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Power Line Interference Removal From ECG Signals Using Notch Filters Of Sharp Resolution

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Abstract
Diseases of the heart are consistently included among the leading causes of mortality on a global scale. The electrocardiogram is one of the reliable methods for determining whether or not a patient has cardiac disease (ECG). In order to determine the health of the heart, the electrical activity of the heart is first converted into a waveform, and then this waveform is analysed. The elimination of noise in an electrocardiogram (ECG) is the focus of this work, which was conducted in MATLAB. ECG analysis is a component of this study, and it comprises of three primary phases at its core. The first step is to get the ECG signal that was recorded. As a result of the fact that the raw ECG that was received contains numerous types of noise, such as interference from powerlines, baseline drift, and electrode mobility on the part of the patient, the second phase involves removing these disturbances from the signal.
The purpose of this paper is to present a method for removing noise from electrocardiogram (ECG) waveforms. The denoising of electrocardiogram signals is investigated using a number of different approaches. The noise artifacts, also known as low frequency baseline wander, muscle artifacts, and interference caused by operating electrical current (Power Line Interference), are investigated and talked about in this article.
Keywords: *PLI; ECG; Notch Filter; IIR Filter; MATLAB*

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I. Introduction

Power line interference, or PLI for short, is one of the types of noise that may be seen in ECG readings. It is also one of the most common types of noise. This particular kind of interference has the potential to have a significant impact on the way the signals are perceived. A PLI with a moderate level may be able to hide the more fine qualities of the primary signal, while a PLI with a severe level may be able to totally dominate it. In contrast, a PLI with a low level may not be able to achieve either of these things. The great majority of the strategies for PLI removal that have been offered in the research that has been published are based on adaptive filters and fixed notches. In the event that the PLI frequency varies, the performance of fixed notch filters is poor, but adaptive filters have problems such as sluggish convergence and the use of an external reference signal. Reducing the amount of background noise in an electrocardiogram (ECG) signal has a significant impact on the ability to make out the fundamental signal characteristics that are obscured by the noise. The reason for this is because the core signal properties are often masked by the presence of background noise. Power line interference, often known as PLI, is by far the most prominent phenomenon that leads to noise in bioelectric signals. PLI is an abbreviation for "power line interference." It is possible to eliminate the PLI from electrocardiogram (ECG) data by using digital notch filters in the appropriate manner. However, issues like as transient interferences and the ringing effect may arise, in particular in situations in which the digitization of PLI does not meet the parameters of full period sampling. These are two examples of potential issues that may arise. This is particularly likely to be the case in situations in which the ringing effect takes place.

It is reasonable to anticipate that the ordinary human being will only live around half as long as they did in times past as a direct result of the bad diets that are becoming more prevalent in today's culture. In a healthy individual, this will result in a heart attack, which is a condition that is notoriously difficult to identify in its earlier stages. In order to achieve this goal, the signals from the electrocardiogram are used as an initial measuring metric in order to ascertain whether or not there are any irregularities present in the functioning of the heart at an earlier stage.

When conducting an ECG, it is necessary to place electrodes in a variety of locations on the chest in order to acquire the majority of the necessary signals. The activity of the heart is recorded as a sequence of pulses, and the major peaks of those pulses are given the moniker PQRST and are noted in the recording of the heart's activity. These peaks are used to symbolise the activity that is taking on inside the heart. In some unavoidable circumstances, such as the one that happened with Covid-19, patients are urged to consult a physician via the use of telemedicine in order to have the diseases detected and to begin treatment as quickly as feasible. As a result, the signal that is received from the ECG is a metric that is given a great deal of importance when determining how the heart is functioning.

An electrocardiogram, or ECG for short, is a signal that records and analyses the electrical activity of the heart. It is also known as an electrocardiogram. The signal that is recorded by an electrocardiogram is produced by the contraction and relaxation of the atrial and ventricular muscles of the heart. Contractions cause depolarization, and relaxations cause repolarization. Components of the electrocardiogram signal include the P wave, which is brought on by atrial depolarization, the QRS complex, which is brought on by atrial repolarization and ventricular depolarization, and the T wave, which is brought on by ventricular depolarization.The electrocardiogram, often known as an ECG, is a graphical depiction of the electrical activity of the heart, and it is used in the process of diagnosing diseases that are related with the heart. Electrodes needed for the electrocardiogram are adhered to the patient's skin in order to create a recording of the electrical activity of the patient's heart over the course of a certain amount of time using the electrocardiogram.

