# ZIGBEE BIOTELEMETRY APPLICATION

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## Abstract

*The mobile telemetry system of biological parameters serves for reading and wireless data transfer of measured values of selected biological parameters to an outlying computer.*

*This article is focused on ZigBee networks solution used in this project and using of dry textile electrodes for ECG measurement.*

*ZigBee communication is not so often used in biotelemetry branch even if it has many advantages contrary to other commercial wireless personal networks solutions. There are used two different hardware ZigBee solutions.*

*ECG measurement is realized by designed bio amplifier. Measured data are sampled and filtered in ZigBee module. Dry Textile electrodes are based on polyanilin. These electodes were tested in our laboratory and used in this telemetry project*

## 1. Introduction

In the present time the health telemetry systems forge an integral part of our everyday lives. Comparatively in the near future embedded systems will ward over our lives and health.

It was created function prototype of wireless biomedical (and any other) data transmission and data analysis system. System transfers data about race vehicle drivers condition and some additional data about ride. These drivers' signals are collected: SpO2, pulse, ECG, and body temperature. Besides these signals data about acceleration of vehicle in X and Y axis (front-back, left-right) and air temperature is measured.

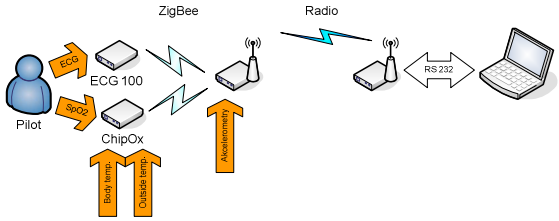


**Figure 1.** Designed telemetry system

There is realized bipolar one lead ECG measurement using designed bio amplifier. There is used special new type of textile electrodes, which were designed and tested in our laboratory with cooperation of Czech Academy of science.

The SpO2, body and outside temperature is measured by OEM SpO2 module ChipOx. These measured biomedical data are transmitted by ZigBee technology to module, which provides next data transmission to remote PC.

For data transmission between this module and remote PC are used radio modems. Transmitted data are in PC visualized and saved for next analysis.

## 2. Materials and methods

Data transmission is ZigBee based. ZigBee is a standard for wireless data transmission. It is based on the IEEE802.15.4 standard for WPANs (wireless personal area networks). It is aimed to applications where extended battery life (15 ÷ 40 mA when transmitting – depends on chip producer) is needed and only low data rate (in kBps) is required. Bands available for ZigBee are 868MHz and 2.4GHz (Europe). Devices available are either modem like when they only retransmit data they receive (XBee) or equipped by programmable MCU where user can create own applications.

### 2.1. PAN4551/4555

SIP PAN4551 is based on the Freescale's first generation ZigBee transciever MC13193 and 8-bit MCU. PAN4555 is based on 2nd generation Freescale SiC MC13213. Both two are fully programmable and with full support for the SimpleMAC and the 802.15.4MAC. Data transmission band is placed in 2.4 GHz and divided into 16 channels. Power consumption is about 28 ÷ 40 mA during transmission (receive or send). It predetermines it to be battery powered.

### 2.2. XBee

The XBee/XBee-Pro is MaxStream's modem based on the the ZigBee standard. Unlike PAN4551/4555, XBee is not fully programmable. Its idea is to be a wireless UART replacement or an universal ZigBee transmitter (commanded by some control device) participating in the 802.15.4 networks.

### 2.3. Pulse oximetry

Pletysmograph OEM module ChipOX measures the non-invasive saturation by oxygen (SpO2), plethysmogram, pulse rate, body temperature and temperature of surroundings.

## 3. ECG measurement

### 3.1. ECG electrode treatment

A great problem occurs at ECG measurement. The medical instrument should be transportable and that's why the electrodes has to be part to not to manipulation illimitability. The problem rises how to create the electrodes which can by only put on the skin and not to be stickered by conducting stick or gel (dry electrode). Resulting this is clear that for constructing kind of the electrode should be no metal and gel. For the construction of this kind electrode the same principles were used as in common electrode. So the interface skin - electrolyte (gel) – metal. Instead electrolyte there was used aterial referred to as conducting polymer (Figure 2).

