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Performance Analysis of Twelve Lead ECG Based on Delivery Distance Using Bluetooth Communication

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ABSTRACT Based on the data issued by the Basic Health Research (Riskesdas) in 2018, the incidence of heart and blood vessel disease is increasing from year to year. At least 15 out of 1000 people or about 2,784,064 individuals in Indonesia suffer from heart disease. Therefore, cardiovascular healthcare can make a better diagnosis through continuous monitoring. The purpose of this study was to develop a 12-lead circuit, a lead selector (Wilson Central Terminal), an instrumentation booster, an analog filter (Notch Filter 50Hz), Arduino UNO, a Bluetooth module, and Delphi7 application to display electrocardiograph signals. The contribution of this research is a developed 12 lead ECG using Delphi7 to display the signal using Bluetooth. The results show that the Bluetooth module is unable to send a signal at a distance of 20 meters, unable to send a signal at a distance of 10 meters if there is a wall obstacle, and unable to send a signal at a distance of 16 meters if there is an obstacle in the form of wood (doors). This study further used a comparative analysis method that measure the delivering ECG signal with obstacle and without obstacle. This study shown that the thicker the barrier (wall) to transmit the ecg signal, the more difficult the signal data are sent. However, if there are no obstacles, then the ECG signal can be sent.

INDEX TERMS Heart, Electrocardiograph, Bluetooth Module

I. INTRODUCTION

Health problems with cardiovascular system disorder still rank high. According to the data issued by the World Health Organization (WHO), around 31% of the causes of death globally are cardiovascular disease [1], [2]. Heart is one of the most important organs in the human body. The heart works for all the blood so that it can be channeled to the body and returns to the heart. The heart is the part of the body that has electrical or bioelectric activity. This electrical activity of the heart can be recorded using a machine called an electrocardiograph [3], [4]. Furthermore, cardiovascular disease is also one of the leading causes of death in the UK, and a common cause of hospital admission [5]. Therefore, heart healthcare is very important. Researchers have developed skills and knowledge regarding these issues if patients are to get the best care at the right time. One of the most important diagnostic tests is the 12 Lead ECG [6]. Experimental evidence suggests that cardiovascular disease can be better diagnosed [7], controlled, and prevented through continuous monitoring and analysis of signals from electrocardiograms [8], [9]. As a disease diagnosis tool, in its development, ECG can be used in daily activities, sports activities, and even for certain special purposes [10]. Electrocardiogram (ECG) is a digital signal recorded by placing electrodes on the surface of the human body so that voltage changes caused by the electrical activity of the heart can be detected [11].

An electrocardiograph is an electromedical instrument that provides graphic data on the electrical potential of the heart when it contracts or an illustration of the formation of the results of the electrical activity of the heart. The electrocardiograph must provide results that are representative of the patient's heart condition [12], [13]. An electrocardiograph should give results that represents the patient's heart condition [14]. In this case, in order to see the complete state of the heart, leads are needed inferior (leads II, III, aVF), lateral (leads I, aVL, V5, V6), septal (V1 and V2), anterior (V3, V4), and aVR. Abnormalities of heart function can be seen from the recording of the ECG signal. The clinical standard ECG technique method uses 10 electrodes to produce 12 heart-leading signals [15]. Each ECG signal has a different heart vector orientation. In general, leads are divided into 3: frontal leads, unipolar extremity leads, and precordial leads [16].

In previous studies, ECG devices have been made by several researchers. One of the studies was carried out by Agustiawan et al., concerning a computer-based 12 Lead ECG Data Acquisition Instrumentation System. Meanwhile, in 2016, researchers named Yan lin and Mana Sriyudthsak conducted a 12 Lead ECG study entitled Design and Development of Standard 12-Lead ECG Data Acquisition and Monitoring System. This study discussed 12 lead ECGs with 3-channel data transmission. Furthermore, Parin Dedhia et al. conducted an ECG study titled Low-Cost Solar ECG with Bluetooth transmitter. In this study, the ECG data were sent via Bluetooth to be displayed on the LCD [17]. Meanwhile, the disadvantage of this research is that it only used 1 lead. In addition, Rizki Aulia Rachman conducted a research project entitled a Development of an Effective and Efficient ECG Device with IIR Digital Filter Design. In this study, researchers developed a 6-lead ECG digital filter, the drawback of this study was that researchers only made an ECG with 6 leads [18]. Meanwhile, the disadvantage of this research was also using only one obstacle. Hilda Rifky and Harits Alpen conducted research entitled Remote ECG with 3 measurement displays on a computer via Bluetooth communication [19]. Again, this research only used one obstacle.

