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Comparison of Two Designs of Wireless Electromyography Sensor Module Using Disposable Electrodes and Dry Electrodes in a Sit to Stand Motion

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ABSTRACT Electromyography is one of the biosignals used to detect muscle signals in humans. Electromyography signals are widely used as input and are engineered to help people with disabilities or assist them in post-stroke therapy recovery. Based on this phenomenon, a lot of electromyography module sensor designs were made to support various purposes in accordance with research. The purpose of this study was to compare the electromyography sensor module using a disposable electrode and a dry electrode using a wireless serial communication system. The results of this study was based on the experiment carried out in the movement from sitting to standing. Therefore, the difference would be more visible by looking at the Mean Power (MNP) value than the mean frequency (MNF). In this case, the tests were conducted using a disposable electrode, all Bluetooth test distances, relaxed conditions with a mean power value of 0.000453, and contraction with a mean power value of 0.000494. In addition, the researchers also compared serial communication transmissions using cables in relaxed conditions with a mean power value of 0.000460 and contraction with a mean power value of 0.000496. Furthermore, trials were further conducted using dry electrodes, all Bluetooth test distances, relaxed conditions with a mean power value of 0.000455, and contraction with a mean power value of 0.000503. In this case, the researchers compared serial communication transmissions using cables in relaxed conditions with a mean power value of 0.000454 and contraction with a mean power value of 0.000499. It was concluded that the design built and analyzed using mean power (MNP), obtained results that were not much different between electromyography modules using wired and wireless serial communications. It was also obtained that the electromyography module design in this study had no problem with the information. In this case, the next research was expected to reduce the circuit design by adding a digital filter to reduce the size of the module and reduce noise that is not needed digitally.

INDEX TERMS Electromyography, Dry Electrode, Disposable Electrode.

I. INTRODUCTION

Biosignal is a device that detects electrical signals in the body. Electromyography is one of the biosignals where electromyography is used for detecting muscle signals in humans. Electromyography has recently emerged and attracted many researchers' attention. Therefore, many researchers conducted study using this device to help people with disabilities or to help them recover from post-stroke therapy. Based on this phenomenon, a lot of electromyography module sensor designs have emerged to support various purposes in accordance with their research. In addition, there are also researchers who used commercial devices because they focus on the results of the classification. The development of electromyography sensor devices was also conducted by several researchers. Related to this development, Emma Farago conducted research on the development of an electromyography-based model of muscle health for elbow trauma patients, where she detected and recorded electromyography signals from 7 muscles of each patient. In this case, the placement of electrodes was done according to SENIAM recommendations. The researchers detected surface EMG signals collected and amplified them with a commercial wireless myoelectric system (Trigno Wireless Systems, Delsys Inc., Natick, MA, USA). The signal was further amplified with a gain of 300, and the sampling frequency was 1925.93 Hz [1]. Furthermore, J Antonio conducted a study that designed an active electronic electrode by eliminating the impedance and filter coupling stage with the aim of optimizing the circuit [2]. In addition, several researchers were also working on electrode comparison for electromyography signal detection. Among them, A Searle et al. worked on quantitative comparisons of three types of bioelectrodes by testing electrode impedance, static interference, and motion artifacts [3][2]. C. Pylatiuk et al also compared the use of electrodes with four different polymeric materials [3]. Araceli Guadalupe Santana Rayo et al further conducted comparison when using a disposable electrode with a gel or with a dry electrode [4]. Furthermore, Momona Yamagami et al investigated the collection of sEMG and impedance data from eight subjects from ESS and clinical electrodes. During the data collection of the research, there was no decrease found in signal quality at the electrodes. In addition, the results obtained that thin and flexible electrodes are more efficient in the long term [5]. Andre Paiva et al further examined the effect of fabric structure on electrode performance during data collection, where the use of textile electrodes with significant differences in fabric structure obtained more sEMG [6]. Yulin Fu et al. then worked on the advantages and disadvantages of using disposable and dry electrodes. In their research, when a gel or disposable electrode was used, it can generate and record an electromyograph signal but it was not stable and caused infection because the gel used could not meet the needs of signal acquisition. Meanwhile, when the dry electrodes were used, no infection occurred because a gel was not involved and these dry electrodes can be used to monitor the bioelectric signal [7]. Furthermore, Marco S. Rodrigues carried out another study concerning Ag/AgCl electrodes which required a gel to be able to intercept the signal for a long time. Thus, dry electrodes made of titanium were made which still required further development. Therefore, both types of electrodes could be used to record surface EMG signals and have advantages depends on the material used [8]. Xiong Zeng et al further found that disposable electrodes caused skin allergies, moved the artifacts, and affected the quality of signal attenuation. Meanwhile, the use of dry electrodes was found better because they could improve the signal quality and held electrodes that could be used for a long time with good results [9]. In addition, Y. Dassonville et al investigated dry electrodes which were more innovative and could compare electrical bioimpedance, where good electrical and mechanical contact between the electrode and the skin is needed when recording EMG signals [10]. RG Scalisi studied HD electrodes that can produce electricity that has good quality in terms of resolution, resistance, and electrode contact impedance with the skin obtained from comparing them with the use of commercial electrodes [11]. Asma M. Naim worked on sEMG signals that were used for a long period of time by generating real-time movements [12]. Pascal Laferriere investigated dry electrodes that have a sensitivity comparable to Ag/AgCl electrodes using a gel to record electromyography signals [13]. Yu Mike Chi et al worked on the use of dry electrodes or plates to minimize the resistance generated from these electrodes which could lead to increased noise [14]. Amanda Myers et al investigated the feasibility of recording EMG signals using AgNWS electrodes) compared to using Ag/AgCl electrodes [15]. Erik Vivrinsky et al. then investigated the advantages of measuring wireless data and electrical activity when recording electromyography signals and the high binding but low noise levels results [16]. Kevin R. Wheeler et al carried out two experiments in electromyography. Furthermore, Li Guo et al investigated 'standard' Ag/AgCl electrodes used to record electromyographic signals instead of disposable or gel electrodes, where dry electrodes have advantages in monitoring drugs and health in the long term because these electrodes are soft and flexible, as well as can absorb air [17]. Emily Lam et al investigated gel or disposable electrodes used to record electromyography signals with the advantages of being applicable to prosthetic control or in-home therapy, while the feasibility of dry electrodes is still in the research stage [18]. Amanda C. Myers et al researched dry electrodes made of silver nanowires used to record electromyography signals. In this case, the electrodes functioned as well as Ag/AgCl gel electrodes even when the respondent was not contracting. Another benefit of this dry electrode is that it did not cause irritation on the respondent when the recording of the signal was taken [19]. Seong Ho Yeon et al investigated dry electrodes which are more flexible for acquisition when recording electromyographic signals compared to commercial electrodes [20]. Ernest N. Kamavuako et al examined the comparison of the performance of the use of gel electrodes and dry electrodes. In this case, the researchers said that with dry electrodes the performance achieved was almost similar to when using gel electrodes [21]. Daxiu Tang et al investigated the three-layer sEMG electrode which has high conductivity, low yielding electrode impedance, excellent strain intensity, high fatigue resistance, and good skin compatibility when used when compared to Ag/AgCl and AgCl electrodes. other traditional copper [22].

