Development of Wireless Central Monitor Using X-bee Pro S2C (Electrocardiogram and Heart Rate)

Bariroh Izzatul Ulumiddiniyah#, Bambang Guruh Irianto, M. Thorib Hamzah
Department of Medical Electronics Engineering Technology Poltekkes Kemenkes Surabaya
Jl. Pucang Jajar Timur No. 10, Surabaya, 60245, Indonesia
barizza58@gmail.com, bgi_ps@yahoo.com, toribhamzah@gmail.com,

Article Info

Article History:
Received Sep 9, 2019
Revised May 20, 2020
Accepted Jun 11, 2020

Keywords:
Electrocardiogram,
X-Bee Pro, BPM.

Abstract

Centralized monitoring of the condition of patients with serious conditions that are carried out continuously and in real-time is very important. in the development of previous researchers have some shortcomings, namely sending data still using cable, completeness of parameters that are still small, close delivery distance, not real-time, and continue. The purpose of this study is that the thick system is done wirelessly, more parameters, longer delivery distance, and can monitor electrocardiogram and heart rate in real-time and continue. the contribution of this research is that the wireless system can send ECG and bpm in real-time, long-distance, and continuously. To make deliveries in real-time, this study uses 2 transmitters and 2 receivers. Electrocardiogram signal obtained from tapping Lead II, then processed using a microcontroller circuit and the results in the form of a heart signal will be. Data is sent using X-Bee Pro. Data is displayed in the form of a patient's heart and BPM signals. In measuring BPM values obtained error values in module 1 0.1388% for BPM 240 and 0.093% for BPM 180, in module 2 0.1388% for BPM 240 and 0.185% for BPM 180, data transmission can be done well at a distance of 8 meters, 10 meters, and 25 meters with a barrier. The results of this study indicate that sending wirelessly can be done at a certain distance and in real-time. This research can be implemented in a central monitor in a hospital with more patients.

Corresponding Author:
Bambang Guruh Irianto
Department of Medical Electronics Engineering Technology
Poltekkes Kemenkes Surabaya
Jl. Pucang Jajar Timur No. 10, Surabaya, 60282, Indonesia
Email: bgi_ps@yahoo.com

I. INTRODUCTION

Central monitoring of the condition of patients with serious conditions that are carried out continuously and in real-time is very important. Especially in some particular rooms, such as ICU and Infection Room. As in hospitals, there are several centralized patient monitors using cables, which the cable installation need special installation, especially if the patient's room and the monitor room distance requires a precise measurement of the cable length, most central patient monitors in the hospital use cables as a connector to the monitoring monitor so that the utilization of wireless can be used. This can facilitate paramedics to easily detect the patient's condition, continually. Electrocardiogram (EKG) is electrical activity in the heart, in the form of a signal-shaped picture, which is very important to be one of the diagnostic parameters of heart disease and heart conditions [1]. ECG signals that have been displayed taken from one's heart rate value and it can be used as one of the diagnose parameters to a heart disease with the units of beats per minute (BPM). Different values can be obtained from human heart rate values, for a normal heartbeat the range are 60 to 100 beats per minute, but it can depend to different age and sex, and it can be concluded from the heart rate value that when the heartbeat is less than 60 bpm is called Bradycardia whereas when the heartbeat is more than 100 bpm is called Tachycardia [2].

Some researchers have talked about monitoring one's health condition. This health monitoring is very important especially for people with certain body conditions or have a history of previous illnesses. This health monitoring includes reading ECG signals, BPM, body temperature, SPO2 values, and a person's blood pressure. However, some of these studies have only done one reading of some of these parameters[3][4][5][6][7][8][9][10]. In other studies have discussed monitoring the condition of patients with several parameters, namely the ECG and the patient's heart rate. In this study, a central transmission has been displayed on one monitor, but the shortcomings of this device are still using PL2303 or cable media as a delivery[11]. Some other researchers discuss the monitoring of one's body's health centrally using wireless as an alternative to cable in sending data, one of which is using HC-11 modules, but in this study has the disadvantage of sending distance only ± 10 meters [12][13]. Some researchers further discuss the use of wireless Xbee, XBee modules are very popular in wireless communication because they have features such as low power consumption (40mA, 3.3 V), low transmission power of 2mW (+3 dBm), and wider transmission capabilities [14][15][16][17][18]. Purnima has conducted research on

