Alpha wave monitoring in wireless sensor networks

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***Abstract*— Wireless Sensor Network (WSN) features such as self-powered, low power consumption, wireless, usable computation capacity, make it a plausible solution for human health monitoring. In this paper we present a hardware-software solution that able to detect, process, collect and classify alpha waves of human brain.**

I. INTRODUCTION

“**Electroencephalography** (EEG) is the recording of electrical activity along the scalp produced by the firing of neurons within the brain.”[1] The recorded data carry plenty of information that can be interpreted with further signal processing. Our aim is to distinguish between awake or sleep state of the patient and this way for example avoid accident caused by fall asleep [10, 11].

A. Brainwaves

The brainwaves, electromagnetic oscillations, were initially discovered by German scientist H.W. Dove in 1839 but the very first recording, in 1924, obtained and published by another German scientist Hans Berger.

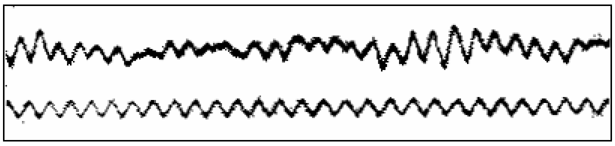

Figure 1. An early EEG recording done by Berger

He classified the waves by frequency and amplitude, into 4 groups:

- **alpha waves**: 8-12Hz, 50µV; meditation or wakeful relaxation with closed eyes
- **beta waves**: 12-30Hz, less than 50µV, active, busy, or anxious thinking and active concentration
- **delta waves**: 0-4Hz; dreamless deep sleep
- **theta waves**: 4-7Hz; Two types (Hippocampal and Cortical)

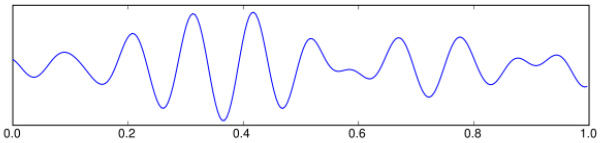

Figure 2. EEG of alpha wave (1s)

Later on **gamma waves** (25-100Hz) were added to the list above and most probably relates to subjective awareness.

B. EEG

EEG refers to the recording of the brain's spontaneous electrical activity and usually involves recording from scalp electrodes. The electrodes placed on the scalp with a conductive gel or paste.[16]

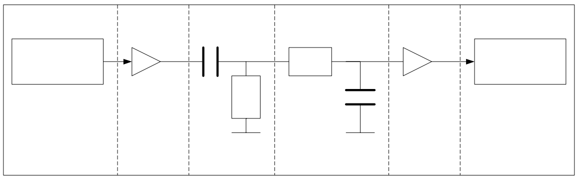

Figure 3. Analog EEG signal handling

Each electrode is connected to one input of a differential amplifier. These amplifiers amplify the voltage between the active electrode and the reference (typically 1,000–100,000 times, or 60–100 dB of voltage gain). In analog EEG, the signal is then filtered, in digital EEG the amplified signal is digitized via an analog-to-digital converter, after being passed through an anti-aliasing filter.

C. WSN technology

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, in our case brainwaves. The WSN devices, addition the sensor(s),

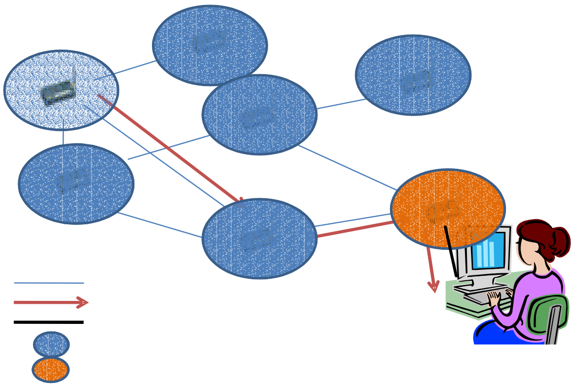

Figure 4. Typical WSN structure

Figure 5. IRIS mote

equipped with radios transceiver (usually ISM frequency capable), microcontroller and a battery. WSN can operate with or without presence of a base station (e.g. PC). The sensor nodes usually build up wireless ad-hoc, multi-hop network for communicating [1-7].

D. Sensor network device

In our project we have used the well-known MEMSIC[15]'s (aka CrossBow) wireless module; Iris.

Iris utilizes the M2110 module that contains:

- Atmel [12] Atmega1281 8 bit MCU
- Atmel AT86RF230 [12] radio transmitter, s a low-power 2.4 GHz transceiver specially designed for low cost IEEE 802.15.4, ZigBee [13]
- 512 KB serial flash for measurements

Iris also features:

- 51-PIN expansion connector: for external sensor board or programming board. (V_{cc}, GND, SPI, I_2C, Digital I/Os and ADCs connected)
- external antenna connector (mmcx)
- 3 LEDs as user interface of application
- 2xAA battery holder
- compatibility with TinyOS/nesC [17]
-

Programming boards e.g. MIB 520, can be use both (virtual) serial programming and data communications.