Based on the description of the literature study that has been described, this research further designed a "Comparative Analysis of 12 Lead ECG Delivery Distance Interface PC via Bluetooth (Frontal Plane)". In this case, 12 Leads were utilized with 1 direct view that can be seen on the computer. These leads were used so that more signals can be diagnosed. In addition, Bluetooth was also utilized so that the diagnosis is more portable for nurses and the signal can also be monitored at any time. The addition of Bluetooth also plays a role in making it easier for nurses because monitoring can be done within a certain distance. The purpose of this study was to develop an ECG so that it can read more signals as many as 12 leads 1 channel [20], and with the addition of Bluetooth, it facilitates the nurses in monitoring patients. The contribution of this research was a 12 lead ECG signal, which were delivered using Bluetooth. The delivering signal was experimented with obstacles (walls and door) and without obstacle. Based on the experiment, we concluded that the best delivery of ECG signal was without obstacle. The contribution of this study are

a. developing ECG 12 Leads with Delphi7 integration and ECG signal data were sent via Bluetooth.
b. added calculation of sending signals with obstacles and without obstacle.
c. signal transmission using bluetooth which is cheap and easy to obtain
d. the delphi7 application in this study was focused on analyzing the distance obtained from signals V1 to V6.

I. MATERIALS AND METHODS

A. Experimental Setup

This study used the Phantom ECG Fluke as a signal source. Data retrieval was carried out until Bluetooth can no longer send signals to remote data.

1) Materials and Tools

This research used a OneMed ECG cable. The AD8232 ECG module [21] was used to measure the electrical activity of the heart. Arduino Uno microcontroller was used for ECG data acquisition and communication to a computer unit using the HC-05 Bluetooth module. Meanwhile, Borland Delphi program was used to display the ECG signal.

2) Experiment

After the design was completed, the device was tested using the Fluke Phantom ECG simulator [22]. In testing the ECG module, the ECG simulator (phantom) was tested with a range of 60 BPM 1mV sensitivity test. In this case, the variables studied were measuring the delivery of ECG signal with and without obstacle.

B. The Diagram Block

FIGURE 1 below shows the ECG signal that is detected using an electrode cable attached to the phantom ECG. In the processing block, the recorded signal enters a multiplexer circuit which functions as lead selection. The multiplexer output further enters the AD8232 instrumentation circuit which is used to process the body signal. Then, the signal is filtered using a passive filter circuit that has set the frequency value according to the signal frequency value in the heart so that only cardiac signals are passed and block other body signals. After that, the signal enters the amplifier circuit and the adder circuit which functions to increase the signal reference from negative to positive because the microcontroller can only read positive voltages. Then, the signal is processed and the reference value is adjusted, so that it can be read by the microcontroller. The output of the adder circuit is connected to the ADC pin of the microcontroller to be converted from an analog signal to a digital one. The modified data are then processed on the microcontroller and the microcontroller will control the multiplexer (two-way communication between the microcontroller and computer) [23]. After the processing in the microcontroller, the data are sent via communication between Bluetooth and the Delphi7 application on a computer and displayed it in the form of an ECG signal graph.

C. The Flowchart

FIGURE 2 below shows that when the device is turned on in the transmitter block, there is a lead initialization process to pick up the body signal using an electrode cable that has been attached to the phantom ECG and the process of receiving lead selection instructions from the PC. Then, the lead selection is carried out using a multiplexer IC then will display all measurements from Lead I, Lead II, Lead III,

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AVR, AVL, AVF, V1, V2, V3, V4, V5, V6. Furthermore, the measurement results are processed in the ADC circuit, by delivering them via Bluetooth to the PC.