This signal, just like the signal coming from any other sensor, is subject to a variety of aberrations that might affect its integrity. The term "baseline wander" refers to one of these artefacts, while "noise caused by random movement of the body" and "movement of the electrode itself" are two other examples. Interference from power lines is one of the most significant variables that contribute to noise, and it's also one of the most common (PLI). PLI might be present in an electrocardiogram if the wires are tangled, the connections are not secure, or the electrodes are filthy. Unclean electrodes are another potential source of stray alternating current fields in an electrical circuit. Because of the impact that these artefacts have on the quality of the ECG signal, it is essential to clean these signals in order to generate a diagnosis that is more accurate for the patient. It has been shown beyond a reasonable doubt that PLI has a considerable impact on the overwhelming majority of the ECG signals that can be detected. PLI brings a frequency component into the system that ranges from 50 to 60 hertz, which results in signal, which results in signal, which results in signal, which results in signal, which results in the corruption of the ECG signal depending on the operating parameters. However, the frequency component of the PLI may vary anywhere from 50 to 60 Hz, but the frequency of the ECG signal can range anywhere from 0.5 Hz to 80 Hz.

The PLI might have been caused by a number of factors, including incorrect grounding of the device, a loss of electrical power, or the presence of another instrument in the recording area. As a result of this, it is of the utmost importance to get rid of the undesired artefacts that paper is adding to the damaged ECG signal.

II. Previous Work

Electrocardiograms (ECGs) and any other bioelectrical signals that are recorded from the surface of the body are susceptible to noise from electromagnetic fields, which are generated by powerlines. This type of noise can also be found in other bioelectrical signals. This form of noise is distinguished by sinusoidal interference at either 50 or 60 Hz, which may or may not be accompanied by a number of harmonics. The frequency of the interference may be either fifty or sixty hertz. The existence of such narrowband noise makes calculations more difficult. This is because of the presence of the noise. This is due to the fact that the delineation of low-amplitude waveforms becomes unstable, which might result in the introduction of spurious waveforms. ECG signals have following applications in the medical field: cardiorespiratory monitoring; seizure detection and monitoring; ECG is used for biometrics verification; real-time analysis of ECG signal rhythm; heart-rate changeability analysis using a smart electrocardiography patch; and the study of cardiac ischemia [6–11]. These are just a handful of the numerous applications that may make use of the information provided by ECG signals. It is important to create an accurate estimation of the morphological and interval properties of the recorded ECG signal in order to use these applications. This signal is susceptible to a wide variety of predominant noises. This signal is also susceptible to a wide variety of other types of noise When the signal is weak, a sort of dominating noise known as base-line drift might become apparent.

Figure 1, which was provided before, illustrates the denoising techniques that are performed. The first category that we will be discussing is the use of EMD with the goal of denoising an electrocardiogram (ECG). This particular strategy is one that is both local and adaptable within the context of the frequency–time analysis that has been presented. A strategy that is driven by data is known as the empirical mode decomposition (EMD), and it was first presented by [1]. According to [2], it functions most well when applied to non-linear and non-stationary signals. The models that are based on deep learning and autoencoders make up the second group (DAEs) [3]. These models purposed to optimize the objective function for better regeneration of a healthy ECG signal. The wavelet transform, which is also often referred to as the wavelet transform (WT), is the foundation for the wavelet-based approaches that are included in the third category of ECG denoising methods. In order to accomplish this objective, the signal will need to be deconstructed first, the kind of thresholding will need to be determined next, and the signal will need to be rebuilt as a final step. The fourth category employs the method of sparse optimization in order to denoise electrocardiogram (ECG) signals by taking use of the sparsity feature of ECG data. There are two subcategories that fall under this main category. Adaptive filtering is an essential method for denoising that is based on an adaptive filtering approach. Adaptive filtering deals with model-based Bayesian filters such as the extended Kalman filter (EKF), Extended Kalman Smoother (EKS), and unscented Kalman Filter. Adaptive filtering is an essential for denoising. Adaptive filters also works with the Unscented Kalman Filter (UKF). The Bayesian filters used to denoise electrocardiogram (ECG) data, which leads to modifications in traditional dynamic ECG model that makes use of the Kalman filter. The final category is referred to as hybrid, and it combines the different approaches that are discussed in the most recent research. It is possible to achieve denoising of electrocardiogram signals by employing a variety of filtering algorithms, such as adaptive filtering [4] and traditional filtering [5]. Denoising electrocardiogram (ECG) data has been the subject of research that has used non-local techniques (NLM) [6]. Other optimization techniques, such as the total variation regularised least squares problem or the related fused lasso problem, are covered as well. These are only some of the many optimization procedures that are included.