Kunal et al explored the control of the function of the rehabilitation device. This study described the development of a wireless electromyography control system. The proposed control system was tested using a miniature wheelchair model. Kunal et al are exploring controlling the function of the rehabilitation device. This study described the development of a wireless electromyography control system. Amplifier instrumentation used IC AD620 (Texas instrument), disposable electrodes Ag/AgCl with a connecting probe, and used an Arduino UNO microcontroller. The proposed control system was tested using a miniature wheelchair model [23]. Furthermore, SS Lee et al developed a noninvasive type of wireless preamplifier and surface electromyography. Researchers focused on developing a preamplifier that includes three electrodes and wireless electromyography. In this case, the A/D converter and Bluetooth module were used for wireless communication. The sampling frequency of this system was 1,024 Hz [24]. The researcher said that the system built was relatively better than commercially available electromyography systems [22]. Another study was also carried out by using Ag/AgCl electrodes. The developed system also included an embedded low-pass filter with a cutoff frequency of 1,000 Hz and a 110 dB amplifier, a high-pass filter with a cut-off frequency of 10 Hz, Bluetooth baud rate set to 115200bps [25]. Teena George et al designed and developed HAL based on Electromyogram (EMG) signals. In this work, surface electrodes were used to provide the summation of all motor unit action potentials (MUAPs) in the pickup area [26]. Researchers used a commercial biosignal detection system, namely Biopac MP 100 with electromyography to support their research [27]. Fariz Ali et al, conducted research on muscle signals as input to move a 4-Dof hand robot [28]. Researchers used the Myoware Muscle Sensor for this project because it was able to measure muscle activation in terms of electrical potential. The sensor can produce two types of output, namely amplified raw electromyography and an electromyography envelope [29].

Based on the literature review above, many studies use electromyographic sensors for rehabilitation, robot control, and prosthetics. In addition to the use of electromyographic sensors, researchers aimed to develop electromyographic sensors that can be used for remote electromyographic signal detection and electromyographic signal detection with moving objects by ensuring the signal did not change the information when transmitting using Bluetooth. Therefore, the current authors were very interested in this theme as a basis to support further research.

This research is expected to significantly contribute to both researchers and health workers such as rehab medical doctors, making it easier for patients who were detected by electromyographic signals to perform movements suggested by doctors without being disturbed by communication cables to personal computers.

II. MATERIALS AND METHODS

A. Experimental Setup

This study compared two wireless electromyography sensor modules that used disposable or dry electrodes when recording the data. During the data collection, the respondent performed a movement from a sitting position to a standing position which was recorded for 24 seconds where at a count of 0 seconds to 16 seconds the respondent was in a sitting position, and in the 16th second, the respondent changed his position from sitting to standing and stood up to 24 seconds. In this case, the data recording was carried out at different distances, namely 1 meter, 5 meters, and 10 meters. Electromyography signal data was further processed using the mean power when relaxed and when the muscle contracts.

1) MATERIALS AND TOOLS

The basic instrument circuit in this study used IC AD620. In the filter circuit, the amplifier used the OPA4277UA IC. The microcontroller used in this study used an Arduino Nano, which distinguished the electromyography design module 1 (E1) and 2 (E2), where, in the input section of the basic instrument circuit, E1 used a header connector and E2 used a jack. The electromyography circuit connection to the microcontroller where the Electromyography 1 design module was connected to pin A0, the Electromyography 2 design module was connected to pin A1 and the Electromyography Commercial design module was connected to pin A2. TX and RX on the microcontroller were the serial communication line to the computer, in which the data sent to the computer were used for data retrieval.