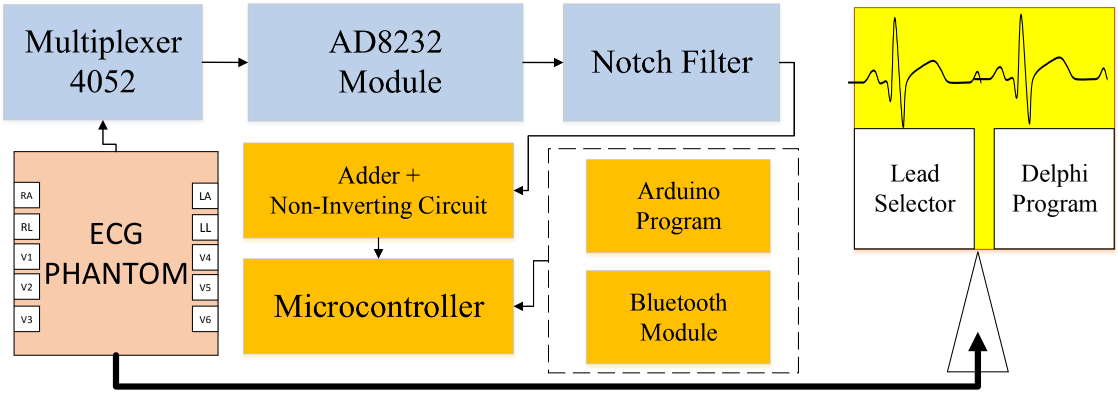


FIGURE 1. The diagram block of the ECG module

FIGURE 3 below shows the receiver diagram when the computer is started to call the input data from the receiver by receiving the Bluetooth signal of all measurements. After connects to the computer, the software initializes. The data received from the receiver is then displayed in the form of an ECG signal that has been selected on the Lead Selector.

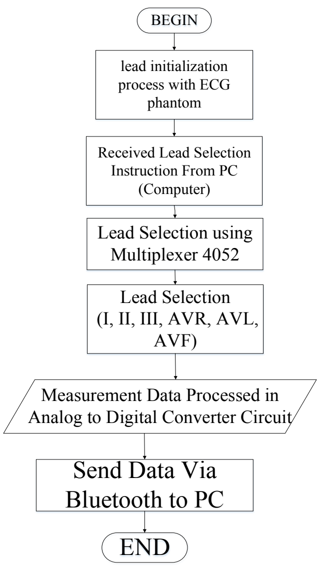


FIGURE 2. The Flowchart of the Arduino Program

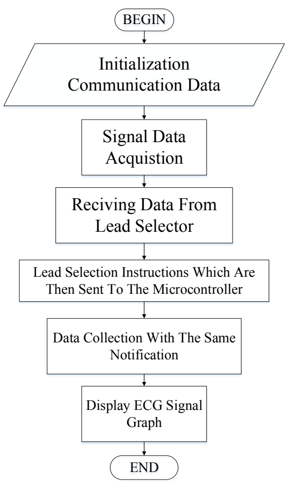


FIGURE 3. The Flowchart of the Delphi Program

D. Circuit

1) Multiplexer

A multiplexer circuit or Switching Lead is a circuit that functions as a lead selection, which is then displayed on the computer. In this case, there are 2 Multiplexer ICs (CD 4052) that are arranged in such a way to display 1 channel.

2) ECG Modul

ECG Modul circuit was used to measure the electrical activity of the heart. With each beat, an electrical impulse or wave travels through the heart.

3) Notch Filter

The notch Filter was used to eliminate the frequencies that exist in the PLN grid, the frequency that is removed is 50Hz.

4) Adder

Adder circuit serves to increase the reference to the ECG signal voltage so that the negative voltage obtained by the ECG signal is increased to the entire positive voltage value.

5) Non-Inverting

A non-inverting circuit serves to increase the reference to the ECG signal voltage so that the final amplifier circuit is a non-inverting amplifier circuit that functions to amplify the input not to reverse the phase so that a higher output is produced.

6) Wilson Central Terminal

Wilson Central Terminal (WCT) [24] circuit is a circuit to obtain a reference voltage from the intake at three different points of the body to produce an average voltage between the three points of the body. The three pick-up points are the Right Arm (RA), Right Leg (RL), and Left Leg (LL). This WCT circuit is connected directly to the electrode and selector circuit.

E. Notch Filter

The transfer function for digital 60-Hz notch filter is represented in the z domain [25].

$$H(z)\frac{1-2\ \cos(2\pi.50.T)z^{-1}+z^{-2}}{1-2r\ \cos(2\pi.50.T)z^{-1}+r^{2}z^{-2}} \quad \text{(eq.1)}$$

where T is the sample interval and r for the radius. If the bandwidth of notch filter decreases, the transient time of the filter increases. The dc gain of the filter is $(1-r+r^2)^{-1}$.