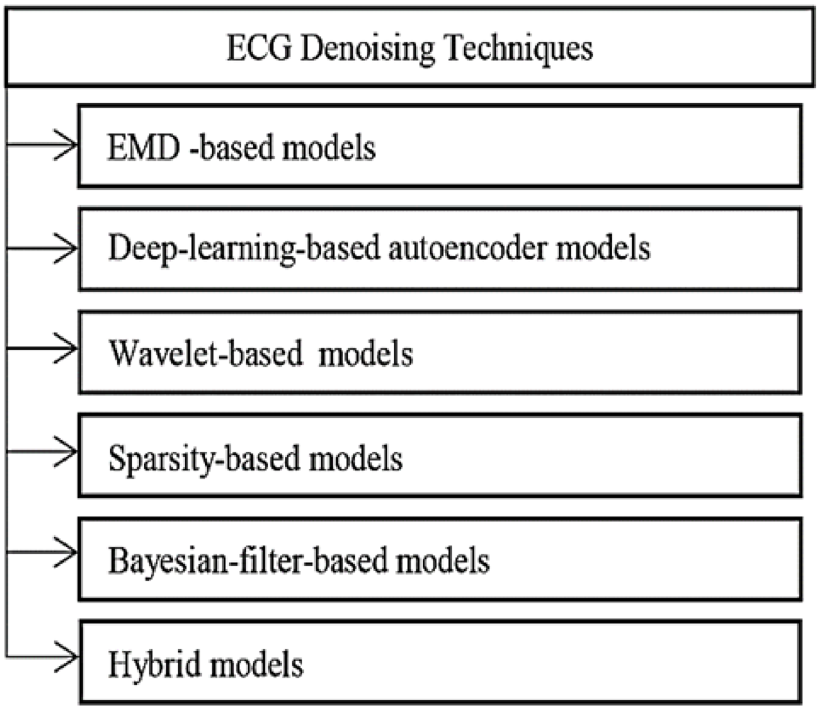

Fig. 1 Denoising in ECG Signals Techniques [4]

Electroencephalography (EEG) signals may have their originality altered when even a little amplitude, measured in microvolts (V), of the signal is altered by numerous artefacts that are present in a recorded signal. The 50 Hz noise that comes from power lines is by far the most prevalent disruption that they cause. Because of this, clinical analysis and information retrieval are made more challenging. In order to provide an accurate diagnosis, it is essential to clean out any and all of these abnormalities in the EEG data. In this work, performance of FIR and IIR analyzed based on different windows for noise reduction from EEG signals. 100th order signal epochs was investigated on digital FIR and IIR filter. Analysis of its effectiveness was carried out by computing the Fast Fourier transform and the signal-to-noise ratio. The findings indicate that Kaiser window-based FIR filters are superior when it comes to filtering out power-line noise from EEG signals [21].

III. Proposed Work

It was necessary to use a wide variety of notches filters, both analogue and digital, in order to arrive at a conclusion on the degree of distortion that was added to the ECG signals. After applying these filters to the electrocardiograms (ECGs) of people and rats, distortion estimates were computed by making use of the signals that were produced after the filters were applied. The use of a tunable notch filter, which is capable of being tuned to the designated frequency range of power line interference and disturbance in the ECG signal caused by muscular contractions, is advocated here. The notched filter that has been recommended has been crafted in such a manner that it will not have any impact on the signal of the electrocardiogram (ECG). pulses that include the most important parts of the information. The implementation of noise reduction from an ECG signal using a notch filter is shown in the flow diagram of Figure 2, which can be seen below.