Charge transmission occurs with the help of alternating structure single bond and double bond and by the charge carrier furred similar to dosed operation.

**Figure 2.** Thin film of polyanilinu with thickness 100nm on lab dish

From that reason the polyamide is suitable matter for making dry bio potential electrode.

Conducting polymers are composed of long repeated constitutional group of chain. Common polymers like polyety-

len or polyvinylchloride are non-conducting and they are usually use as an insulating material. There has however been group of polymers which chemically conducting is. Examples include polyacetylene, polypyrrol, polythiofen, polyfenilen or poly (p-fenylen-vinilen).

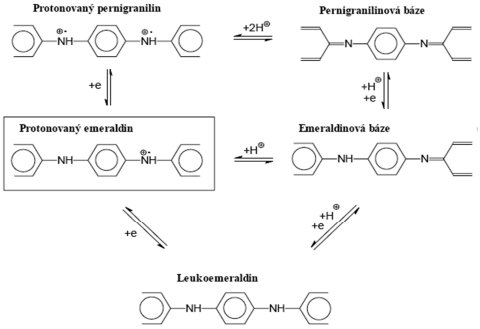


**Figure 3.** Forms of polyaniline

Their conductivity is 4 S.cm-1 is sufficient because they are settled in thin film form with thickness 100nm.

A production this type of electrode takes apx. 15 minutes and there is also a need for another 12 hours of desiccation. The production is very cheap and easy to attach for single use. For manufacturing the electrodes we can use it with advantages that weren't registered any toxic or irritable character. We can qualify it as harmless. The other advantage is to utilization of the material can be manufacture electrode on any matter to resisted acidic medium. Textile materials are fine to use it for electrodes and that is why the electrodes on Velcro fastener were made. Both side of Velcro fastener is covered by polyanilin.

### 3.1.2. ECG electrode tests

During a testing on three leads ECG were found of that manufactured electrodes are well usability. The measurement were done on ECG being short (pectoral) bipolar placement gained by bioamplifier g.BSamp, 16 channels from g.tec medical engineering GmbH and digitalized by A/D card NI DAQPad-6052E. The results were measured with common stick electrodes on computer at the same time. The result was mathematically compared and results were very good.

Electrodes were mounted on flexible t-shirt made on elastics fiber. Adherence pressure was too small to well connect skin with electrode and that is why the great interference voltage arose. Consequently were added the elastic belt on thoraxes to improve adherence pressure of the electrodes Figure 5.

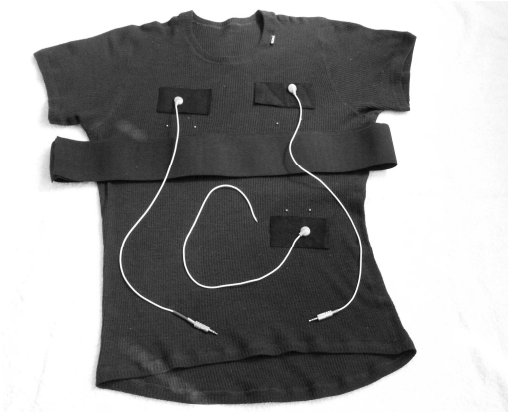

**Figure 4.** Distribution of ECG electrodes on the T- shirt

Out of signal record we can clearly see the changing level of a signal same direction constituent and also extend of a signals amplitude which is very interesting. This could be explained by the person who breathed in the moment and the tissue capacity under the electrode reduced. The signal could get into smaller tissue capacity. On the next picture there is a signals amplitude life cycle signified and its same direction component Figure 6. In the same time you can see low-frequency breathing caused by impedance changes.