F. Method

The method that researcher used was a developed 12 lead ECG signal using Bluetooth and the signal is shown in PC using Delphi7. The delivering measurement method that researcher used are with obstacle (walls and door) and without obstacle.

III. RESULT

After conducting experiments in this study, the ECG development can be carried out. The development carried out is the development of a 12 lead ECG with the integration of Delphi7. The success of this ECG development cannot be separated from the use of the WTC terminal and notch filter. In this study, the ECG module was tested using an ECG Phantom (fluke MPS450) as a signal source. The proposed designs are shown in FIGURE 4 as it displays the Delphi.

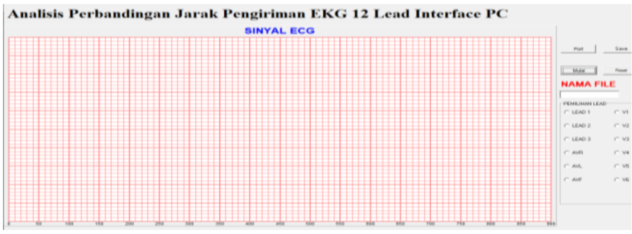


FIGURE 4. Display on Delphi

A. The ECG Modul Design

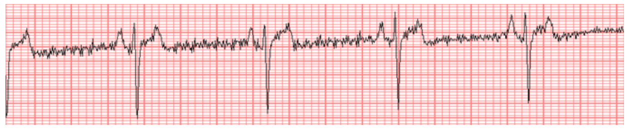
The analog part consists of the AD8232 ECG module. There were also several variable resistors (10k multiturns) for gain and offset adjustments. Then, the multiplexer used 2 CD4052 ICs as logic controller switching leads. The digital part consisted of the Arduino Uno microcontroller which is the main board of the ECG module device, and the Bluetooth module (HC-05) which was used to communicate data between the microcontroller and the computer unit.

B. Signal Result

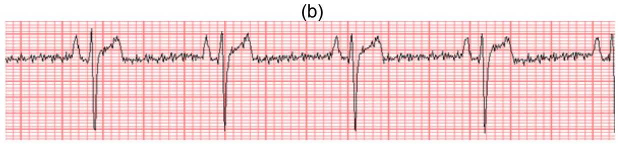
1) V1 Signal

Pictures (a), (b), (c) and (d) are shown in FIGURE 6. Each picture shows the difference in BPM including 60, 80, and 90. The picture also shows that there is still a lot of noise.

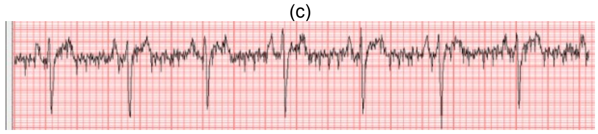
(a)



(b)



(c)



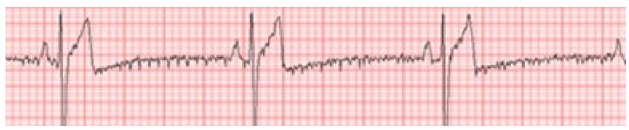
(d)

FIGURE 4. (a). V1 Signal with 60 BPM, (b). V1 Signal with 80 BPM, (c). V1 Signal with 90 BPM, (d). V1 Signal with 120 BPM

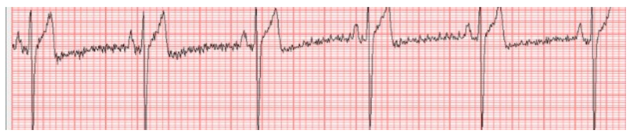
FIGURE 6. (a) is a V1 signal using the BPM 60 setting and 1mv sensitivity on the Phantom ECG. FIGURE 6. (b) is a V1 signal using the BPM 80 setting and 1mv sensitivity on the Phantom ECG. FIGURE 6. (c) is a V1 signal using the BPM 90 setting and 1mv sensitivity on the Phantom ECG. FIGURE 6. (d) is a V1 signal using the BPM 120 setting and 1mv sensitivity on the Phantom ECG.

2) V2 Signal

The following pictures (a), (b), (c) and (d) are shown in FIGURE 7. Each picture shows the difference in BPM including 60, 80, 90 and 120 BPM. There is a lot of denser noise, which interferes with signal reading.