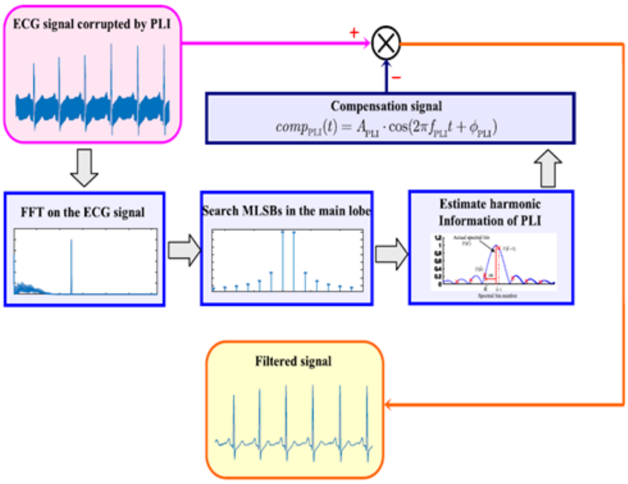

Fig. 2 Flow Chart Notch Filter

A notch filter is a sort of aggressive filter that, in most cases, decreases the power across a particular area of the frequency spectrum by a substantial amount. Notch filters are also known as notching filters. For example, a notch filter with a frequency setting of 60 Hz/50 Hz may be used to filter out noise caused by power lines while simultaneously causing just a little degree of disruption to the signal that is still being sent. Eliminating a particular frequency or a frequency range that is relatively limited in scope may be accomplished with the use of a notch filter. In audio systems, one kind of filter known as a "notch filter" may be used to get rid of frequencies that are creating interference, such as powerline hum. This type of filter is also known as a "notch pass filter." Radio receivers, the reduction of noise from electrocardiograms (ECG), and software-defined radios are a few examples of technology that may make use of notch filters in order to exclude a certain frequency that is causing interference. The MATLAB implementation code is seen in Figure 3.

Fig. 3: Code Implementation

The FFT of the signal after the notch filter was applied can be seen in Figure 4, and Figure 5 displays the original signal. Adaptive Notch Filters, abbreviated as ANF, are a well-known type of variable notch filter in which the notch frequency is changed in real time by an adaptive algorithm. This kind of variable notch filter is also known as ANF. This adaptive mechanism makes it possible to automatically identify and remove an unknown sinusoid that is masked by a wide-band signal such as white noise. This is made possible by the fact that the mechanism is adaptive. This is due to the malleability of the system in and of itself, which makes it possible.

