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Design of The Wireless Devices to Record Body Position for Sleep Apnea

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Abstract **– The aim of this paper is to design a device to record the conditions of the body in sleep apnea patients. For the diagnosis of sleep apnea usually the patient comes to a sleep lab and a sleep technician should always be in attendance and is responsible for attaching the electrodes to the patient and monitoring the patient during the study. The PSGs were analyzed for data on the respiratory disturbance index (RDI), time spent in each body position, number of apneic events in each position, oxygen saturation, and time spent in each stage of sleep. In this paper, we can measure the body movements and position with sensor attached to the body with sticky tape. This device is wireless and effective at limiting healthy subjects from sleeping in a supine position. Final results will be shown on the monitor and polysomnogram.**

Keyword **– Body position, sleep apnea, Polysomnogram, wireless.**

1. INTRODUCTION

Sleep apnea is very attractive[1-3]. Sleep apnea is a sleep disorder characterized by pauses in breathing or instances of shallow or infrequent breathing during sleep. Each pause in breathing, called an apnea, can last for several seconds to several minutes, and may occur 5 to 30 times or more in an hour [4]. Sleep apnea is often diagnosed with an overnight sleep test called a polysomnogram, or "sleep study".

There are three forms, central (CSA), obstructive (OSA), and complex or mixed sleep apnea for sleep apnea. Obstructive sleep apnea (OSA) is the most common category of sleep-disordered breathing. Unsuitable Position is one of the main reasons for the Obstructive sleep apnea during sleep, Hence Sleeping on the left or right side useful in reducing symptoms.

Device Proposed in reference [5], effective at limiting healthy subjects from sleeping in a supine position. The device appears to be most effective between 150° and 230°. In [6], sixteen patients with positional OSA used the device for record of the body condition. With Using from this device and test it in 8 hours value of apnea-hypopnea index (AHI) decreased from 26.7 ± 17.5 to 6.0 ± 3.4, oxygen desaturation (3%) index also fell from 18.4 ± 11.1 to 7.1 ± 5.7 and time spent supine fell from 42.8 ± 26.2% to 5.8 ± 7.2%. Results in reference [7] demonstrate that the feasibility of implementing an accelerometer based portable device as a simple and cost-effective solution for contributing to the screening of sleep apnea-hypopnea syndrome and other breathing disorders.

In this paper, the body position measure with sensors attached to the body with sticky tape and it shows the five states of prone, supine, left, right and upright. Usually with movement of patient the wires of device is cut and it will be has fault but in this paper the device is wireless and with movement of patient, can sent relevant information up to 100 meters.

This paper is organized as follows. Section 2 deals with the introducing of the polysomnography. In section 3, we present the design of wireless device. Later, some simulations are executed to verify the validity of the device in section 4. Finally, in section 5 we able to concludes the results of this paper.

2. POLYSOMNOGRAPHY

Polysomnography is a sleep study and it shown in figure(1) [8]. PSG evaluation is necessary because physiological functions change during the sleeping state and many disorders are specifically induced by sleep. A sleep study measures your sleep cycles and stages by recording:

- Air flow in and out of your lungs as you breathe
- The level of oxygen in your blood
- Body position
- Brain waves (EEG)
- Breathing effort and rate
- Electrical activity of muscles
- Eye movement
- Heart rate

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Fig. 1. The polysomnography device

Information is gathered from all leads and fed into a computer and outputted as a series of waveform tracings which enable the technician to visualize the various waveforms, assign a score for the test, and assist in the diagnostic process. The analysis of PSG device is shown in figure 2.

States of the patient is shown in section "position" of figure(2). Accurate body position monitoring is important to the diagnosis of sleep-disordered breathing.