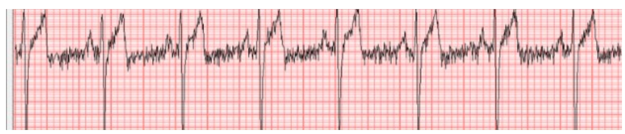


(a)



(b)

(c)



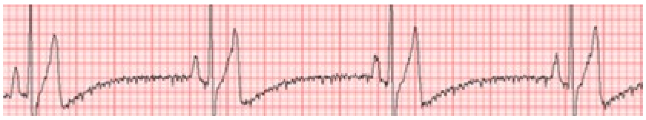
(d)

FIGURE 7. (a). V2 Signal with 60 BPM, (b). V2 Signal with 80 BPM, (c). V3 Signal with 90 BPM, (d). V4 Signal with 120 BPM

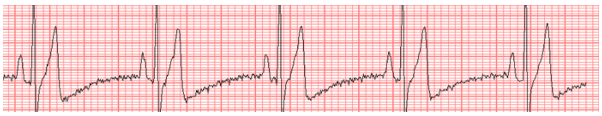
FIGURE 7. (a). is a V2 signal using the BPM 60 setting and 1mv sensitivity on the Phantom ECG. FIGURE 7. (b). is a V2 signal using the BPM 80 setting and 1mv sensitivity on the Phantom ECG. FIGURE 7. (c). is a V2 signal using the BPM 90 setting and 1mv sensitivity on the Phantom ECG. FIGURE 7. (d). is a V2 signal using the BPM 120 setting and 1mv sensitivity on the Phantom ECG.

3) V3 Signal

The following pictures (a), (b), (c) and (d) are shown in FIGURE 8. Each picture shows the difference in BPM including 60, 80, 90 and 120 BPM. The noise is getting less, yet it still interferes with the signal reading.

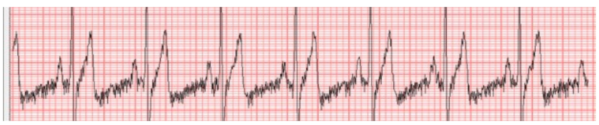


(a)



(b)

(c)



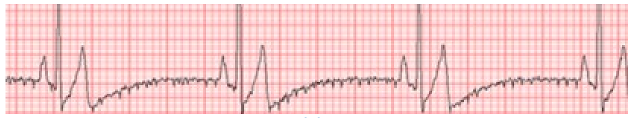
(d)

FIGURE 8. (a). V3 Signal with 60 BPM (b). V3 Signal with 80 BPM, (c). V3 Signal with 90 BPM, (d). V3 Signal with 120 BPM

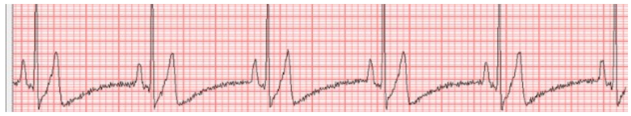
FIGURE 8. (a). is a V3 signal using the BPM 60 setting and 1mv sensitivity on the Phantom ECG. FIGURE 8. (b). is a V3 signal using the BPM 80 setting and 1mv sensitivity on the Phantom ECG. FIGURE 8. (c). is a V3 signal using the BPM 90 setting and 1mv sensitivity on the Phantom ECG. FIGURE 8. (d). is a V3 signal using the BPM 120 setting and 1mv sensitivity on the Phantom ECG.

4) V4 Signal

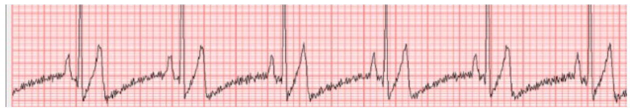
The following pictures (a), (b), (c) and (d) are shown in FIGURE 9. Each picture shows the difference in BPM including 60, 80, 90 and 120 BPM. ECG signal readings are seen better in FIGURE 9.



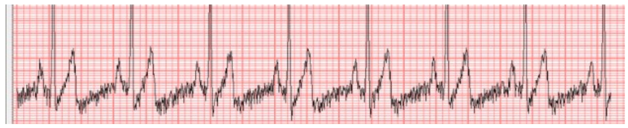
(a)



(b)



(c)



(d)

FIGURE 9. (a). V4 Signal with 60 BPM (b). V4 Signal with 80 BPM, (c). V4 Signal with 90 BPM, (d). V4 Signal with 120 BPM.