Zigbee and GSM-based patient health monitoring, the research measuring body temperature, heart rate, and electrocardiogram that utilizes Zigbee's wireless system as data transmission, but this research was carried out from one patient to one monitor [19]. In Gong, Tan, and Liu's research on the management of the position of patients with mental illness in Zigbee-based hospitals has the advantage of being able to monitor the patients' position and their activities in real-time, but in the research, it has not been equipped with patient health monitoring support [20]. In some studies using Xbee wireless, delivery can be done with several nodes or more than one patient to one coordinator, but some of these studies have the disadvantage of random delivery errors that occur so it is not suitable to be used as vital monitoring in humans in real-time.[21][22]. Sharma and Vashisth have researched the Zigbee-based central patient monitor where the advantages of this tool are already using a mesh network for sending some of its parameters, but the center display is using Matlab and the ECG signal results that are not yet clear[23]. Bhat, Kaul, Gupta, and Prakash have researched the use of signals from hand movements to detect changes in the direction of a wheelchair using Zigbee technology so that its reach is wider, but this research has the shortcoming that it has not been directed at direct implementation in the medical field for use on disabled people [24]. In Aparna, Yaswanth, Nair, Ganesan, and Akshay's research on ECG monitoring and heart rate value processing, the advantages of this study are the use of computer technology to provide a more precise and faster diagnosis, but this research also has a shortcoming in the process of sending data that can be accessed by doctors via the web so that it requires a good wifi network so that it does not affect the diagnosis timeliness [25]. In Borrero, Jimenez, and Anzola's research on ECG monitoring with an appearance on an android application using Bluetooth that can be easily accessed, is an advantage in this research, but this research also has the shortcoming of not being equipped with the processing and displaying of BPM values so ordinary people who use ECG monitoring cannot understand the initial conditions of the patient [26].

Based on the identification of the problem above, the purpose of this research is to create a Personal Computer (PC)-Based Central Monitor via Wireless (Electrocardiogram and Heart Rate Parameters). Development that can be carried out is monitoring through the central system using wireless or without using cable media as the data transmission that sent in real-time using 2 transmitters and 2 X-Bee Pro module receivers and displayed on one monitor. The results displayed are in the form of an electrocardiogram signal and the patient's heart rate.

This article is composed of: Chapter II which contains Material and Methods, Chapter III which contains results, Chapter IV contains discussion, and Chapter V contains Conclusion.

II. MATERIALS AND METHODS

A. Experimental Setup

The collection of electrocardiogram signal delivery and BPM values data were carried out with 2 respondents at a distance of 8m, 10m, 25m, and 30m. The interpretation of BPM was carried out 6 times on BPM 30-240 using Phantom Fluke (MPS450 Multiparameter simulator).

B. Materials and Device

This study was used the TL084 IC as a basic set of instruments, the X-Bee Pro S2C wireless as a shipping module equipped with a shield and an X-bee adapter. Arduino UNO was used as the data processing, and a monitor as the displayer.

C. Experiment

In this study, BPM measurements were carried out 30-240 in Module 1 and Module 2 where the results will be compared with Phantom as standard. Transmission using wireless X-Bee is carried out at different distances and the results can be seen on the display monitor.

D. The Diagram Block

The block diagram consists of the transmitter diagram block module 1 (**Fig.1**), the transmitter diagram block module 2 (**Fig. 2**), and the receiver diagram block (**Fig.3**).

In (**Fig. 1**) (**Fig.2**) the heart signal is detected by a series of instruments that are attached with the help of electrodes for tapping the patient's heart signal. The instrumentation output will be filtered using LPF and HPF filters with frequency values according to the heart signal frequency and amplified by the amplifier. Furthermore, the series output will be adjusted, so that the reference value can be read by the microcontroller using an adder circuit so that no signal data is cut off or lost. Adder series output will be connected to a microcontroller that functions to convert from analog data into digital data. Then the data is sent by the transmitter using a wireless module.