2) EXPERIMENT

The data collection process in this study is illustrated in FIGURE 1. where FIGURE 1a is the starting position, in which the measurement point seen is the Vastus Medialis muscle [30]. Meanwhile, Figure 1b shows the respondent changing position from sitting to standing. The respondent was positioned in the initial sitting position and then stood for contraction and relaxation, the measuring point of the electrode was attached to the Vastus Medialis muscle on the right. Respondents further performed contractions by changing positions from sitting to standing in the 16th second. In this case, the respondents stood still for up to 24 seconds. Furthermore, the data from one respondent were taken 10 times. In this case, the electromyography board design was connected to the microcontroller and the data were sent to the computer via serial communication. Electromyography signal data was recorded using Borland Delphi 7. Furthermore, the data retrieval process is illustrated in Figure 2 below.

(a) (b)

FIGURE 1. Data Collection Process (a) when sitting position (b) when changing to stand position

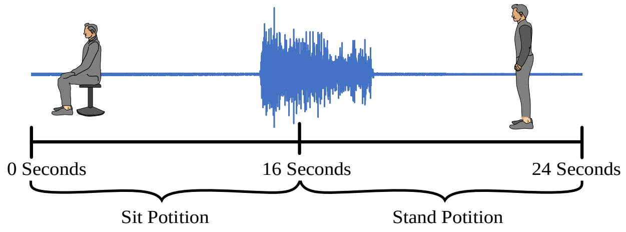

FIGURE 2. Explain the change in position in the data collection process from the initial sitting position to standing. In this position change, the Vastus Medialis muscle is active

3) METHODS

During the data processing in this study, the output of the electromyography design made went to pins A0, A1, and A2. Pins A0, A1, and A2 are analog input pins where the output of the electromyography circuit was converted from analog data to digital data by the microcontroller. Before being sent to the computer, the decimal data was converted into ASCII data. Furthermore, the data were sent using serial communication to a computer and displayed using a GUI from Delphi 7. The sample rate in this study is 1000Hz. After the data were collected, the raw data were processed using python 3 to find the frequency spectrum using FFT [31]. Since digital computers only work with discrete data, a technique called Discrete Fourier Transform (DFT) was further used. Fast Fourier Transform (FFT) is the name of a practical application used for DFT that maps a discrete time sequence to a discrete frequency of representation as in an equation Eq.1 [32]:

$$X = \sum_{n=0}^{N-1} X_n e^{-\frac{2R}{N} n} \qquad k = 0 \ldots\ldots N-1 \qquad (1)$$

After we found the frequency spectrum in the data we had, the researcher analyzed by looking for the mean frequency value (MNF)[33][34], and Mean Power (MNP) [35]. Where is the formula to find the average Frequency (MNF) value above as Eq. 2 [31]:

$$M = \sum_{j=1}^{m} f_j P_j \Big/ \sum_{j=1}^{m} P_j \qquad (2)$$

Where, f_j is the value of the frequency j_{th} at the frequency, P_j is the value of the surface EMG power spectral density. Where the formula for finding the mean value of Power (MNP) above is described in Eq. 3 [31]:

$$M = \sum_{j=1}^{m} P_j \ / \ m \qquad (3)$$

Where, P_j is the surface EMG power spectral density value, and m is the amount of data average.

