	$X(\omega_1)$	$Y(\omega_1)$
$\omega_2$	→	→	→	→	$X(\omega_2)$	$Y(\omega_2)$
$\omega_6$	→	→	→	→	$X(\omega_6)$	$Y(\omega_6)$

Table 1

The X and Y components resulting from the projection of the impedance's module on the two axis in the fazorial plane defined in (II), (III) contain the three wanted parameters Re, Rd and C. It is obvious that a two equation system with three variables can not be solved. So it was defined an original computational method, using two pair of values extracted from Table 1, for example pulsation  $\omega_1$  and  $\omega_2$ , with the following notations:

$$X(\omega_1) = X_1, X(\omega_2) = X_2, Y(\omega_1) = Y_1 \quad \text{and} \quad Y(\omega_2) = Y_2$$

After solving this equation system using values from Table 1, we obtained the following relations to determine the parameters of the equivalent circuit shown in figure 1:

$$C = \frac{Y_2 \omega_1 - Y_1 \omega_2}{Y_1 Y_2 (\omega_1^2 - \omega_2^2)} \quad (*)$$

$$R_e = \frac{Y_1 Y_2 (\omega_2^2 - \omega_1^2)}{\omega_1 \omega_2 (X_1 - X_2)} \quad (**)$$

$$R_d = \frac{\omega_2 Y_1 X_2 - \omega_1 Y_2 X_1}{\omega_2 Y_1 - \omega_1 Y_2} \quad (***)$$

For a given current intensity, chosen between the three nominal values, at six different pulsations, we obtain six values for each parameter of the equivalent circuit. The final result table contains 54 experimental determined values.

### 3. DATA PROCESSING

For the experimental measured values was elaborated an numerical computation algorithm which implements the calculation of C, Re and Rd components using a personal computer. The software's user interface permits the manual

input of the experimental data set which afterwards is saved in a 3 set database. Then is generated a second table with some intermediate values required to determine of unknown components. This table contain the value of  $|Z(\omega)|$  given in  $K\Omega$ , faze  $\varphi$ , the values of functions sin and cos of the faze and finally the components X and Y given in  $K\Omega$ . Based on this intermediate table it is made after an iterative computation, a new database containing all the values of C, Re and Rd for all possible combinations.

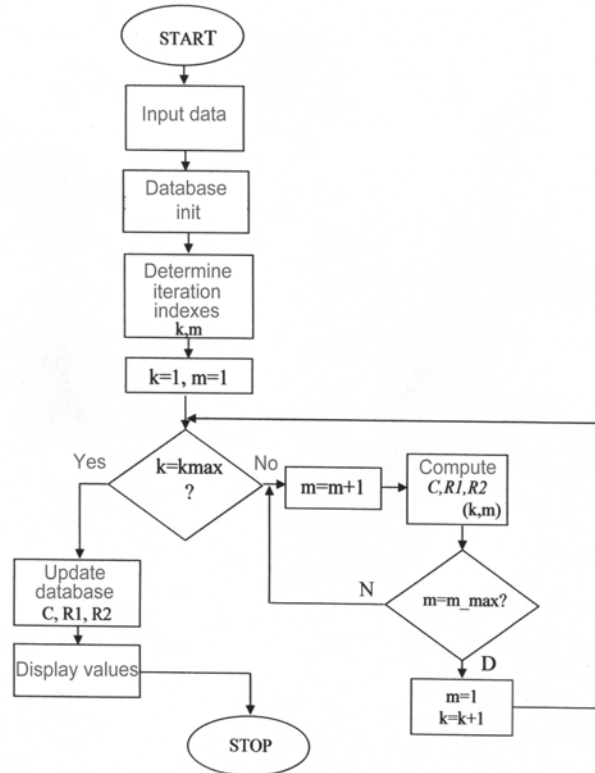


Fig. 6 Computational flowchart

The flowchart of the algorithm is given in figure 6.

The implementation of this algorithm is made by a software written in Visual Basic 4.

The user interface offers the possibility to input 3 sets of measured data, each one saved in a separate database. Then, one can chose for which set computation is made.

