Portable Brain Activity Monitor

Background

Neurological disorders such as epilepsy can severely disrupt a person's life robbing them of their livelihood. Epilepsy is characterized by having recurrent seizures, a synchronized abnormal activity of the brain. Epilepsy is misdiagnosed in approximately 50% of the cases. Tripolar concentric ring electrode (TCRE) sensors have been shown to have at least four-times improvement in signal to noise ratio, spatial resolution, and ten-times improvement in mutual information. We have developed a wired TCRE clinical recording system and have that has shown promise for improving the diagnosis of epilepsy and hopefully other brain disorders. The current TCREs connect with wires and prevent patients from walking about in there environment.

The objective of this project is to design and prototype a wireless TCRE sensor that can be used by Dr. Besio and other researchers for monitoring brain activity. The final deliverables will be detailed design drawings, electronic schematics and layouts, materials list, interconnect diagram, control algorithms, and a prototype.

Previous Progress:
This is the first team to work on this project. The previous Capstone Team completed the Brain Modulator project.

Functional specification:
For the Wireless Brain Activity Monitor it is necessary to develop an integrated system that will measure the skin-to-electrode impedance, preamplifier the brain activity (electroencephalography (EEG), digitize the EEG, and wirelessly transmit the digitized signals to a base station for further processing. The Wireless Brain Activity Monitor must be a portable device capable of functioning for up to twenty-four hours of continuous use.

This can be accomplished in two stages: (1) a portable Brain Activity Monitor, and (2) independent wireless brain activity TCRE sensors.

In order of priority

<u>Portable Brain Activity Monitor</u>
The Portable Brain Activity Monitor will be capable of: (1) measuring the skin-to-electrode impedance, (2) preamplifying TCRE signals, (3) digitizing the preamplified TCRE signals, (4) transmitting the digitized signals to a base station via (a) wires, or (b) wirelessly. The TCRE signals are of the order of 100 nano Volts peak-to-peak. The preamplifier has already been developed and provides a gain of approximately 50 V/V. The digitizer needs to be 24 bit. We need to see frequencies up to 1000 Hz therefore sampling at 2000 S/s is appropriate but ten-times oversampling is desired for 20,000 S/s per channel. The system may have to run for days at a time so it either needs to be powered via wires or with hot-switchable batteries. Communication between the portable system and base station can be performed many ways but many of the commercially available devices use TCP IP.

Data storage

Working backwards from the analog to digital conversion- if we have 24 bits at 20,000 samples per second for each of the two channels per TCRE then there are 40 output channels. This is approximately 1.6 M bits per second. We need to be able to store data for days, one, two, three, possibly more. It is unlikely that the data can be stored to a laptop hard drive or even an external hard drive. Most likely we will need some type of internet-based data storage.

Wireless Brain Activity Monitor

Each TCRE sensor will be capable of acquiring brain electrical activity independently or in an array of TCRE sensors. The wireless TCRE sensor can be developed in stages:

The first stage incorporates a TCRE and:

1. Off TCRE sensor preamplifier
2. The TCRE sensor can initially be powered by an off sensor power source.
3. The wireless transmission can also be performed by an off sensor transmitter device for proof of concept.
4. The analog to digital converter can be off sensor.

In stages two or more the four separate system components above need to be combined into a single sensor.

The independent TCRE sensors will need to be capable of operating for days (at least one day). This may be performed by hot-swapping batteries, power harvesting, or other methods.

The TCRE sensor must be no larger than 1.0 cm diameter. The sensor can be no taller than 1.0 cm.

The wireless transmission should be capable of transmitting at least 1.0 meter. A repeater type (transceiver) may be used to receive the data from the TCRE sensor and communicate with the base station.

Impedance meter (This was previously completed and can be incorporate into the design.)

An alternating current such as a sine wave at 30 and 300 Hz should be applied through known resistors to the electrodes. The voltage measured across the resistors is proportional to the skin-to-electrode impedance. An automated process for determining the skin-to-electrode impedance that can be activated manually or via a software-controlled input must be developed. The impedance range should be from 500Ω to 100 KΩ. If the impedance is greater than 100 KΩ a “over range” message should be displayed. The impedance should be measured between each element of the electrodes and the reference as well as between each element of the electrodes. (If possible, the system should be able to measure skin-to-electrode impedance between stimulation pulses. To do so may mean increasing the skin-to-electrode signal beyond 30 Hz.)

Required skills: Dr. Besio needs a diverse team to accomplish the objectives of this project.

1. Electronics and microcontrollers
2. Analog to digital converters
3. Wireless communications devices
4. TCP IP hardware and software for communication