B. The Diagram Block

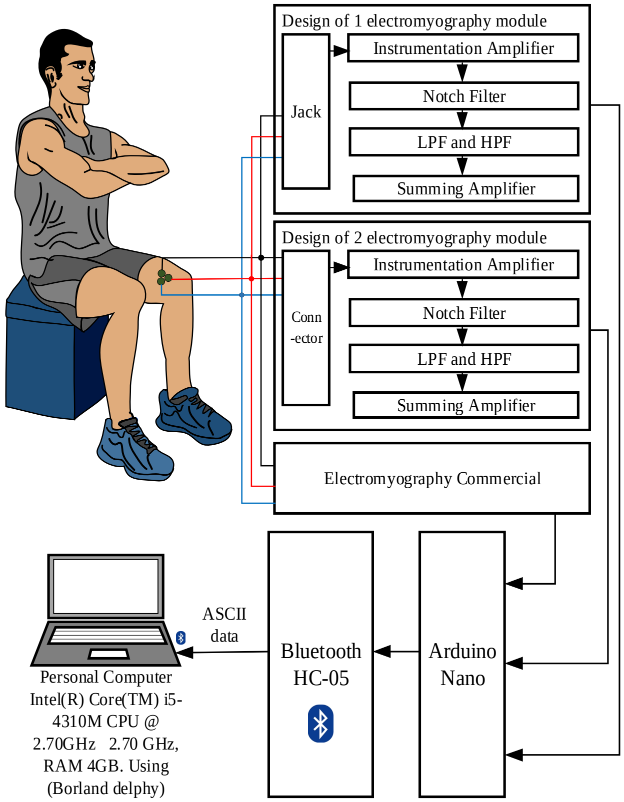

FIGURE 3. Block diagram with detection of the Vastus Medialis muscle

FIGURE 3 displays the block diagram in this study. The Block diagram of this homemade electromyography module consisted of several circuits, namely the instrumentation amplifier, notch filter, High Pass Filter (HPF), Low Pass Filter (LPF), and adder. The basic instrument circuit as circuit detected the initial electrical signal in a muscle used IC AD620 [36]. Notch filter to suppress the frequency of 50 Hz on the electric grid. Researchers used HPF and LPF to pass electromyography frequencies at 20 Hz-500 Hz. This HPF and LPF filter circuit used Op-Amp TL072 [37][38]. Adder circuit to increase the reference of the electromyography signal. The last output of the adder circuit is input to the microcontroller. This experiment used 3 modules simultaneously where the three outputs of design 1, design 2, and commercial modules entered the ADC pin of the microcontroller. The 10-bit resolution for the analog/digital converter provided a resolution of 4.8 mV per sample, this means that the 10-bit resolution ADC was capable of detecting a voltage value corresponding to the sEMG signal. The data sent were ASCII data and the sample rate used was 1000Hz [2]. On the computer, the data were converted into voltage values so that it can be read in the GUI graph created. After that, the visualized signal on the Personal Computer data can be saved in .txt format. The calibration process of the electromyography module design was done by comparing the peak-to-peak voltage value when the input circuit was given a sine signal with a function generator. The two circuits produced in this study were set to have the same output as circuit design 1 and design 2.

C. Flowchart

The electromyography signal detected using the research module was still in the forms of analog data. Analog data were converted into digital data using ADC. Data that have been in the form of digital data were sent using Bluetooth HC-05 to the Bluetooth receiver on the laptop. In the personal part of the computer, data were recorded and saved in .txt format. The data that have been obtained were further processed to find the mean power value (MNP) and the mean Frequency (MNF) using python. Where the flowchart is shown in FIGURE 4.

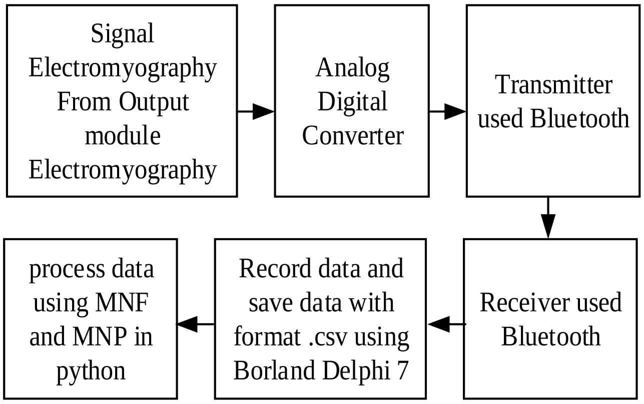

FIGURE 4. Flowcharts process from raw data to getting MNF and MNP results.

D. Analog Circuit

The circuit board made in this study consisted of three pieces of electromyography modules; those are one microcontroller, 1 Bluetooth, and 1 personal computer.

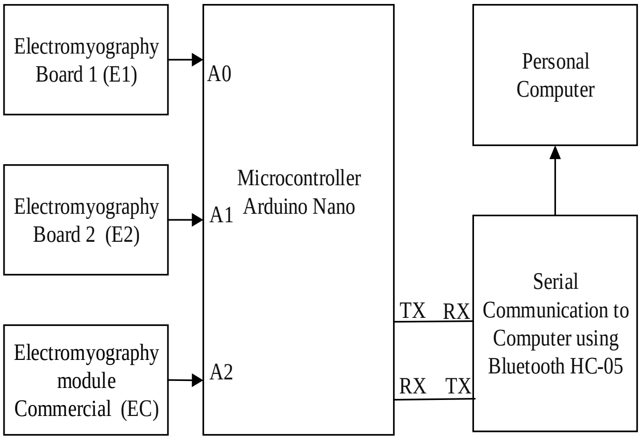

FIGURE 5. Block Diagram Circuit Design Research

FIGURE 5 is a series of basic instruments in this study using IC AD620. In the filter circuit, the amplifier used the OPA4277UA IC. The microcontroller used in this study used an Arduino Nano, which distinguished the electromyography design module 1 (E1) and 2 (E2), where, in the input section of the basic instrument circuit, E1 used a header connector and E2 used a jack. The electromyography circuit was connected to the microcontroller where the Electromyography 1 design module was connected to pin A0, the Electromyography 2 design module was connected to pin A1, and the Electromyography Commercial design module was connected to pin A2. TX and RX on the microcontroller is a serial communication line to the computer. Where the data sent to the computer were used for data retrieval.