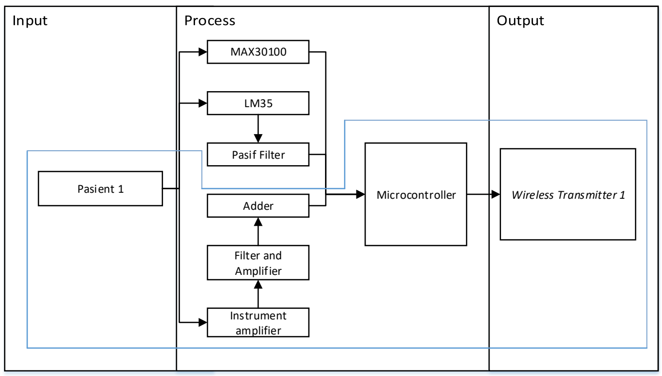

Fig. 1. Transmitter Diagram Block 1

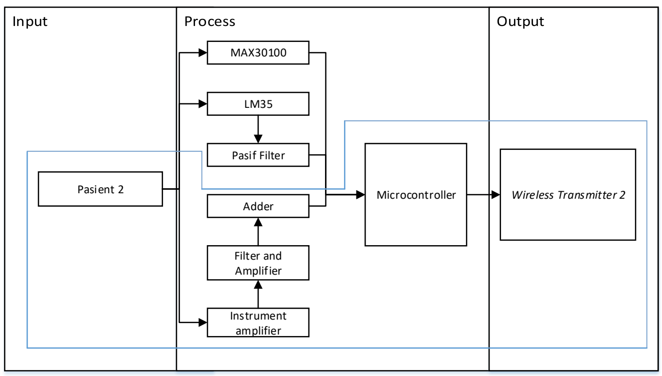

Fig. 2. Transmitter Diagram Block 2

In (**Fig.3**) the data sent will be received by the receiver block using the wireless module and the data received will be processed and displayed on the PC, by

DOI: 10.35882 / ijeemi.v2i1.76; ISSN: 2656-8624

calling the data according to the value of COM/data input. The data will be displayed in ECG signals and BPM values chart.

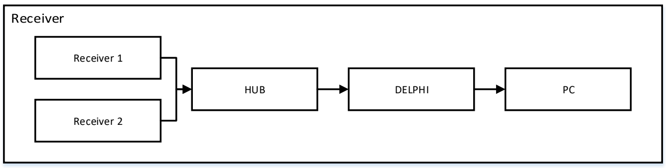

Fig. 3. Receiver Diagram Block

E. The Flowchart

Flowcharts consist of a sender flowchart (**Fig. 4)** and a receiver flowchart (**Fig. 5**).

In the transmitter block (**Fig. 4**), when the device is turned on, the user attaches electrodes to the patient for tapping the heart signals. After the device is turned on it will initialize, so the ADC data will be obtained from the leads of the ECG instrumentation which will be processed on the microcontroller and sent through the transmitter.

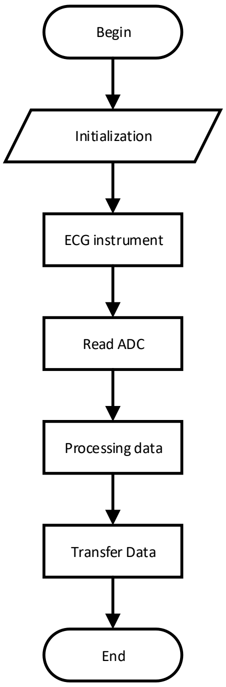

Fig. 4. Transmitter Flowchart

In the receiver block (**Fig. 5**), the user connects/starts on the PC to call input data from the receiver. After connecting to the PC, it will initialize the software. Data received from the receiver is then displayed in the form of signals and BPM values.

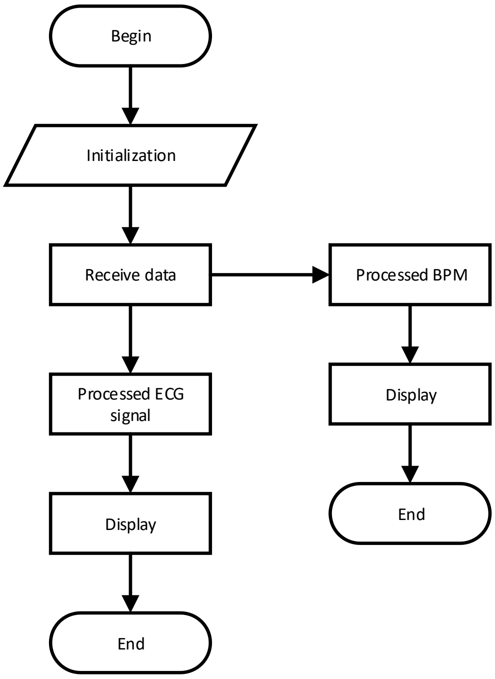

Fig. 5. Receiver Flowchart

F. Circuit

1) Circuit of microcontroller

In (**Fig. 6**) this processing circuit uses an Arduino Uno microcontroller IC ATmega 328, where all the outputs of the modules are connected to the analog pin. Also, this whole series has been connected to the X-Bee wireless module as the data transmitter in the form of ECG signals and BPM values.

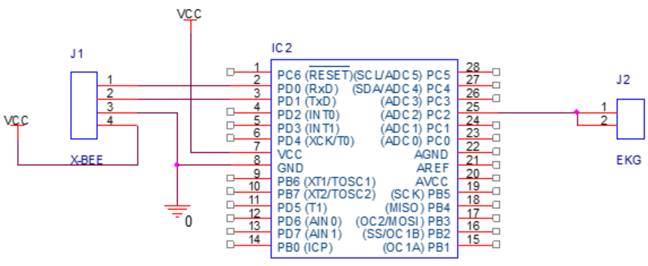

Fig. 6. Circuit of microcontroller

2) Circuit of Instrumentation

In (**Fig. 7**) The instrument amplifier series is composed of a series of differential amplifiers and a buffer. To set the desired amplifier is set by varying the value of Rg (resistor gain). This series serves to amplify the signal obtained from the body through the electrodes, at the output, there is still a lot of noise (unwanted signals). Using IC TL084 as a basic instrument.