After displaying the intermediat values table, the user can view the final results in a new screen window.

Each table can be also sent to a printer.

The "View data" option gives the opportunity to load a set of experimental measured values into the computer's memory. Using a selection mark, the user can load one of the three data sets into memory.

After loading, there is a main menu which permits viewing the intermediate values or final values table.

To view all data, each window has its own scrollbar.

The Edit window is shown in figure 7.

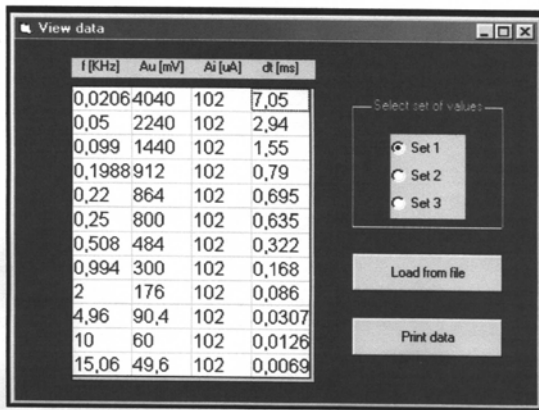


Fig. 7 Edit data window

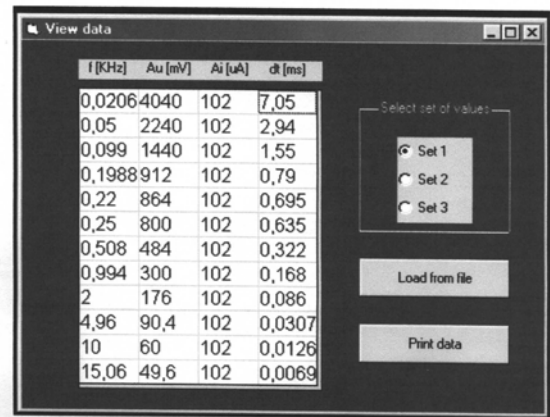


Fig. 8 Viewing data sets

Viewing data sets can be done by opening the “View data” window, as shown in figure 8.

#### 4. EXPERIMENTAL RESULTS

Based upon a given data set, we obtained the following results after running the software:

Nr	Z  [Ko]	$\varnothing$ [sx]	cos $\varnothing$	sin $\varnothing$	X[Ko]	YKo]
1	4.801587	62.64648	0.459508	0.8881736	2.206368	4.264623
2	2.936508	64.464449	0.4311004	0.9023039	1.26593	2.649623
3	1.714286	61.6104	0.4754924	0.8797198	0.8151299	1.508091
4	0.8968254	56.0196	0.5589332	0.8292127	0.5012655	0.743659
5	0.5753969	43.7778	0.7220439	0.6918472	0.4154618	0.3980867

Fig 9 Final values table

The graphical interpretation of the final values is shown in figure 10.

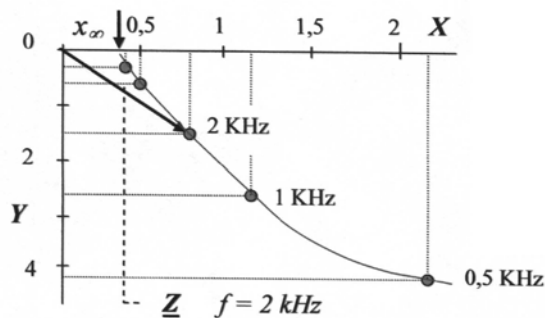


Fig. 10 The relation between X and Y in the fazorial plane

#### 5. FINAL CONCLUSIONS

Electroacupuncturists use electrical devices to measure the impedance (resistance and capacity) in different points and the body's reaction, and the resistance changes, on different acupuncture points, in response to different medications brought into the patient energy field.

The measurement of the electrical properties of acupuncture points was accomplished by the presence of a constant current then by a given prescribed voltage. Both techniques use repeated square wave pulses with such a width to match precisely the transitory processes which occurs by connecting or interrupting the applied current.

The experiments made by the author had shown a good concordance of the measured parameters with the most of the values taken by granted from the bibliographical sources [4].

#### 6. REFERENCES

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