FIGURE 9. (a). is a V4 signal using the BPM 60 setting and 1mv sensitivity on the Phantom ECG. FIGURE 9. (b). is a V4 signal using the BPM 80 setting and 1mv sensitivity on the Phantom ECG. FIGURE 9. (c). is a V4 signal using the BPM 90 setting and 1mv sensitivity on the Phantom ECG. FIGURE 9. (d). is a V4 signal using the BPM 120 setting and 1mv sensitivity on the Phantom ECG.

5) V5 Signal

The pictures (a), (b), (c) and (d) are shown in FIGURE 10. Each picture shows the difference in BPM including 60, 80, 90 and 120 BPM. ECG signal readings are better in FIGURE 10. A lot of noise reappears when using the V5 measurement.

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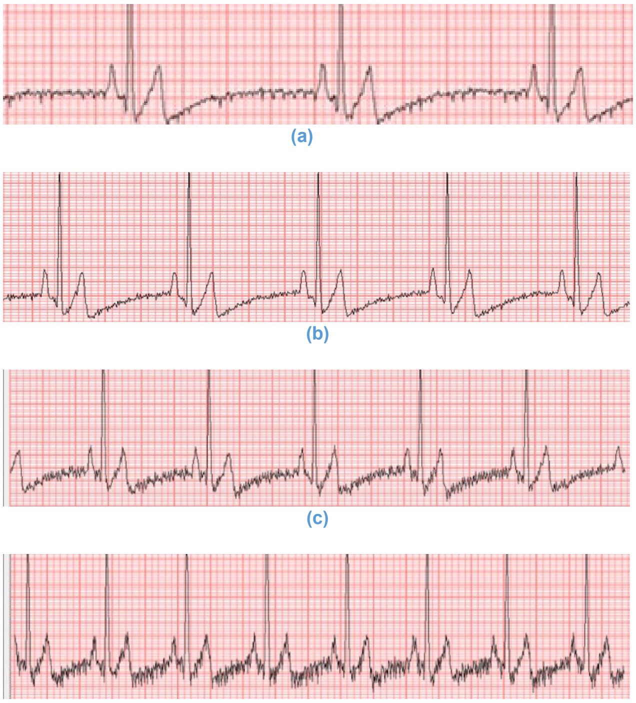

FIGURE 10. (a). V5 Signal with 60 BPM (b). V5 Signal with 80 BPM, (c). V5 Signal with 90 BPM, (d). V5 Signal with 120 BPM

FIGURE 10. (a). is a V5 signal using the BPM 60 setting and 1mv sensitivity on the Phantom ECG. FIGURE 10. (b). it is a V5 signal using the BPM 80 setting and 1mv sensitivity on the Phantom ECG. FIGURE 10. (c). is a V5 signal using the BPM 90 setting and 1mv sensitivity on the Phantom ECG. FIGURE 10. (d). is a V5 signal using the BPM 120 setting and 1mv sensitivity on the Phantom ECG.

6) V6 Signal

The following pictures (a), (b), (c) and (d) are given in FIGURE 11. Each picture shows the difference in BPM including 60, 80, 90 and 120 BPM. ECG signal readings became better in FIGURE 11. There is a lot of noise in the V6 measurement, namely at 120 BPM.

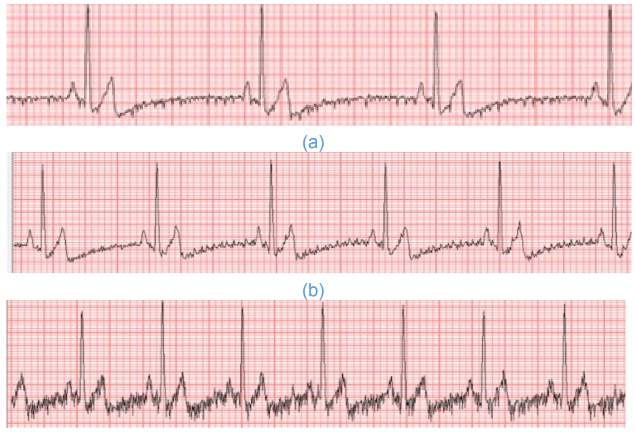

FIGURE 11. (a). V6 Signal with 60 BPM (b). V6 Signal with 80 BPM, (c). V6 Signal with 90 BPM, (d). V6 Signal with 120 BPM

FIGURE 11. (a). is a V6 signal using the BPM 60 setting and 1mv sensitivity on the Phantom ECG. FIGURE 11. (b). is a V6 signal using the BPM 80 setting and 1mv sensitivity on the Phantom ECG. FIGURE 11. (c). is a V6 signal using the BPM 90 setting and 1mv sensitivity on the Phantom ECG. FIGURE 11. (d). is a V6 signal using the BPM 120 setting and 1mv sensitivity on the Phantom ECG.