Figure 6. MIB 520 programming board

II. ALPHA WAVE SENSOR NODE

Our aim was to develop a sensor that able to detect alpha waves (8-12Hz, 50µV).

The voltage level, 50µV, is too low to measure it directly on an ADC. On Fig. 3 can be seen how the signal handling takes place: in the first stage a pre-amplifier has t be used (Texas Instruments INA1144 [14] precision instrumentation amplifier), in the second stage the signal has to filter by low- and high pass filters. And finally it has to amplify (Texas Instruments TLC277 [14] dual precision single supply operational amplifier) to the adequate level.

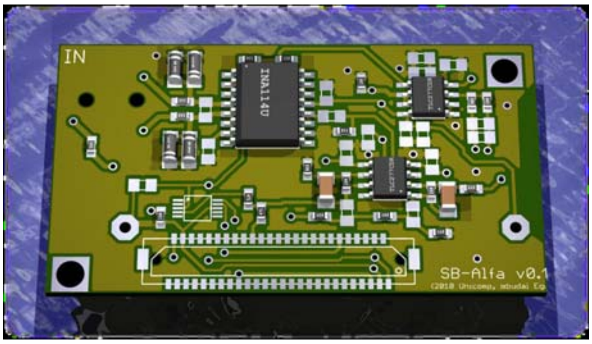

Figure 7. 3D model of SB-Alfa

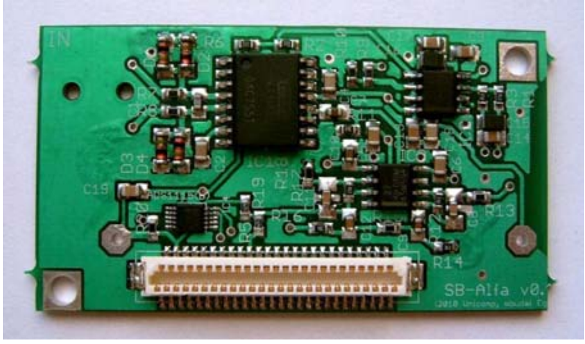

Figure 8. SB-Alfa: the alpha wave sensor board

At first look, the 13Hz limit seems easier than it is. The 50 times oversampled signal very sensitive to the electrical noises. On order to get the best result, we added a 16-bit ADC to the board (Atmega1281 has 10 bit ADCs) and we transfer the analog signal and its digital version (I^2C) to the MCU [8].

As we have chosen IRIS mote designed a sensor board that connects to the device with the 51-pin connector. The board has two layers, both side assembled with SMD parts. The physical dimensions can be reduced dramatically, but in our case the dimensions of the mote (31mm * 56mm) are significant and also we used SMD parts greater or equal than 0402 to support manual mount assembly.

Providing the proper supply voltages to the INA114 instrumental amplifiers requires both positive and negative supply voltages, but the mobile devices usually operates from positive voltage (typically: 1.5V, 3V, 3.6V) and also the INA114 active from ± 2.25V. To solve later one we needed to add an extra 1.5V battery (serial to the 2xAA battery holder) [9].

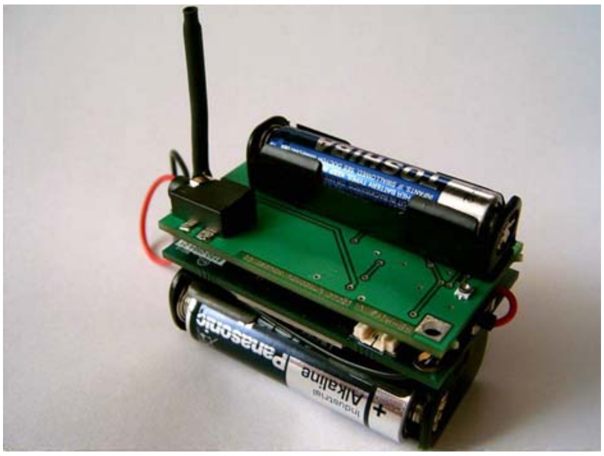

Figure 9. IRIS + SB-Alfa sensorboard

In order to solve the amplifier positive-negative supply problem we had to develop a virtual ground. The optimal value for the virtual ground is the 1.5V, because in case of no-signal, this is in the middle of the supply voltage. And this way the ADC will be on the middle of its range. The virtual ground has to be attached to the patient (right leg electrode) that is buffered by amplifier.

The electrodes connect to a stereo jack connector. This solution provides easy and polarity safe plug-in type connection. If no electrode connected to the board the input is on ground to avoid flotation.