DOI: 10.35882 / ijeeemi.v2i1.76; ISSN: 2656-8624

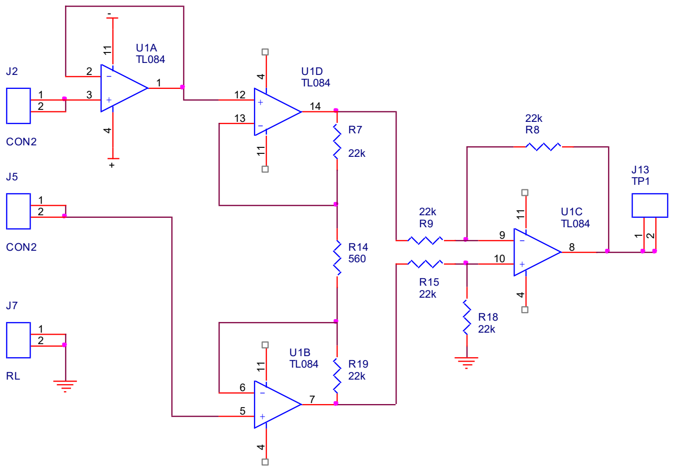

Fig. 7. Circuit of instrumentation

3) *Circuit of High Pass Filter*

In (**Fig.** 8) High pass filter (HPF) is a type of filter that has a function of passing high frequency and suppressing low frequency or which is less than the cut off frequency. The high pass filter used in this circuit is a passive high pass filter, a simple circuit consisting of one resistor and one capacitor.

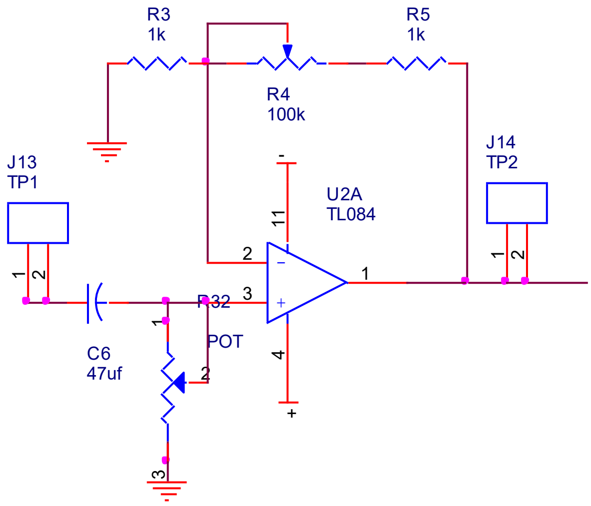

Fig. 8. Circuit of high pass filter

4) *Circuit of Low Pass Filter*

In (**Fig.** 9) Low Pass Filter (LPF) is one type of filter that serves to pass low frequencies and suppress frequencies higher than the cut-off frequency.

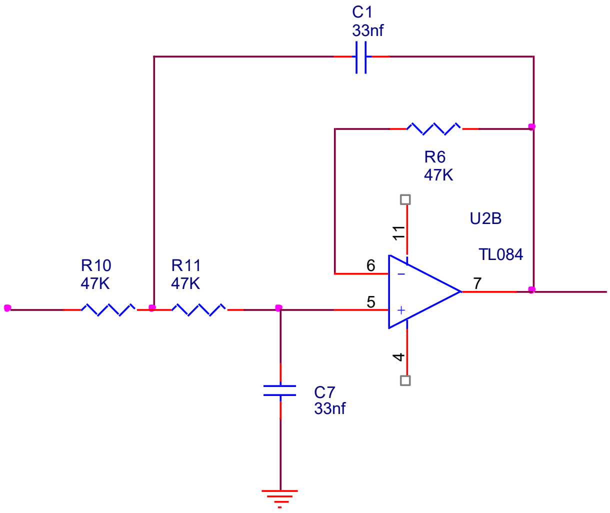

Fig. 9. Circuit of low pass filter

5) *Circuit of Notch Filter*

In (**Fig. 10**) Band notch filter (bandstop filter) functions to hold a signal that has a frequency by the cut-off frequency and will pass a signal that has a frequency outside the cut-off frequency either less than or more than the cut-off frequency.