III. RESULT

Experimental combinations that can be analyzed in this study are the six combinations that we draw in the following table:

TABLE. 1
Possibility to Test the proposed design function

	Design Module Type		
Electrode Type	Module Design EMG 1 (E1)	Module Design EMG 2 (E2)	Module Design EMG Commercial (EC)
Disposable (DS)	First Possibility (DS+E1)	Second Possibility (DS+E1)	Third Possibility (DS+EC)
Dry Electrode (DE)	Fourth Possibility (DE+E1)	Fifth Possibility (DE+E2)	Sixth Possibility (DE+EC)

Where: E1 = EMG Design Module 1, E2 = EMG Design Module 2, EC = Commercial EMG Design Module, DS = Disposable Electrode, DP = Dry Electrode

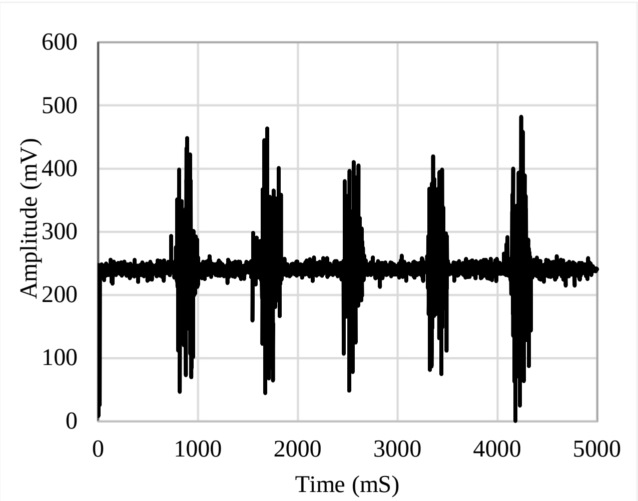

FIGURE 6. Disposable Electrode Jack Design

In this study, the data that have been collected 10 times were used to determine the value of the frequency spectrum using the Fast Fourier Transform calculation or better known as

FFT. After that, the researchers calculated the mean frequency value (MNF), and the mean power value (MNP) in relaxed and contraction conditions. TABEL 1 describes the results of the design trials made where the tests were conducted to first detect an electromyography signal using a disposable electrode using a connector design and simultaneously using a jack design. Second, it was used to detect electromyography signal using an electrode jack using a connector design and simultaneously using a jack design. The results of these experiments obtained the results of the electromyography signal as displayed in FIGURE 6. Based on the data retrieval above, the design of the tool made could detect electromyography signals properly. After obtaining the raw data for the electromyography signal, the data were processed in a fast Fourier Transform (FFT) before finding the Mean frequency (MNF) and Mean Power (MNP) values.

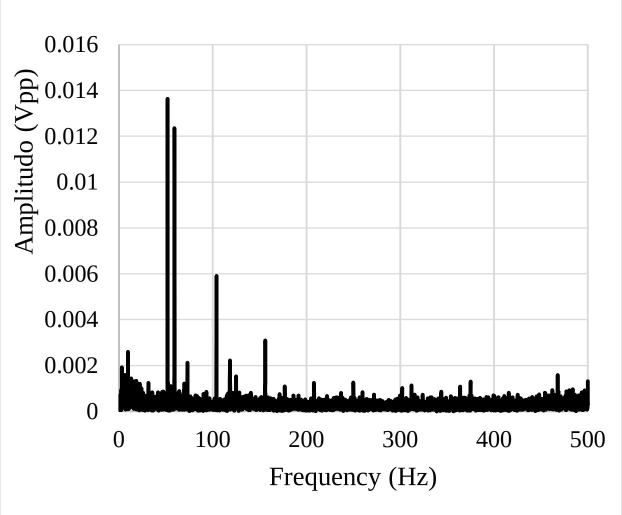

FIGURE 7. Fast Fourier Transform (FFT) results in relaxed conditions

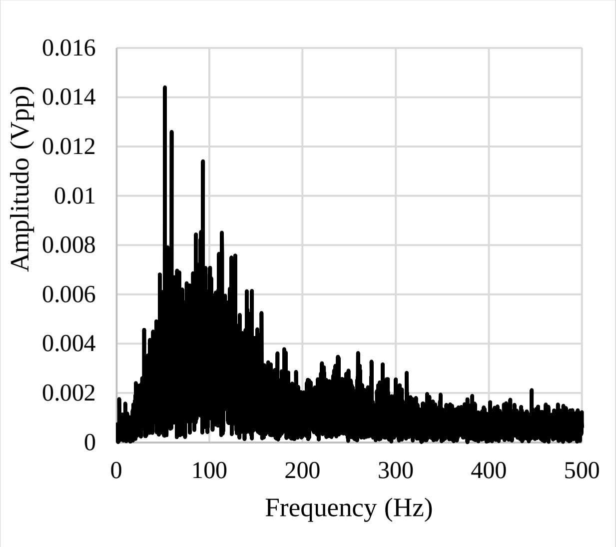

FIGURE 8. Fast Fourier Transform (FFT) results in contraction conditions

FIGURE 7 is the fast Fourier Transform (FFT) of the electromyography signal in relaxed conditions or when sitting. The FIGURE 8 image is the fast Fourier Transform (FFT) of the electromyography signal when it changed position from sitting to standing. FIGURE 9 shows the distribution of the mean frequency value (MNF) between contraction and relaxation position at the disposable electrode with data transmission within 1 meter, 5 meters, and 10 meters using the EMG 1 module design, the design of the EMG 2 module, and the commercial EMG module. Furthermore, it obtained different data distribution during relaxation and contraction as well as during the Bluetooth and serial reading process. These two variables produced a combination of four data distribution values as follows.