## 4. Network design

IEEE 802.15.4 standard network was chosen because of cooperation with

XBee. XBee can participate in 802.15.4 star networks as an end device or a coordinator or in peer-to-peer networks. Because the structure of communication is mostly from data-gathering nodes to the storage and analysis device (computer in this case), star network was chosen (one PAN coordinator and two end devices). But in fact the peer-to-peer network can be used too.

Parameters of the network are: non-beacon, no security, acknowledge, logical channel is one of 13-23 selected by PAN on its startup (the one with the least energy / the preset one). Addressing is 16-bit in default but the coordinator handles also 64-bit (device serial number). Coordinator's PAN ID is preset.

The coordinator allows end device association by comparing with its table of granted devices (table of serial numbers) non-granted devices is refused automatically. End devices have the same table of granted coordinators so it cannot happen that device will associate to different coordinator.

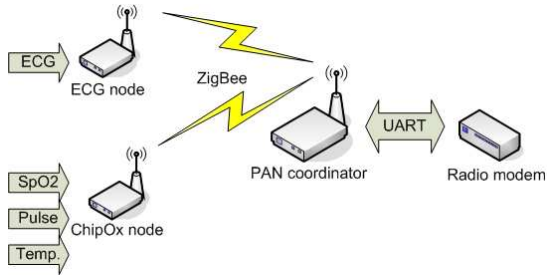


**Figure 5.** Zigbee Network Topology

Main data flow is from the ECG node (it has to transmit huge amount of sampled and filtered analog data) it transmits approximately every100ms and total amount is about 600B per second. Second node (ChipOx) with XBee sends significantly lower amount of data - at about 200 Bytes per second.

The PAN coordinator translates all the data and retransmits them to the PC.

## 5. Network realization

As can be see from network structure, network consists of three nodes. The first one is the PAN coordinator.

The PAN coordinator used is PAN4551. It was necessary to use PAN4551 because the coordinator has to handle communication with the PC initialization/de-initialization of end devices translate incoming packets, recognize devices. It is created as FFD without support for beaconed networks and without security. Program part is modified Freescale Beekit's output. Packets send to a PC have the same format as in the past project – original visualization can be used.

### 5.1. ChipOx Node

ChipOx node is based on the XBee. XBee here has the only obligation – to transmit incoming coded data from the ChipOx and send them to the coordinator. Communication from the coordinator to this device is direct because ChipOx does not know periodical polling (without sleep).


**Figure 6.** ChipOx node PCB

### 5.2. ECG node

ECG node uses PAN4551. PAN4551 is advantageous because it has 10bit ADC and can be programmed to buffer data and do some filtration. It samples data every 1ms and filters them before sending (or samples data every 2ms but without filtering). The only suitable filter for a biomedical signal and that sampling speed (combined with 8-bit processor) is a FIR filter.

This FIR filter (Hamming window) is a low-pass filter with cutoff frequency 150Hz and cuts undesired high frequencies and is used to downsample data to the half frequency. This filter had to be quantized to the 16bit binary unsigned fixed-point with range of 0 to ~1 (→ shifted 16bits right). This was the only way for the 8-bit architecture to handle calculations at so high frequencies.

Filter calculations can be divided in 8bit multiplications and 16bit additions (8bit and carry). To speed up calculations some additions can be removed (results in calculation error – but maximally error of 2). Whole filtering consumes from at about 10% of MCU time (11th order filter and downsampling) to 5% (7th order filter and downsampling) – for MCU bus frequency of 16MHz.

The data is buffered for 0.4 second. Filtering was used due to "bottleneck" of the radio-modem

## Conclusions

The biomedical data transmission system was successfully created using IEEE 802.15.4 standard cooperating with XBee.

There we used OEM modules for pulse oxymetry measurement and designed bioamplifiers for ECG measurement. There were used ECG dry textile electrodes.

Designed telemetry system were used for monitoring base life function of pilot of race vehicle powered by hydrogen

From so far acquired results of experiments we are able to observe that polyamides are suitable material for biopotential electrodes construction. But there is a need now to concentrate on measuring and monitoring of parameters long term firmness both an electrotechnical and a mechanical.

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