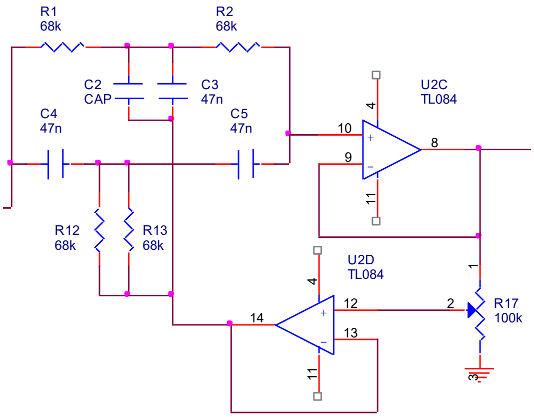

Fig. 10. Circuit of notch filter

6) *Wireless*

The transmitter block (**Fig. 11**) connects the wireless X-bee to the minimum system (Arduino Uno) contained in each module (in modules 1 and module 2) which is assisted by an X-bee shield for Arduino Uno.

DOI: 10.35882 / ijeeemi.v2i1.76; ISSN: 2656-8624

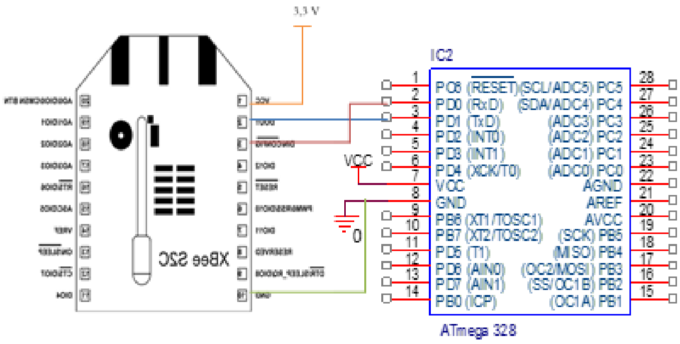

Fig. 11. Circuit of transmitter

The receiver block (**Fig. 12**) connects the X-Bee wireless module and the USB which is then HUB between receiver 1 and receiver 2 to be connected to the PC.

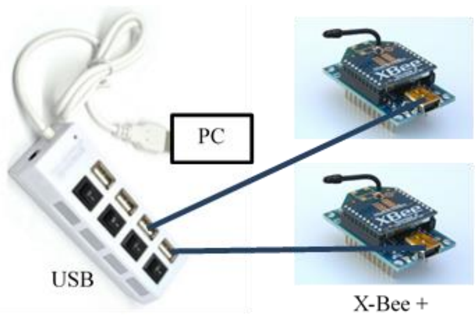

Fig. 12. Transmitter block series

III. RESULTS

A. ECG Series Results

In (**Fig. 13**) is an instrument amplifier circuit board with 3 tapping inputs. This series serves to amplify the signal obtained from the body through the electrodes, at the output, there is still a lot of noise (unwanted signals). Using IC TL084 as a basic instrument.


Fig. 13. ECG instrument series results

B. *Calculation results of instrumentation*

$$Acl = 1 + \frac{2R}{Rg}$$

$$= 1 + \frac{44k}{560}$$

$$= 1 + 78{,}57$$

$$= 79.57 \text{ kali}$$

C. *Calculation results of high pass filter and amplifier*

$$fc = \frac{1}{2\pi RC}$$

$$fc = \frac{1}{2x3{,}14x16{,}5x10^3x47x10^{-6}}$$

$$fc = \frac{1}{2x3{,}14x775{,}5x10^{-3}}$$

$$fc = \frac{1}{4870{,}14x10^{-3}}$$

$$fc = \frac{10^3}{4870{,}14}$$

$$= 0{,}205 \ Hz$$

$$Acl = 1 + \frac{2R}{Rg}$$

$$= 1 + \frac{44k}{560}$$

$$= 1 + 78{,}57$$

$$= 79.57 \text{ kali}$$

D. *Calculation results of low pass filter*

$$fc = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$$

$$fc = \frac{1}{2\pi\sqrt{47x10^3x47x10^3x33x10^{-9}x33x10^{-9}}}$$

$$fc = \frac{1}{2\pi\sqrt{2209x1089x10^{-12}}}$$

$$fc = \frac{1}{6{,}28\sqrt{2405601x10^{-12}}}$$

$$fc = \frac{1}{6{,}28x1{,}551x10^{-3}}$$

$$fc = \frac{1000}{9{,}74028}$$

$$fc = 102{,}6665 \ Hz$$

E. *Calculation results of notch filter*

$$fc = \frac{1}{2\pi RC}$$

$$fc = \frac{1}{6{,}28x68kx47n}$$

$$fc = 49{,}82 \text{ Hz}$$

F. *Transmitter Series*

In (**Fig. 14**) is a transmitter board consisting of Arduino Uno, shield X-Bee, and X-Bee Pro S2C.