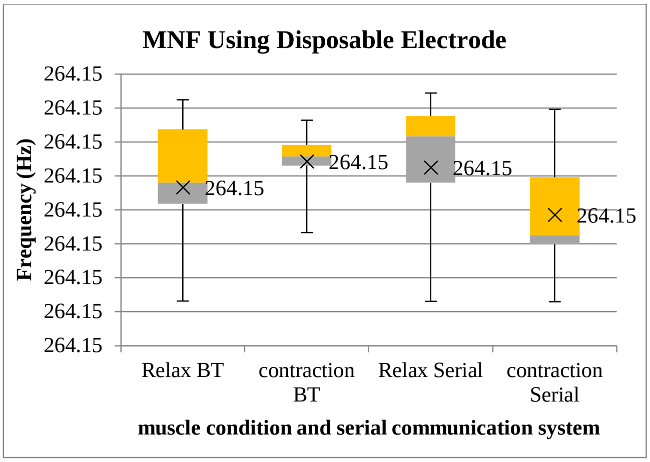

FIGURE 9. The boxplot of the mean frequency value (MNF) with the Disposable electrode

The average distribution of the mean frequency value (MNF) through the Bluetooth readings during the relaxation movement of Bluetooth readings obtained 264.149999999832, while during the contraction movement obtained 264.1499999999985. Meanwhile, the distribution using serial readings during the relaxation movement obtained 264.1499999999950, while during the contraction movement, it obtained 264.149999999669. Furthermore, the minimum mean frequency (MNF) value for the Bluetooth reading during the relaxation movement was 264.149999999164, while during the contraction movement was 264.149999999794. Meanwhile, in the serial reading during the relaxation movement, it obtained 264.149999999162, while during the contraction movement, it obtained 264.149999999159.

The maximum mean frequency (MNF) value for Bluetooth reading during the relaxation movement was 264.150000000349, while during the contraction movement was 264.150000000229. Furthermore, the serial reading during the relaxation movement was 264.150000000389, while during the contraction movement was 264.150000000293.

Based on the distribution of the existing data, it was found that the Q1 value in the relaxation movement of the Bluetooth reading was 264.149999999735, while during the contraction movement was 264.1499999999961. Furthermore, the serial reading during the relaxation movement was 264.149999999860, while the contraction movement was 264.149999999497.

In addition, the value of Q2 (median) of the Bluetooth reading during the relaxation movement was 264.149999999860, while the contraction movement was 264.150000000015. Meanwhile, the serial reading during the relaxation movement obtained 264.150000000134, while the contraction movement obtained 264.149999999551.

Furthermore, the value of Q3 on the Bluetooth reading during the relaxation movement was 264.150000000175, while the contraction movement was 264.150000000084. Furthermore, the serial reading in relaxation movement was 264.150000000253, while in contraction movement was 264.149999999893.

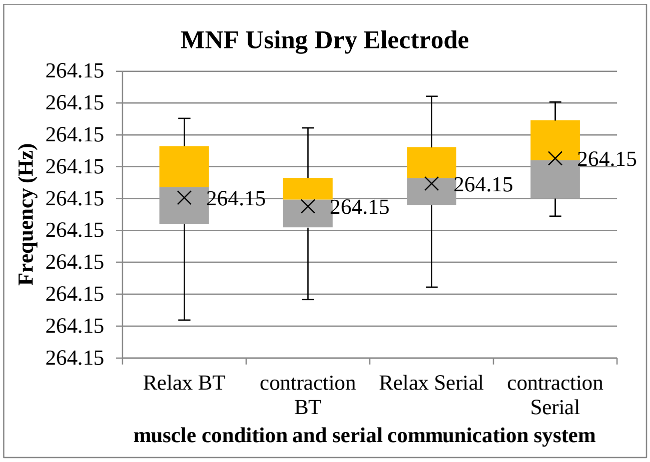

FIGURE 10. Boxplot of mean frequency (MNF) with dry electrode

Based on the FIGURE 10 above, the distribution of the mean frequency value (MNF) between contraction and relaxation on the plate electrode with data transmission is 1 meter, 5 meters, and 10 meters with the EMG 1 module design, EMG 2 module design, and commercial EMG module obtained different distribution. The data were different during relaxation and contraction as well as during the Bluetooth and serial reading process. These 2 variables produced a combination of 4 data distribution values as follows.

The average distribution of the mean frequency value (MNF) in Bluetooth readings during the relaxation movement was 264.149999999807, while during the contraction movement was worth 264.149999999752. Meanwhile, the serial readings of the relaxation movement was 264.149999999894, while the contraction movement was 264.150000000054.

Furthermore, the minimum mean frequency (MNF) value for Bluetooth reading in relaxation movement was 264.1499999999039, while in contraction movement was 264.149999999167. In addition, the serial reading during relaxation movement obtained 264.149999999245, while during the contraction movement obtained 264.149999999691.

The maximum mean frequency (MNF) value for Bluetooth reading in relaxation movement was 264.150000000304, while in contraction movement was 264.150000000244. Furthermore, serial reading in relaxation movement was 264.150000000444, while in contraction movement was 264.150000000407.

Based on the distribution of existing data, it was found that the Q1 value in the Bluetooth reading during the relaxation movement was 264.149999999642, while during the contraction movement was 264.149999999619. Meanwhile, the serial reading during the relaxation movement was 264.149999999760, while during the contraction movement was 264.149999999800.

Furthermore, The value of Q2 (median) of Bluetooth reading during the relaxation movement was 264.149999999873, while during the contraction movement was 264.149999999795. Meanwhile, the serial reading during the relaxation movement was 264.1499999999929, while during the contraction movement was 264.150000000041.