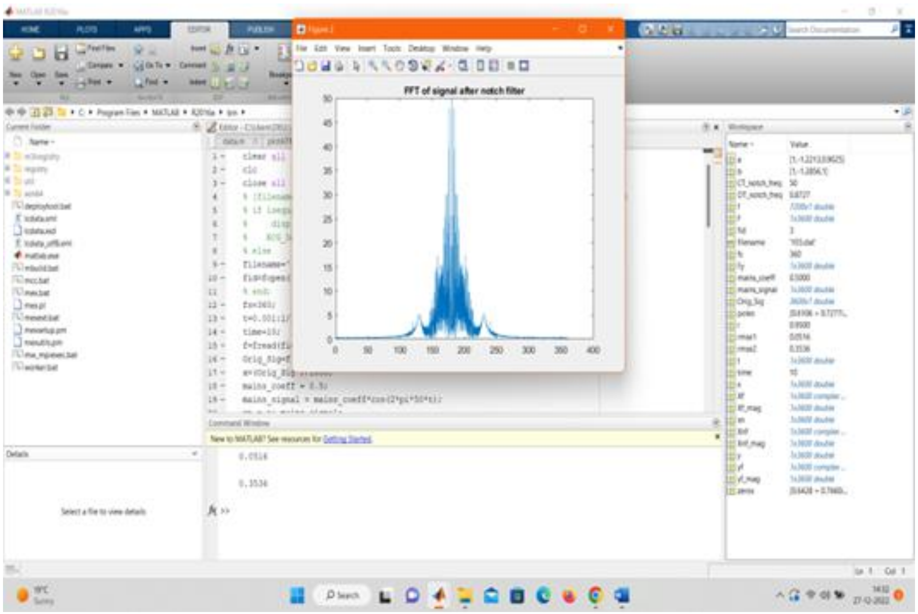

Fig. 4: FFT after Notch Filter

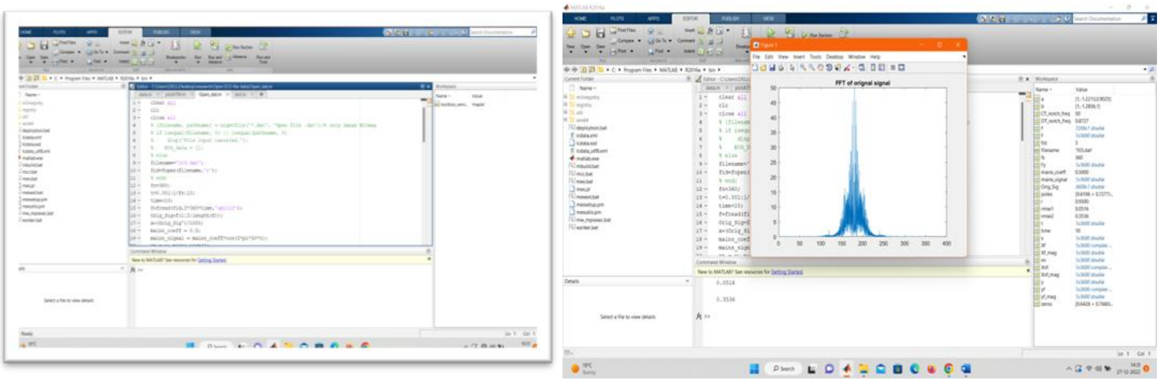

Fig. 5: FFT of original signal

Fourier spectra of the simulated signal as well as the result of using the proposed method to alter the signal. The amplitudes of the leakage components along the entire frequency axis have experienced a significant decrease as a result.

IV. Results

The first stage in the process of processing an electrocardiogram (ECG) data is the removal of any background noise that may be present [6]. An alternating current (AC) source that originates from a power supply is the primary contributor to PLI noise. This kind of noise is one of the primary sources of noise that has to be addressed at the beginning of the processing stages. Depending on where in the country the transmission is taking place, the frequency of the signal might vary anywhere from 50 to 60 hertz (Hz) [7]. The United States of America and a few of other countries use an AC source that has a frequency of 60 hertz, while India and the majority of Europe use an AC source that has a frequency of 50 hertz. The primary contributors to this type of noise are the stray effect of an alternating current field, which is brought about by loops in the electricity wires; disengaged electrodes; electromagnetic interference, which is brought about by the power supply; improper grounding of ECG equipment; and heavy current load, which is brought about by other equipment in the room. Incorrect grounding of the electrocardiogram equipment is another possible reason. When recording an electrocardiogram, there is also the potential for a low-frequency noise known as baseline wander noise to occur. This noise may be distracting. It is possible for it to run at any frequency between 0.15 and 0.3 Hz. This noise is brought on by the process of breathing that is taking place in the person who is being checked, and it brings about a shift in the baseline of the ECG readings. The other probable explanations may be that the cables moved while the ECG signal was being recorded, that the lead electrodes or wires were dirty, or that the connection between the electrodes became loose. It's possible that any or all of these things may happen.

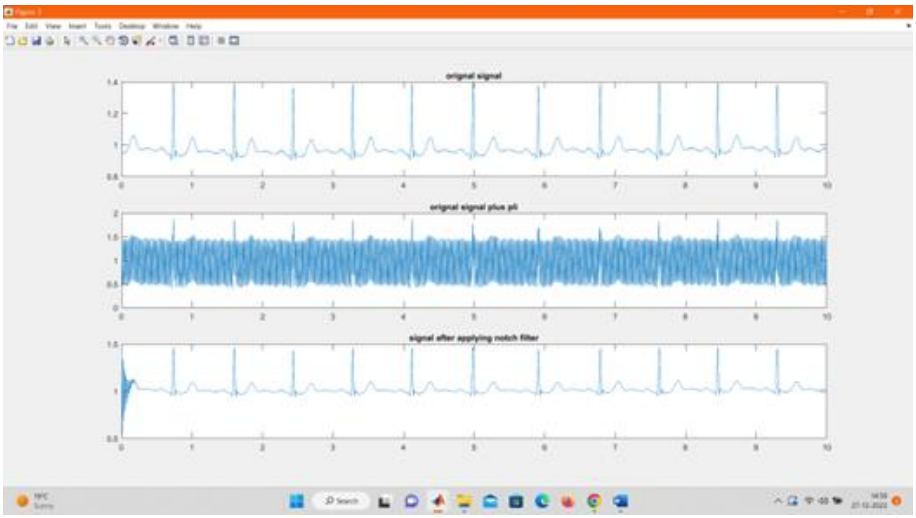

Fig. 6 Result Output

For the purpose of removing the SHW, an IIR notch filter is built. The notch filter has a centre frequency of 50 Hz and a bandwidth of 0.4 Hz; these values were chosen by the user. Fig. 6, Fig. 7 and Fig. 8 shows the result of noise removal from ECG signals.