DOI: 10.35882 / ijeeemi.v2i1.76; ISSN: 2656-8624

Fig. 14. Transmitter series result

G. Listing of programs for initialisation

```
//-------------------bpm------------------//
unsigned long waktuBPM,waktuawal=0;
float ref,hold, BPMpalsu ;
int ecg;
int BPMasli;
int b=0;
void setup() {
 Serial.begin(9600);
 }
```

The program above is used to enter variable initiation to provide baud rate commands and settings.

H. Listing program for BPM processing

```
void loop()  {
 //-----------------ECG&BPM----------------//
 ecg=analogRead(A1);
   //=pembacaan    output    rangkaian    dan
autoreferensi=====  //
       if (ref<=ecg){ref=ecg;}
   else{ref=ref;hold=(ref*0.75);}

   //==========Pembacaan===============//
   waktuawal=millis()-waktuBPM;
   if (ecg>hold)
   {
    b=1;
   }
    if (ecg<(hold*0.5))
    {
    if(b==1){
    BPMpalsu++;
    hold=0;
    b=0;
    ref=0;
    }
if(BPMpalsu==3){
    BPMasli=180000/waktuawal;
    BPMpalsu=0;
    //ref=0;
    waktuBPM=millis();
```

```
  }}
```

The program above explains that the ECG tapping output is connected to A1 for BPM value processing by auto reference, where there is a use of hold which states the recalculation when it meets the requirements specified above.

I. Listing program for shipping

```
     //----------------KIRIM  PAKET------------
//
     Serial.print("a");
     Serial.print(ecg);
     Serial.print("b");
     Serial.print("c");
     Serial.print(BPMasli);
     Serial.print("d");
```

The program above is used to send ECG and BPM data processing results. Each parameter is sent using the respective shipping package which will later be adjusted to the address on the application that appears on the PC.

J. Error value from BPM measurement

In **(Fig. 15)** is the result of measurements in module 1 which were carried out each time 6 times using phantom measurements at bpm 30-240. At BPM 180, there are as many readings as the standard at X3 measurements and 240 read differences occur at measurements X2, X3, X4, and X5. So that the error value obtained at 180 bpm was 0.093% and 240 bpm was 0.1388%.

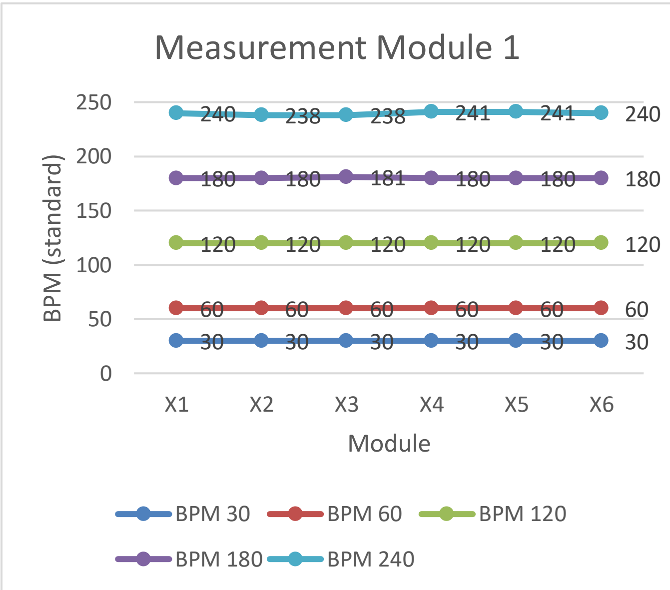

Fig. 15. Measurement result of module 1

In **(Fig. 16)** is the result of measurements in module 2 which were carried out each time 6 times using phantom measurements at bpm 30-240. At BPM 180, there are as many readings as the standard at X2 measurements and 240 read differences occur at measurements X2 and X5. So that the error value obtained at 180 bpm was 0.0185% and 240 bpm was 0.1388%.

DOI: 10.35882 / ijeeemi.v2i1.76; ISSN: 2656-8624

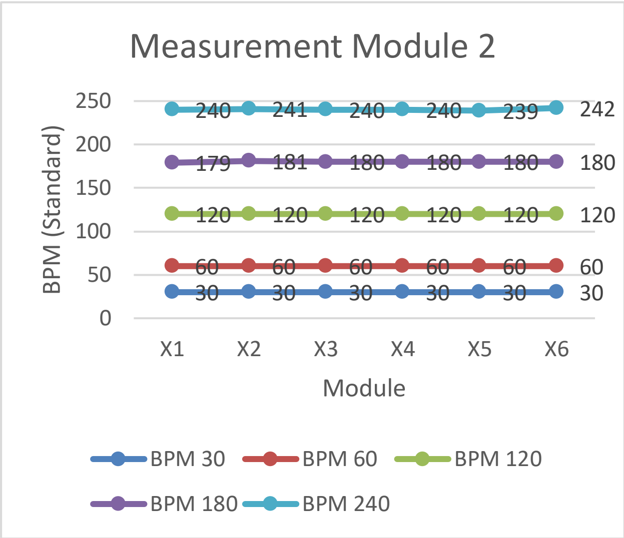

Fig. 16. Measurement result of module 2

In **(Fig. 17)** is the transmitter result of module 1 and module 2 together with the barrier at a distance of 25 meters, it is known that the ECG signal and the BPM value are still well transmitted.