Furthermore, the value of Q3 in the Bluetooth reading during the relaxation movement was 264.15000000129, while during the contraction movement was 264.1499999999931. Meanwhile, the serial reading of the relaxation movement was 264.150000000123, while during the contraction movement was 264.1500000000291.

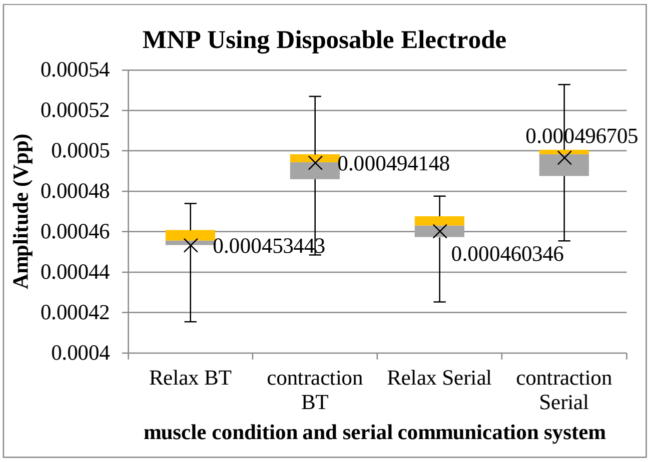

FIGURE 11. Boxplot of mean power value (MNP) with Disposable electrode

FIGURE 11 displays the distribution of the mean power value (MNP) between contraction and relaxation condition on the disposable electrode with data transmission within 1 meter, 5 meters, and 10 meters using the EMG 1 module design, EMG module design 2, and commercial EMG modules that obtained different distribution. The data were different during relaxation and contraction conditions as well as during the Bluetooth and serial reading process. These 2 variables produced a combination of 4 data distribution values as follows.

The average distribution of the mean power value (MNP) of Bluetooth readings in the relaxation movement obtained 0.000453442637700163, while the contraction movements obtained 0.000494147639855062. Furthermore, the serial readings in the relaxation movements obtained 0.000460346293611576, while the contraction movements obtained 0.000496704564821838.

In this case, the minimum mean power (MNP) value for Bluetooth reading in relaxation movement was 0.000445814609511171, while in contraction movement was 0.000482916661056649. Furthermore, the serial reading in relaxation movement obtained 0.000455741129190422, while the contraction movement obtained 0.000485220602346800.

Furthermore, the maximum mean power (MNP) value for Bluetooth reading in the relaxation movement obtained 0.000474039758375207, while the contraction movement obtained 0.000520475442774732. Meanwhile, the serial reading in relaxation movement obtained 0.000477628180356924, while in contraction movement obtained 0.000515320396316198.

Based on the distribution of the existing data, it was found that the Q1 value of the Bluetooth reading during the relaxation movement was 0.000453456563006356, while during the contraction movement was 0.000486014891206582. Meanwhile, the serial reading in relaxation movement was 0.000457309534783352, while in the contraction movement was 0.000487622321760095.

The value of Q2 (median) of Bluetooth reading during the relaxation movement was 0.000455683233465654, while during the contraction movement was 0.000494358429690501. In the case of serial reading, the relaxation movement obtained 0.000463125046819530, while the contraction movement obtained 0.000498363210706829.

The value of Q3 on the Bluetooth reading during the relaxation movement obtained 0.000460812336385035, while during the contraction movement, it obtained 0.000498247581562386. Meanwhile, the serial reading of relaxation movement obtained 0.000467673792742364, while in the contraction movement, it obtained 0.000500581805736306. FIGURE 12 above shows the distribution of the mean power value (MNP) between contraction and relaxation conditions on the plate electrode with data transmission of 1 meter, 5 meters, and 10 meters using the EMG 1 module design, the EMG module design 2, and the commercial EMG module. The data obtained were different during relaxation and contraction conditions as well as during the Bluetooth and serial reading process. These 2 variables produced a combination of 4 data distribution values as follows.

The average distribution of the mean power value (MNP) of Bluetooth reading during the relaxation movement obtained 0.000455048292427709, while the contraction movement obtained 0.000503860814866685. Meanwhile, the serial reading in the relaxation movement obtained 0.000454033303774987, while the contraction movement obtained 0.000499501597616807.

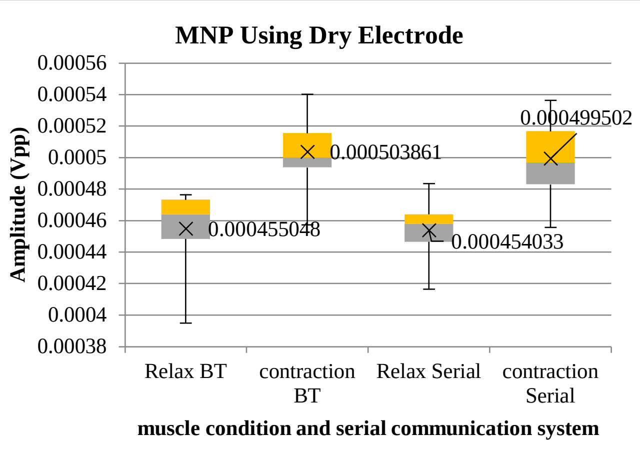

FIGURE 12. Boxplot power mean value (MNP) with dry electrode

Furthermore, the minimum mean power (MNP) value for the Bluetooth reading in the relaxation movement was 0.000394990029288660, while the contraction movement was 0.000457411454892020. Meanwhile, the serial reading of relaxation movement was 0.000416496875656460, while the contraction movement was 0.000455709570651953.

