The real-time monitoring of acupoint impedance

Methods and equipment used

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To monitor either the resistance (DC) or impedance (AC) of an acupoint, it is necessary to pass a current into the acupoint and measure the resultant voltage.

In the experiments, all acupoints were first located electrically, as described in the separate document Detecting acupoints electrically. The document also describes the electrodes used, how to manufacture them, and the techniques used, such as the use of gel between the electrode and skin, and the placement of the earth electrode.

The electrode assemblies were held in place on the subject with an elasticated band, which was wrapped around the limb or the torso, depending on the acupoint location. The tension on the band needs to be adjusted so as to keep the electrode pair in constant contact with the skin and both electrodes held level, but while not applying too much pressure, so that the electrodes become uncomfortable after a few minutes.

In the experiments, an AC signal was used. This was generated by a PicoScope 2204A, but any suitable signal generator could be used. The signal was a 200mv sine wave at 40 KHz, which is the signal that the following electronics was designed to work with.

The signal was connected to the box described in the accompanying circuit impedanceH3.pdf. See also the circuit board layout used, and the assembled board, which may be helpful, though these are suggestions only. This box passes the signal through each electrode and monitors the voltage across the electrode. The resultant sine wave is then half rectified, smoothed, and the peak voltage sent to the box's output.

In the design of the electronics, many different combinations of RC and frequency and level of signal were tested, and it was found that the resultant circuit was the best compromise. The AC signal needed to be converted to DC, but if the smoothing RC circuit had too long a decay phase, this would limit the responsiveness of the signal to changes in the electrode voltage. When a test signal was changed by 100mv (increasing and decreasing), it was found that the box's output signal rose to the new value in around 2ms, and fell to the new value in around 20-30ms. This response time seemed acceptable when considering the probable speed of impedance changes at acupoints. But when a response time in this range is being considered in the samples, the above delay in the monitoring electronics needs to be taken into account.

Diodes were not used for protection against electro static discharge (ESD), since it was found that the small voltage that leaked from them, affected the signal. Instead, a switch is used to temporarily earth the electrodes when they are first placed on the skin and attached to the box. When the sampling is about to begin, the switch can be thrown to place the electrodes in circuit. This protects the opamp from ESD, and also discharges any static charge that may be present on the subject's skin at the electrode locations, prior to the sampling beginning.

Version H3 of the box offers the ability to either use a continuous signal, or for the signal to be periodically disconnected from the electrodes. This is under the control of the data logger. When operated in this mode, the signal remains on for around 20ms, and is then switched off until the following sample is taken, with the interval between each sample being typically a few seconds. This mode was designed to rule out the possibility that the continuous signal was affecting the acupoint, and thus the organ function, and so providing false readings. But this mode can also be used in experiments where the subject is required to move between samples; in which case the sampling needs to be ceased, to avoid movement artefact.

The box requires a +/- 12volt supply. The supply used in the experiments is shown in the accompanying circuit, power.pdf.

The data logger used was a PicoLog1216, which was connected to the output of the above box.

The accompanying Access database and macro was used to control the data logger, collect the samples, and also control the signal switch in the above box.

Note that the "PicoSDK" must be installed for this macro to work. This can be downloaded from: www.picotech.com/downloads.

The macro is routinely updated, to cater for changes in experimental design, but the version used for each experiment is included in that experiment's dataset; see www.curiouspages.com/research.

The Access software uses the following equations to convert the ADC samples to the impedance values stored, in KOhms:

The ADC sample is first converted to volts:

$$adc2V = value / maxValue * 2.5$$

And the Volts value is then converted to KOhms:

> volts2Kohm = (((sample - 0.05) / 7.1) * 10) / (signal - ((sample - 0.05) / 7.1))
>
> This assumes a "signal" of 200mv (thought the software allows this to be adjusted), and a voltage divider resistor of 10KOhms (as shown in the accompanying circuit, impedanceH3). The "7.1" value refers to the amplification factor used by the TLC272 opamp, this value being determined during calibration of the equipment.

From the Access database, the collected samples were then exported to an Excel sheet (version 2007 or later needs to be used to cater for rows in excess of 65,000), which was then imported into Matlab for filtering and displaying the results. For those working to a tight budget, free software is available that is largely compatible with Matlab.
See www.gnu.org/software/octave, though this experiment's accompanying Matlab scripts have not been tested on GNU Octave.

In Matlab, the experiment's samples were passed through a low pass filter, to remove all frequencies above around 1Hz, and the results plotted. The Matlab scripts used are included in the dataset to each experiment; see www.curiouspages.com/research.

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