III. TEST RESULTS

A. *Awake states*

We used digital oscilloscope during the measurements to validate SB-Alfa.

The alpha waves (first channel) can be seen on the following Fig. 10. (the second channels is the TTL signal inputs into the MCU)

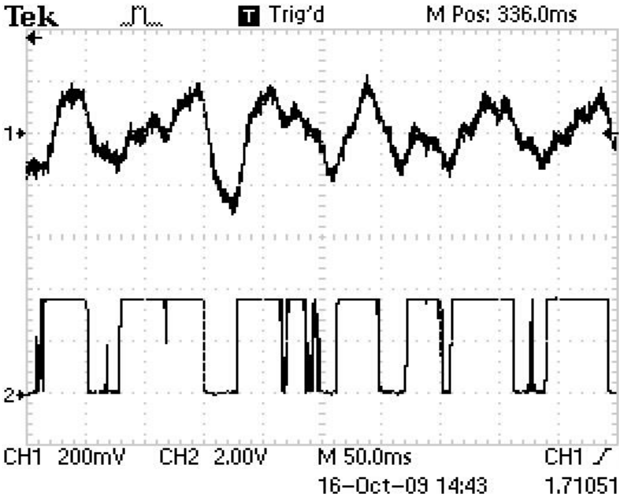

Figure 10. SB-Alfa test: alpha waves

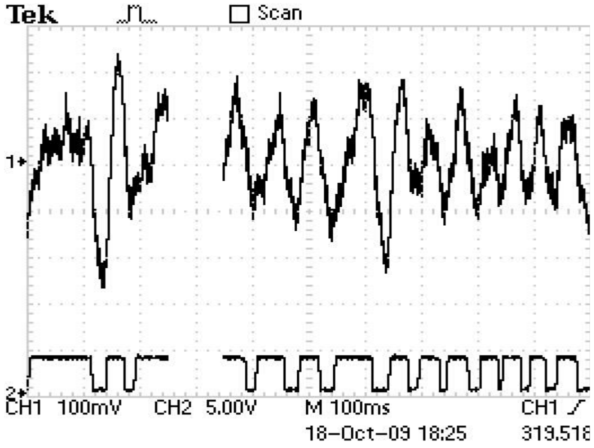

Figure 11. SB-Alfa test: beta waves

The beta waves (channels are the same) can be seen on the Fig. 11.

B. *Biological noises*

There are noises that cannot be filtered out using electronic components. Some of these noises are produced by the human body, e.g. hearth beating, talk, eye movements and wink. These types of noises can be detected quite easily but handling them requires complicated algorithms usually on the software side.

Heart beating and winks:

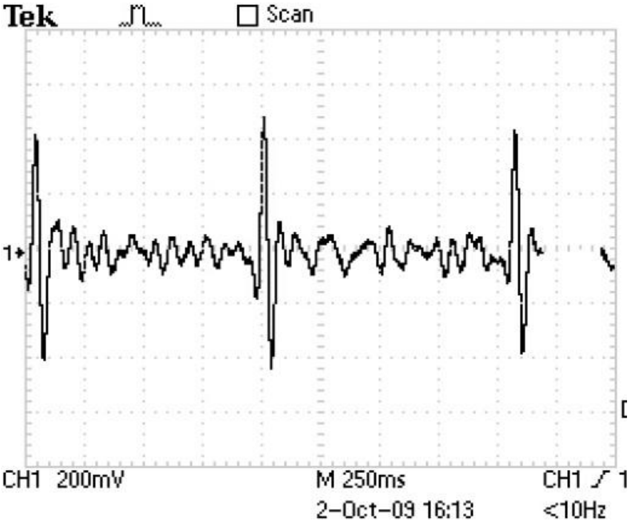

Figure 12. SB-Alfa test: heart beating effect

If the electrode situated on the back of the neck the heart beating can be monitored (see Fig. 12) and if it is situated on the temporal winks can generate strong noises (see Fig. 13)

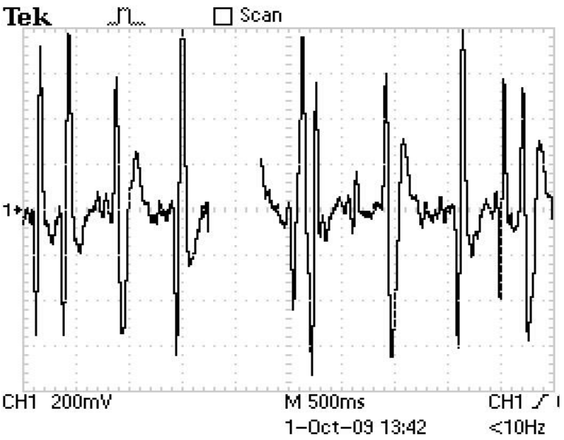

Figure 13. SB-Alfa test: wink effect

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