B. Result of Processing Measurement Data

Measurements were made using a Phantom ECG with the Fluke MPS450 specification. Measurements were made at 60, 80, 90, and 120 BPM mode settings and a sensitivity of 1mV on a 12 Lead Phantom ECG. TABLE 1 it can be seen that the lowest error is at 80 BPM. In this case, the biggest average errors occurred at 60, 90 and 120 BPM.

TABLE 1.
Error Value of 3rd Times of BPM Measurement with 60, 80, 90, and 120 Average Setting Using Phantom ECG.

BPM	Error Value (%)
60	4.167
80	1.375
90	4.167
120	4.167

TABLE 1. shows the results of BPM measurement using Phantom ECG. The average setting of 60 BPM was 62.5 BPM, while the error value was 4.167%. The average setting of 80 BPM was 78.9 BPM, while the error value was 1.375%. The average setting of 90 BPM was 93 BPM, while the error value was 4.167%. The average setting of 120 BPM was 125 BPM, while the error value was 4.167%.

C. Bluetooth Performance Testing as a Data Delivery Source

This test aimed to find out the maximum distance of the Bluetooth HC-05 module was in transmitting ECG signals. The test was done using 2 methods, namely delivery without obstacle and delivery with obstacles. The results of the distance test can be seen in table 2 below.

TABLE 2.
Bluetooth Module Test Result with Obstacle (walls and doors) and Without Obstacle

Condition	Sent (%)	Not Sent (%)
Without Obstacle	95	5
With Obstacle (Walls)	45	55
With Obstacle (Doors)	75	25

TABLE 2. shows the results of the Bluetooth module test result. It can be concluded that the best signal transmission is those without obstacle. If there is an obstacle, then the signal sent ranges between 45-75%.

IV. DISCUSSION

A distance test has been carried out on Bluetooth transmission using a Bluetooth module. In this case, the results obtained on the distance test without obstacle are unable to send a signal at a distance of 20 meters, unable to send a signal at a distance of 10 meters with a wall obstacle and unable to send a signal at a distance of 16 meters with a wooden obstacle.
In the whole circuit, when the device was turned on, the multiplexer selected which leads were issued as outputs according to the selected ones. After that, they were read by the AD8232 ECG module and enterred the notch circuit to remove 50 Hz noise from the grid. PLN then enterred the adder to increase the reference of the signal and finally the output was amplified using a non-inverting circuit so that the signal can be read. Furthermore, the signal was sent to the Arduino UNO microcontroller as a signal from an analog filter and then sent to Delphi via Bluetooth communication.
Limitation from this research is that this device is not real-time mode. Meanwhile, the weaknesses of the ECG module are that the BPM value can only be seen by calculating the signal, and the value cannot be seen directly. In addition, there was also a lack of clarity of the signal wave on some waves. Furthermore, when the device was turned on in a room that has a poor grounding system, a signal sometimes appears which causes the signal reference to rise and fall or noise to appear. Then, when the Lead transfer process took some time to stabilize the signal, and when it appears on the PC, the display was not very smooth. In this case, the implication of this research is that the future work must be clean from all the noise of signal, so that a better vision can be obtained.

V. CONCLUSION

The purpose of this research is to develop an ECG tool so that it can read more signals by utilizing 12 leads. The contribution of this research is to make 12 leads so that more signals can be diagnosed, and by using Bluetooth we aim to make diagnosis more portable for nurses and signals can also be monitored at any time. This research has found that a 1-channel 12-lead ECG module can be made using Bluetooth delivery. In summary, this ECG module has an error value at BPM 60 of 4.167%, an error value at BPM 80 of 1.375%, an error value at BPM 90 of 4.167%, and an error value at BPM 120 of 4.167%. These error values indicate that this ECG Module is suitable to be used as a medical device. Further experimental investigation is needed to develop this module by displaying the BPM value on the Computer display, using high-quality materials to produce a better signal, processing the signal on the Computer to stabilize the signal reference point up and down, making the device with a good grounding system so that the ECG signal is unaffected by 220 V, and adding more channels to ECG.

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