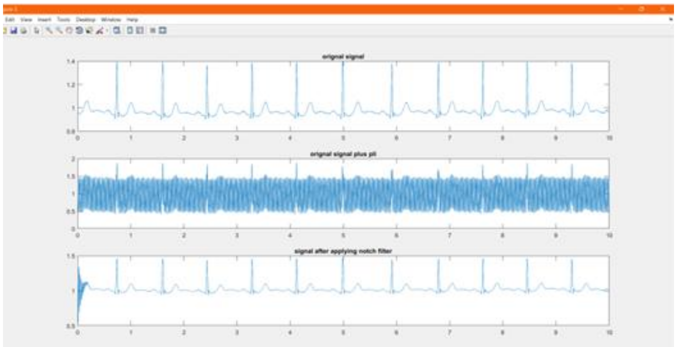

Fig. 7 Enhance ECG signal

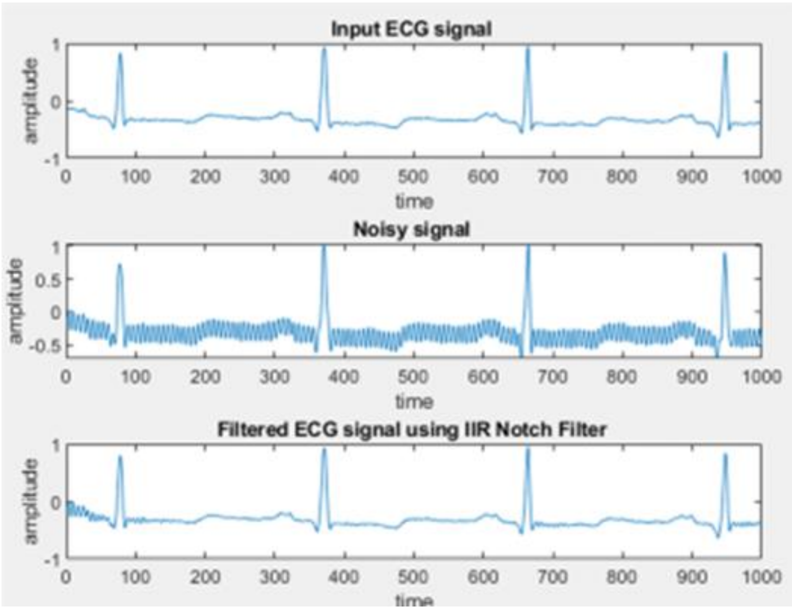

Fig. 8 Filtered ECG signal

Fig. 9 to 12 show more screenshots for different result variations.