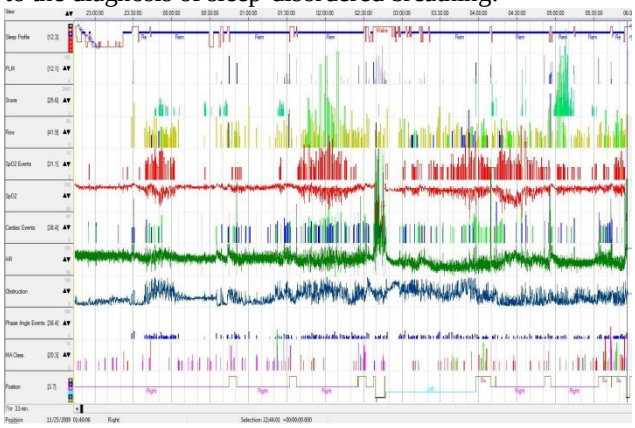
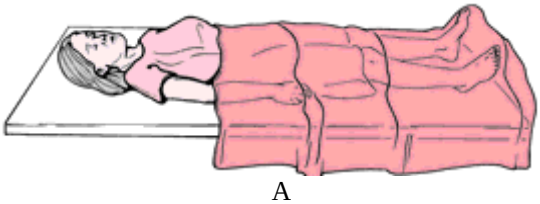


Fig. 2. Analysis of PSG device

The body position sensor is designed to easily and comfortably mount onto thoracic respiratory effort belts and are compatible with most PSG systems. Output signals of sensor are prone, supine, left, right, upright. this cases are shown in figure (3).



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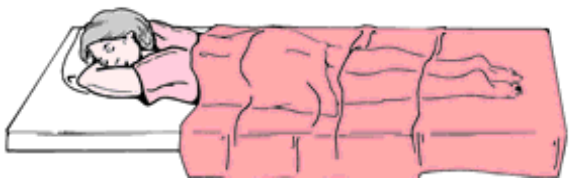

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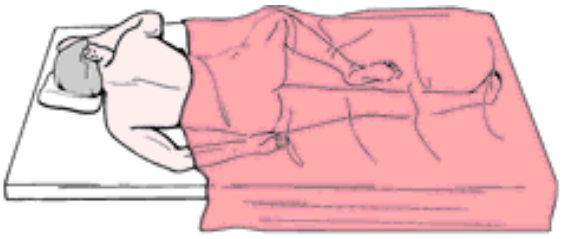

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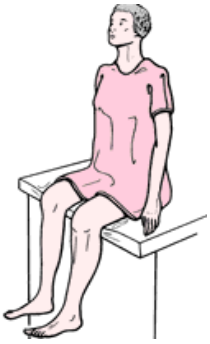

D

Fig. 3. A) supine, B) prone, C) left or right, D) upright

3. Design of the Wireless Body Position

Pro-Tech body position sensors is shown in figure (4). It have the ability to identify 5 primary sleep positions. Body position can be continually monitored no matter how much the patient moves during sleep.

Fig. 4. Pro-Tech body position sensor

Table (1)Pro-Tech and wireless body position sensors

Product Prices			
Product	Size	System	Price
Pro-Tech body position sensor	Newborn (34-40cm)	SPI Sensor DC	$240.00
Wireless body position	34-40cm	I2C Sensor Digital	$80

As seen in the table(1), sensor pro-tech has the following disadvantages[9]:

1- high price positioning sensor used
2- The lack of wireless sensor positioning

3- Excessive damage (with patient of movement the wires of device is cut and the device has faulty)

The wireless body position device is fastened to the chest using a velcro strap (figure 5). In this case, output signals of sensor sent to receiver, then voltage of proportional is produced.

