WIRELESS EEG/EMG DATA ACQUISITION DEVICE FOR USE AS A CONTROL INPUT AND FOR RESEARCH STUDIES

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Abstract
Significant work has been conducted on developing various controls using EEG or EMG as the control input. All of this work has been conducted using equipment that requires the patient electrodes be wired through a signal processing unit which is then wired to a controller. This means that the user needs to be physically connected to the control device. This obviously has limitations; the user is not free to move about, relative to the controller. Since personal computers have frequently been the controller, the user either needs to remain relatively stationary, or needs to move the computer around with himself.

An eight-channel wireless physiological monitor has been developed to acquire EEG/EMG data, and transmit the data 50-100 feet through several walls with a 900 MHz radio frequency signal. This allows the user to be physically remote from the controller.

Introduction/Background
Various programs have used EEG or EMG for controlling devices used by disabled patients. Most of these programs have been to control a computer. Other programs have used computers and electronics to attempt to control other systems such as the environment or FNS Hand Grasp Systems. In all these cases, the user was required to be wired to a computer or large electronics box. This limits function for the user and complicates the procedure for the researcher. For research programs, if the subject needs to take a break, they need to be untethered to allow them to tend to bodily functions. For the user, it is inconvenient and adds to discomfort.

A new system that will allow the taking of EEG and EMG signals without being tethered to large equipment was needed. The NIH requested that such a system be built under various grants and contracts.

Methods
Under support of the National Institute of Neurological Disorders and Stroke, National Institute of Mental Health, and the United States Army, an eight-channel wireless physiological monitor has been developed to acquire EEG and/or EMG data, and transmit the data 50-100 feet through several walls with a 900 MHz. radio frequency signal. This allows the user to be physically remote from the controller.

In 1995, Cleveland Medical Devices developed its first miniature wireless EEG device under a grant from the National Institutes of Mental Health (Fig. 1). This 4-channel device was used to record auditory evoked responses from infants for cognition testing (Fig 2). It was decided to use the 902-928 MHz. Instrumentation, Scientific, and Medical (ISM) band for several reasons. This 26 MHz. wide band allowed sufficient numbers of devices to operate in close proximity that this first EEG device could potentially lead to a “Wireless Hospital” concept. Also, the chosen A/D, microcontroller, and 900 MHz. radio components were available at low cost, allowing the new devices to be manufactured at a price lower than commercial EEG were currently selling for, essentially allowing the radio component to be provided for free.

Figure 1. The world’s first ISM band wireless EEG Device

(2a) (2b)
Figures 2a and 2b. The first generation wireless EEG used on an infant for Auditory Evoked Response testing.

The National Institutes of Neurological Disorders and Stroke then requested that an 8 channel EEG device be developed to allow seizure patients to be monitored, without the restrictions of being tethered to a large
A second generation EEG device was designed and fabricated (Fig. 3).

Figure 3. A single board 8-channel EEG including the amplifiers, A/D converters, microprocessor, and radio.

The device, which was tested on an epileptic patient, utilized an integrated analog to digital converter (ADC) that included a programmable gain amplifier, A/D converter, and a digital filter. This provided a significant improvement over the previous device, as it allowed the gains to be programmed in software. The prior device had all of the amplifiers built-in in hardware. This allowed the newer EEG device to also be used for EMG, ECG and other physiological signals. This was sufficiently novel to allow a US patent to be issued. Integration of the systems allowed the same microcontroller to control the modulation, synthesizer, and buffer of the radio (Fig. 4). This high level of integration allowed the complete programmable data acquisition/radio transmitter to be only 2 ½” by 2” for all 8 channels, tiny enough to be worn conveniently on a headband (Fig 5).

An even smaller 3-channel version was developed for the Army to conduct EMG studies on soldiers. This was further refined under a program for NINDS. The board (Fig. 6) proved out new Voltage Control Oscillator (VCO) concepts, that are an order of magnitude smaller and cheaper than commercially available VCO’s.

Figure 4: Transmitter Block Diagram

Figure 6. This 3-channel EMG board was only 2” by 1½”, including the microcontroller and radio. It was packaged with an n-cell battery.

The previous devices were designed as prototypes, not to be commercially available products. The packaging needed to be upgraded to withstand a six foot drop onto a concrete floor. The connectors did not meet the newly revised FDA requirements for “no-touch.” The battery life needed to exceed 12 hours for convenient use. The software needed to be upgraded to a commercial standard. And the entire system needed to be designed to meet both FCC and FDA requirements.
This work was all accomplished, in part under two NIH Phase II SBIR grants.\textsuperscript{6,7}

Results

The final result of the overall development was the development of the BioRadio\textsuperscript{®} 110 (Fig. 7).\textsuperscript{11} The specifications are shown in Table 1.

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<th>Table 1 The BioRadio 110 Specifications</th>
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<tr>
<td><strong>Size of Transmitter</strong></td>
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<td><strong>Weight of Transmitter</strong></td>
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<td><strong>Analog channels</strong></td>
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<td><strong>Input Range</strong></td>
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<td><strong>Resolution</strong></td>
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<td><strong>Noise</strong></td>
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<td><strong>Sampling Rate</strong></td>
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<td><strong>Power Source</strong></td>
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<td><strong>Filter Bandwidth</strong></td>
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The software (and labeling) of the BioRadio was upgraded to meet FDA requirements and a 510K was submitted to the FDA. The Crystal-EEG\textsuperscript{®} was approved to market as a medical device.

Discussion/Conclusions

This paper summarizes the multi-project development of a commercial device. It is an example of the requirement for continued funding over a period of years that is needed to take a concept through a number of prototypes to a manufacturable device that meets the regulatory requirements so it can be sold for medical purposes.

The BioRadio can be used by researchers to acquire EEG and EMG signals, process them and transmit them around a lab, ward, or home where the signals can be stored on the hard drive of a PC or used as control inputs for other devices. The Crystal-EEG can be used by clinicians for the acquisition of EEG signals.

References


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Figure 7. The BioRadio is an 8-ch. Physiological Data Acquisition System