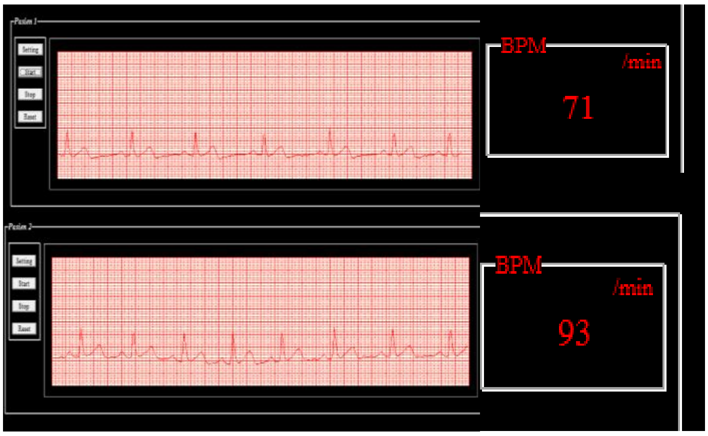

Fig. 17. The transmitter results of module 1 and module 2 with a distance of 25 meters

IV. Discussion

Based on the results of the module above, the ECG signal is the result of leads on Lead II using a series of instruments equipped with several filters. Instrument output of 79.57x, high pass filter with frequency cut-off of 0.205 Hz, amplifiers have gain of 79.57x, low pass filter with frequency cut-off 102.6665 Hz, and notch filter with frequency cut-off of 49.82 Hz. (Table I) (Table II) shows the results of measuring BPM using phantom obtained error values in module 1 0.1388% for BPM 240 and 0.093% for BPM 180, in module 2 0.1388% for BPM 240 and 0.185% for BPM 180 . in (Fig. 12) shows the results of the delivery carried out between spaces with a ± 25 m wireless distance barrier with X-Bee Pro, related to the signal shape visible PQRST waves so that the BPM value can be read properly. In the study [12] has carried out the same measurement using phantom, but has an error value on the overall error reading on BPM 180 has an error value of 0.99926% and wireless delivery is only at a distance of ± 10m using HC-11. This is very important, sending monitoring centrally using Wi-Fi can be used as an alternative to cable replacement [15]. In a centralized monitoring method, what needs to be improved is the use of 1 receiver for several transmitters.

V. Conclusion

The purpose of this study is to create a personal computer-based central monitor using wireless X-bee Pro two transmitters and two receivers to centrally monitor ECG signals and heart rates. This research has found the delivery of ECG signals lead II and heart rates wirelessly or without cable. the use of X-bee modules enables data transmission in real-time and 25 meters range with obstructions. Wireless delivery could be used as a technology to improve the quality of medical services.

References

[1] H. Ronald, "HEART and BLOOD CIRCULATION," vol. 4, 2011.

[2] H. AL-Ziarjawey, "Heart Rate Monitoring and PQRST Detection Based on Graphical User Interface with Matlab," *Int. J. Inf. Electron. Eng.*, vol. 5, no. 4, pp. 311–316, 2015.

[3] H. L. Yuan, J. Wang, J. Liu, and S. L. Li, "Research of Zigbee and big data analysis based pulse monitoring system for efficient physical training," *Procedia Comput. Sci.*, vol. 80, pp. 2357–2361, 2016.

[4] D. H. Gawali and V. M. Wadhai, "Implementation of ECG sensor for real-time signal processing applications," *2014 Int. Conf. Adv. Electron. Comput. Commun. 2014*, 2015.

[5] B. G. Irianto, B. Budhiaji, and D. H. Andayani, *TELEMETRY BASED HEART MONITORING TOOLS*. 2017.

[6] E. Spanò, S. Di Pascoli, and G. Iannaccone, "Low-Power Wearable ECG Monitoring System for Multiple-Patient Remote Monitoring," *IEEE Sens. J.*, vol. 16, no. 13, pp. 5452–5462, 2016.

[7] R. Piyare and S. Lee, "Performance Analysis of XBee ZB Module Based Wireless Sensor Networks," no. April 2013, 2014.