Furthermore, the maximum mean power (MNP) value for Bluetooth reading in the relaxation movement was 0.000476536681928698, while in the contraction movement was 0.000540298555523760. Meanwhile, the serial reading in relaxation movement was 0.000483677794513673, while in the contraction movement was 0.000536543644067781.

Based on the distribution of existing data, it was found that the Q1 value of Bluetooth readings for the relaxation movement was 0.000448401986269812, while for the contraction movement was 0.000493843638670190. Meanwhile, in the serial readings for the relaxation movement was 0.000446564647420064, while for the contraction movement was 0.000483061794093075.

The value of Q2 (median) of Bluetooth reading in the relaxation movement was 0.000463886581595835, while in the contraction movement was 0.000499957284661112. Meanwhile, the serial reading for the relaxation movement was 0.000457867816857527, while in the contraction movement was 0.000496950358970473.

Furthermore, the value of Q3 on the Bluetooth reading of relaxation movement was 0.000473278341232222, while in the contraction movement was 0.000515603151332642. Meanwhile, the serial reading of relaxation movement was 0.000464030489138305, while in the contraction movement was 0.000516808713875390.

IV. DISCUSSION

The tests in this study was carried out directly on the output by analyzing the mean value of frequency and mean power in the case of sitting to standing movements, where the difference was more visible by looking at the Mean Power (MNP) than the mean frequency (MNF). Based on the FIGURE 11 trials using a disposable electrode, all Bluetooth test distances in relaxed conditions obtained a mean power value of 0.000453, while the contraction condition obtained a mean power value of 0.000494. Furthermore, the researchers compared serial communication transmissions using cables in relaxed condition with a mean power value of 0.000460 and contraction condition with a mean power of 0.000496. The boxplot display is very clear, and the distribution of data were almost similar between the Bluetooth and serial. Furthermore, based on the FIGURE 12 trials using the dry electrodes, all Bluetooth test distances in relaxed conditions obtained a mean power value obtained 0.000455, while the contraction condition obtained a mean power value of 0.000503. In this case, the researchers compared serial communication transmissions using cables in relaxed condition with a mean power value of 0.000454 and contraction condition with a mean power of 0.000499. The boxplot display in FIGURE 11 and FIGURE 12 is very clear that the distribution of data is almost similar between serial communication using wired and wireless. Seong Ho Yeon et al investigated dry electrodes which are more flexible for acquisition when recording electromyographic signals compared to commercial electrodes [20]. Ernest N. Kamavuako et al further also examined the comparison of the performance of the use of gel electrodes and dry electrodes. The researchers said that dry electrodes performance achieved almost similar result with gel electrodes performance [21]. Furthermore, Daxiu Tang et al investigated the three-layer sEMG electrode which had high conductivity, low yielding electrode impedance, excellent strain intensity, high fatigue resistance, and good skin compatibility compared to Ag/AgCl and AgCl electrodes of other traditional copper [22].

The limitation of this study is the use of battery which was too large. This caused the design of the integrated electromyography module too large as well so it was a bit annoying when the respondent made movements. Furthermore, based on the design proposed in this study, it was also found that the weakness of the design of 2 electromyography modules was the use of connectors. This design was not very good because the modules were less resistant to shocks when respondents made movements. The method proposed in this study also used mean power MNP and mean frequency MNF, while the results of analysis used a boxplot. The frequency value in this research trial could not distinguish between relaxed data and contraction data. In FIGURE 11 and FIGURE 12, the use of a dry electrode has a greater amplitude difference range than using a disposable electrode. This research further implies that it can be used as a learning and research activity to record electromyography signal data with movements that are not possible using non-wireless electromyography sensors.

V. CONCLUSION

In this study, data that have been collected 10 times obtained raw data on each Electromyography module designed in this study. The purpose of this study was to compare the two design outputs of the wireless Electromyography module, which measures electromyography signals with movements that are not possible using non-wireless electromyography sensors. The module that is made can detect Electromyography signals and transmit data at a distance of 1.5 and 10 meters.

In this study, it was concluded that the design that was built and analyzed using the mean power (MNP) is more capable in distinguishing the relaxation and muscle contraction conditions when performing a sitting to standing movement. In addition, judging from the MNP value, the results are not much different. In this case, the difference of MNP value when using disposable electrodes and in relaxed condition between Bluetooth and cable transmission is 0.000007. Meanwhile, the difference of MNP value when using a dry electrode and in relaxed condition between Bluetooth and cable transmission is 0.000001. Furthermore, the difference of MNP values when using disposable electrodes and in contraction conditions between Bluetooth and cable transmissions is 0.000002. In addition, the difference of MNP values when using dry electrodes and in contraction conditions between Bluetooth and cable transmissions is 0.000004. Therefore, based on this value, it can be concluded that the proposed design can distinguish the respondent's movements by looking at the mean power (MNP) value and the electromyography module design in this study did not have problems with the information sent, to be further used as a tool to conduct research or learn about electromyographic signal characteristics.

The next research is further expected to reduce the circuit design by adding a digital filter to reduce the size of the module and reduce noise that is not needed digitally.

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