Fig. 5. The device on the patient's body

In this paper, a MPU-6000/6050 from company " Invensense" was used. sensor is shown at figure(6) in three Axis. In order to define the angles of the accelerometer in three dimensions the pitch, roll and theta are sensed using all three outputs of the accelerometer. Pitch (ρ) is defined as the angle of the X-axis relative to ground. Roll (φ) is defined as the angle of the Y-axis relative to the ground. Theta (θ) is the angle of the Z axis relative to gravity.[10]

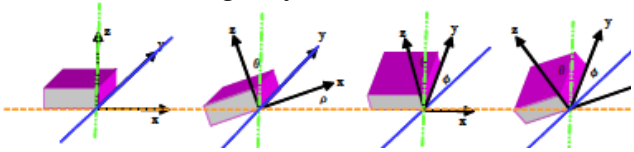

Fig. 6. Three axis for measuring tilt

Measuring angles as following [9]:

$$\rho = \arctan\left(\frac{A_X}{\sqrt{A_Y^2 + A_Z^2}}\right) \quad (1)$$

$$\varphi = \arctan\left(\frac{A_Y}{\sqrt{A_X^2+A_Z^2}}\right) \quad (2)$$

$$\theta = \arctan\left(\frac{\sqrt{A_X^2+A_Y^2}}{A_Z}\right) \quad (3)$$

As shown in the figure(7), the MPU-6000/6050 devices combine a 3-axis gyroscope and a 3-axis accelerometer on the same silicon die together with an on board digital motion processor™ (DMP™) which processes complex 6-axis Motion Fusion algorithms. The device can access external magnetometers or other sensors through an auxiliary master I²C bus, allowing the devices to gather a full set of sensor data without intervention from the system processor.[11]

Fig. 7. MPU-6000/6050™ System Diagram

Detection sleep mechanism done based on changes of static acceleration. Static acceleration will change due to the changes in body position. Data generated by the sensor Sent to the first microcontroller and then the microcontroller with data processing detects sleep state patients (five state of prone, supine, left, right and upright) and this information was sent to the transmitter and module send data to a receiver. Finally, receiver delivers the received data to the microcontroller and it generated a electrical signal by process the data. After determining the sleep mode, the amount specific in binary system was a placed on a port. With a voltage divider Between resistances and Reduce diode voltage drop, dc voltage is obtained by using the following equation:

$$V_{DC} = \frac{R_1}{R_1+R_2} \times (5 - 0.7) = \frac{R_1}{R_1+R_2} \times 4.3 \quad (4)$$

Block diagram of the system is shown in figure (8).

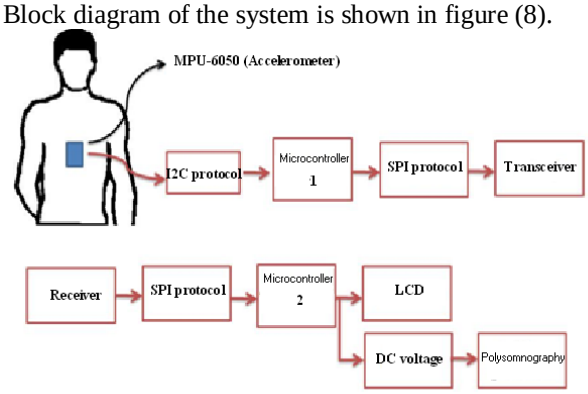

Fig. 8. Block diagram of the recording system body position consist of sensors accelerometer, a microcontroller and transceiver

4. SIMULATION

Hardware was includes of the receiver and transmitter.

Transmitter:

As shown in figure (9), a accelerometer on the transmitter was located. The power circuit in transmitter consists of a two-pin connector for connecting to battery, a rectifier and protection diode, a capacitor to eliminate noise, resistance of pull up for a I2C protocol, a microcontroller atmega 8, NRF SMD module transmitter 2.4 GHz, GY-521 and a module for reading the static acceleration.