[8] H. Kumbhar, "Wireless sensor network using Xbee on Arduino platform an experimental study," *Proc. - 2nd Int. Conf. Comput. Commun. Control Autom. ICCUBEA 2016*, 2017.

[9] H. Daud, N. F. I. Gulcharan, M. A. M. Azhar, M. Z. Samsudin, N. M. Nor, and T. Ibrahim, "Monitoring heart rate and body temperature using wireless technology (Zigbee)," *Appl. Mech. Mater.*, vol. 490–491, pp. 1565–1574, 2014.

[10] T. Suryani Sollu, M. Bachtiar, A. Amir, and B. Bontong, "Heart Rate and Body Temperature Monitoring System Using Arduino," *Agustus*, vol. 17, no. 3, pp. 323–332, 2018.

[11] S. Abdilah, "Central Patient Monitor Based on Personal Computer (PC) (Electro Cardiograph and Heart Rate Parameters)," 2018.

[12] M. Nezar, B. G. Mufarid, Abdullah, Irianto, and A. Pudji, "Central Monitor Based On Personal Computer Using One Wireless Receiver," vol. 1, no. 1, pp. 7–13, 2019.

[13] A. B. Dhariyanto and D. Titisari, "CENTRAL MONITOR BASED ON PERSONAL COMPUTER (PC) VIA WIRELESS (ELECTROCARDIOGRAPH AND HEART RATE PARAMETERS)," 2018.

[14] M. Noushad, B. Tauheed, S. A. Khan, and A. Khan, "Wireless Monitoring of Temperature and Humidity Using Sensor Array," 2015.

[15] T. Sumalan, E. Lupu, R. Arsinte, and E. Onaca, "Low-cost wireless system for patient monitoring," *2015 E-Health Bioeng. Conf. EHB 2015*, pp. 2–5, 2016.

[16] I. N. B. Hartawan and I. G. M. N. Desnanjaya, "Zigbee Protocol Performance Analysis Inside And Out Of The Room As A Data Communication Media On The Wireless Sensor Network," *J. Resist. (Rekayasa Sist. Komputer)*, vol. 1, no. 2, pp. 65–72, 2018.

[17] T. P. Sari, Darwinson, and R. Aisuwarya, "Heart Rate Monitoring System Using Arduino Microcontroller and Xbee Communication Module," *J. Semin. Nas. Sains*, vol. 1, no. 1, pp. 1–9, 2015.

DOI: 10.35882 / ijeeemi.v2i1.76; ISSN: 2656-8624

[18] L. Ardiyanto and R. Sumiharto, "Implementation of Xbee Based Wireless Sensor Networks Case Study of Temperature and Humidity Monitoring," *IJEIS (Indonesian J. Electron. Instrum. Syst.*, vol. 2, no. 2, pp. 119–130, 2012.

[19] P. S. Purnima, "Zigbee and GSM based patient health monitoring system," *2014 Int. Conf. Electron. Commun. Syst. ICECS 2014*, 2014.

[20] G. Jiangtao, T. Chuanwu, and L. Lijun, "A Mental Patient Positioning Management System in Hospital-Based on ZigBee," *Proc. - 2017 Int. Conf. Robot. Intell. Syst. ICRIS 2017*, pp. 5–7, 2017.

[21] S. Hadiyoso, R. Mayasari, and A. Rizal, "The effect of mesh network on ECG data transmission by XBee toward the data error rate," *ARPN J. Eng. Appl. Sci.*, vol. 10, no. 20, pp. 9442–9446, 2015.

[22] S. Pathak, B. Kumar, T. Rashid, and A. Kumar, "Energy-efficient intra-hospital multi-patient cardiac monitoring through ZigBee network," *2nd Int. Conf. Signal Process. Integer Networks, SPIN 2015*, pp. 400–404, 2015.

[23] S. Sharma and R. Vashisth, "Zigbee Based Centralised Patient Monitoring System," *Proc. - 2015 Int. Conf. Comput. Intell. Commun. Networks, CICN 2015*, pp. 212–217, 2016.

[24] S. Bhat, N. Kaul, A. Gupta, and V. Prakash, "XBee based novel wireless technique to simplify locomotion of physically handicapped persons," *4th Students Conf. Eng. Syst. SCES 2015*, pp. 4–8, 2016.

[25] S. Aparna, S. B. Yashwanth, P. V. Nair, M. Ganesan, and K. Akshay, "Design of Wi-Fi-based ECG system," *Proc. IEEE Int. Conf. Signal Process. Commun. ICSPC 2017*, vol. 2018–Janua, no. July, pp. 7–11, 2018.

[26] E. Borrero, A. Jiménez, and J. Anzola, "Design and construction of an electrocardiogram with visualization of data in an app," *Int. J. Appl. Eng. Res.*, vol. 12, no. 24, pp. 14019–14025, 2017.