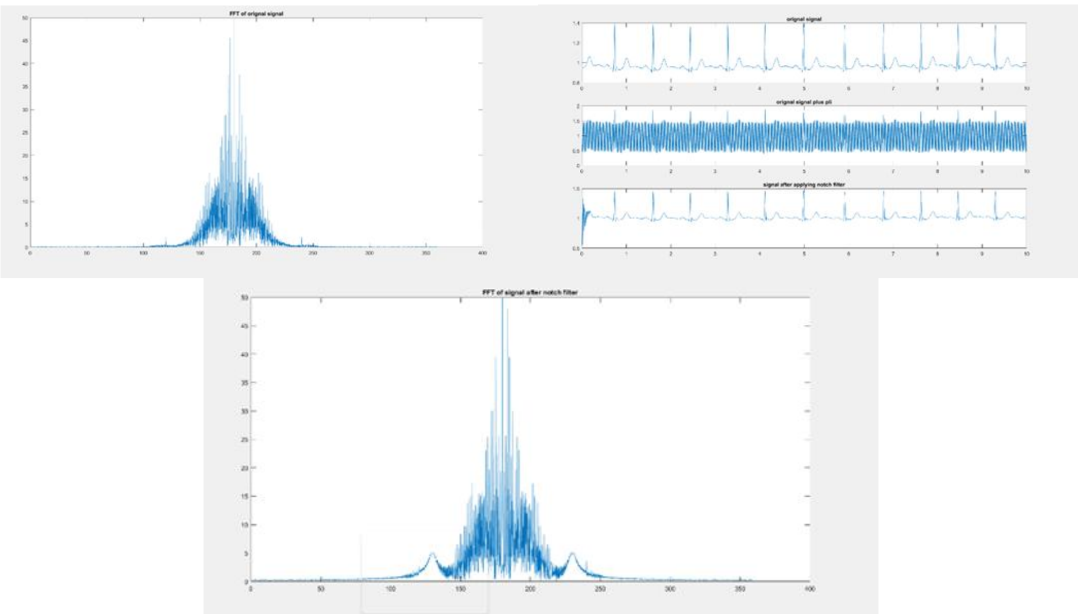

Fig. 9 Filtering process ECG signal

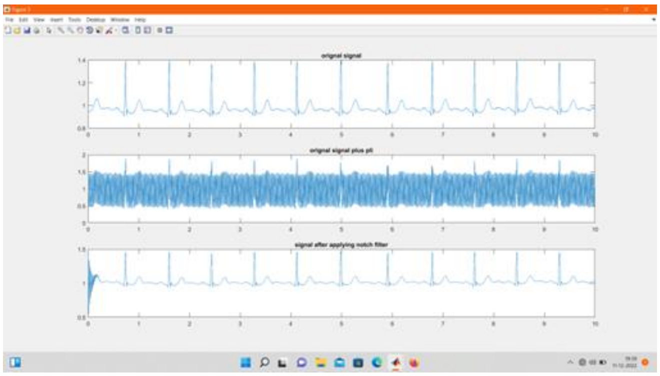

Fig. 10 ECG output Signal

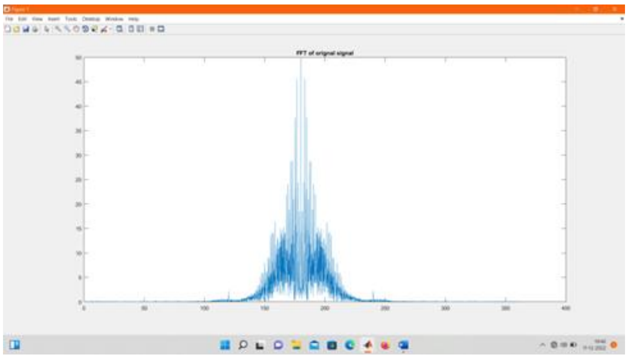

Fig. 11 FFT of original Signal

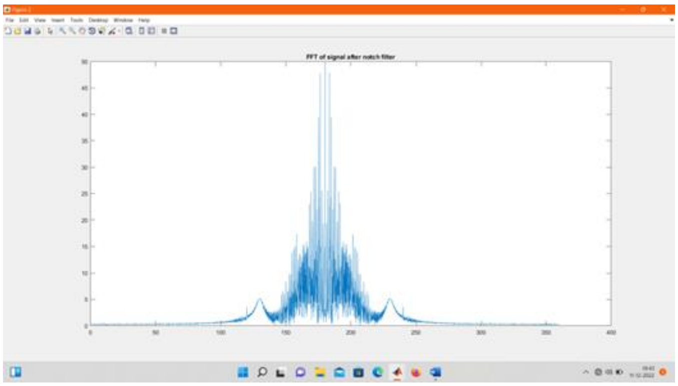

Fig. 12 FFT after notch Filter

V. Conclusion

Electrocardiograms, sometimes known as ECGs, are used as a parametric indicator to identify a variety of cardiac conditions. When the ECG signals are being acquired, a significant amount of noise is introduced to the data, which might have an impact on the diagnosis of the patient when using telemedicine. The noisy ECG signals include things like drift in baseline, motion electrodes artefacts, interference of line, and noise from muscle contractions, among other things. The use of an adaptive filter that makes use of wavelet transform is what ultimately leads to noise reduction being achieved.The filtering idea that makes use of a notch filter produces improved outcomes in the eradication of base wander as well as white noise when compared to more typical approaches to the problem. When taking an electrocardiogram, it is feasible to apply the same procedure to the powerline noise that is generated throughout the process (ECG).

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