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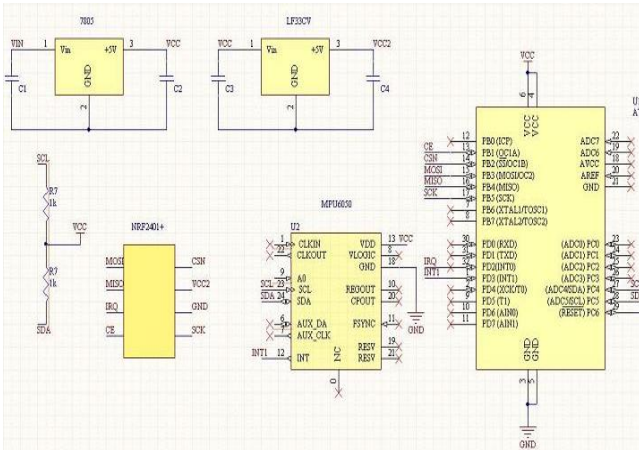

Fig. 9.Transmitter and sensor

Receiver:

As shown in figure (10), the circuit feeding in the receiver consists of a two-pin connector for connecting the power supply, a regulator of five volt to power the microcontroller, 2 * 16 LCD, a regulator of 3.3 volt for feeding the NRF, two capacitors to eliminate noise, six resistors R1, R2, R3, R4, R5, R6, five 1N4007 diode to generate a voltage divider, a microcontroller atmega 16SMD and a NRF module transmitter 2.4 GHz.

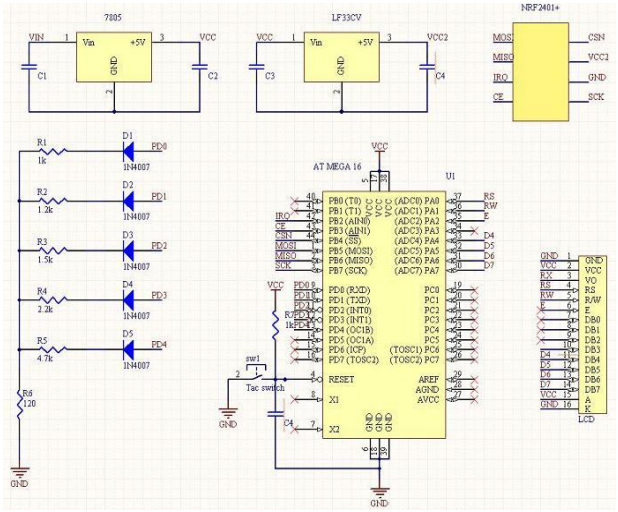

Fig. 10.Receiver and the blocks of the DC voltage

The DC voltage generated by the receiver for each case are shown in table 2.

Table (2) The DC voltage was generated to determine the position of the body in five states

Type of state	supine	right	left	upright	prone
DC voltage	131mv	248mv	341mv	420mv	484mv

Figure 11 shown sample of analysis of device in order to determine the body position using wireless sensor design.

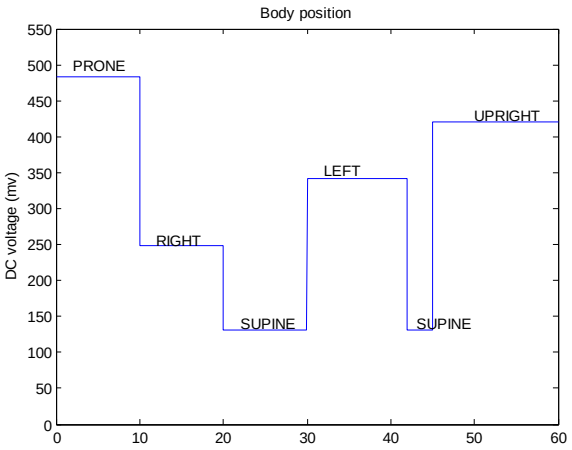

Fig. 11.The sample of analysis of device using wireless sensor

9. CONCLUSION

In This study, according to figure (11) and table (2), the device can be reduce the number of apnea and avoid sleeping on supine for OSA and snoring. According to table (1) the advantages of sensor are:

- ✓ The device is small.
- ✓ The device could sent relevant information up to 100 meters.
- ✓ A rechargeable lithium polymer battery
- ✓ wireless module has high speed
- ✓ The MPU6050 has high accuracy.
- ✓ Network a large number of sensors

Thus, this device with abovementioned characteristics, can be potentially a therapeutically proposal to patients whom OSA for it's cost effective.

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