Form № 24

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

National University "Polytechnic of Zaporizhzhia"

Faculty of Radioelectronics and Telecommunications

(Full name of institute, faculty)

Electronic information technology

(full name of the department)

Explanatory note

to the diploma project (work)

Master

(higher education degree)

on topic Investigation of powerline interference suppression Algorithms for ECG recordings

Completed: student _6_course, group PT 519M

Specialties 172 Telecommunications and radio engineering

(code and name of the specialty)

Educational program (specialization)

Intelligent technologies of microsystem radio electrical engineering

Romanov M.V.

(surname and initials)

Head Ogrenich E. V.

(surname and initials)

Reviewer Zelenyova I.Y.

(surname and initials)

2020

Form № 25

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National University "Polytechnic of Zaporizhzhia"
(full name of the institution of higher education)

Institute of Informatics and Radio Engineering
nstitute, faculty ___ Faculty of Radio Electronics and Telecommunications ______
hair _________ Information technologies of electronic means ____________
egree of higher education Master ___________________________________
pecialty ________172 «Telecommunications and radio engineering»____________
(code and name)
ducational program (specialization) Intelligent technologies of microsystem radio electrical engineering
(the name of the educational program (specialization)

I APPROVE
Head of Department ____ Shilo G.M.____
Ph.D. Associate Professor of ITEZ_____
«_15_» _____12______ 20_20_year

T A S K
FOR THE GRADUATE PROJECT (WORK) OF THE STUDENT

______________Romanov Mykhailo Vitaliovitch ____________________
(Full Name)

1. Topic of project (work)________ Investigation of powerline _________ interference suppression algorithms for ECG recordings_________

roject manager (works)___ Ogrenych Yevhen Viktorovych Ph.D. Associate Professor ___, (surname, name, patronymic, scientific egree, academic title)
pproved by the order of the institution of higher education from "_15 _" _ ctober_20_20_year №_450__2. Deadline for submission of a project (work) by a student ___________________

. Initial data to the project (work) _________types of noise in the signals of electrocardiograms methods and algorithms for their elimination, development of filters to suppress grid noise

. Contents of the settlement and explanatory note (list of issues to be developed) ______
1. The concept of biomedical technologies ___________________________
2. Electrocardiograph signal, properties . ___________________________
3. Grid noise removal _____________________________________
4. Economic justification of work ___________________________
5. Occupational health and safety in emergencies____________________

List of graphic material (with exact indication of obligatory drawings)
resentation (20slides)

Project section consultants (works)

Chapter	Surname, initials and position consultant	Signature, date	
		task issued	task issued accepted
1-6	Ogrenich E.V		
7	Levchenko N.M		
8	Yakimtsev Y.V.		
9	Pozpeeva. I.E		

Date of issuance of the task "__15___" __October__2020__year.

CALENDAR PLAN

№ з/п	The name of the stages of the diploma project (works)	Deadline for project stages (work)	Notes
1	analysis of incoming data	2 weeks	
2	Review of the field of development and solution of tasks	2 weeks	
3	Development of filters and noise removal	4 weeks	
4	Testing the operation of filters	3 weeks	
5	Calculation of economic efficiency	1 week	
6	Occupational health and safety in emergencies	1 week	
7	Analysis of outcoming data	2 weeks	

Student ____________ (signature) _____**Romanov M.V.**_____
(surname and initials)

Project manager ____________ (signature) _____ **Ogrenich E.V.** _____
(surname and initials)

Форма № 24

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
Національний університет «Запорізька політехніка»

Факультет радіоелектроніки та телекомунікацій
(повне найменування інституту, факультету)

Інформаційні технології електронних засобів
(повне найменування кафедри)

Пояснювальна записка

до дипломного проєкту (роботи)

Магістр
(ступінь вищої освіти)

на тему Дослідження алгоритмів подавлення шуму електромережі в електрокардіограмному сигналі

Виконав: студент(ка) _6_ курсу, групи РТ 519М

Спеціальності 172 Телекомунікація та радіотехніка
(код і найменування спеціальності)

Освітня програма (спеціалізація)

Інтелектуальні технології мікросистемної радіоелектричної техніки

Романов М. В.
(прізвище та ініціали)

Керівник Огренич Є. В.
(прізвище та ініціали)

Рецензент Зеленьова І.Я.
(прізвище та ініціали)

2020

Форма № 25

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
Національний університет «Запорізька політехніка»
(повне найменування закладу вищої освіти)

Інститут інформатики та радіотехніки
Інститут, факультет ___ Факультет радіоелектроніки та телекомунікацій ______
Кафедра _________ Інформаційні технології електронних засобів __________
Ступінь вищої освіти _____Магістр____________________________________
Спеціальність ___172 «Телекомунікація та радіотехніка»____________________
(код і найменування)
Освітня програма (спеціалізація) Інтелектуальні технології мікросистемної радіоелектричної техніки
(назва освітньої програми (спеціалізації))

ЗАТВЕРДЖУЮ
Завідувач кафедри _____Шило Г.М.____
_к.т.н. доцент кафедри ІТЕЗ_________
«_15_» _______12_________20_20_року

З А В Д А Н Н Я
НА ДИПЛОМНИЙ ПРОЄКТ (РОБОТУ) СТУДЕНТА(КИ)

________Романов Михайло Віталійович _________________________________
(прізвище, ім'я, по батькові)

1. Тема проєкту (роботи)_________Дослідження алгоритмів_________________
________подавлення шуму електромережі в електрокардіограмному сигналі_________

керівник проєкту (роботи)___ Огренич Євген Вікторович к.т.н доцент______________,
(прізвище, ім'я, по батькові, науковий ступінь, вчене звання)
затверджені наказом закладу вищої освіти від « _15_» _жовтня_20_20_року №_450__
2. Строк подання студентом проєкту (роботи)_____________________________________
3. Вихідні дані до проєкту (роботи)_________типи шумів в сигналах електрокардіограм методи та алгоритми їх усунення, розробка фільтрів для подавлення шуму електромережі____

4. Зміст розрахунково-пояснювальної записки (перелік питань, які потрібно розробити)
1. Поняття біомедичних технологій____
2. Електрокардіограф сигнал, властивості.______________________________________
3. _Видалення шуму електромережі____
4. Економічне обґрунтування роботи____
5. Охорона праці та безпека в надзвичайних ситуаціях____________________________

5. Перелік графічного матеріалу (з точним зазначенням обов'язкових креслень)

Презентація_(20слайдів)____

____

Консультанти розділів проєкту (роботи)

Розділ	Прізвище, ініціали та посада консультанта	Підпис, дата	
		завдання видав	прийняв виконане завдання
1-6	Огренич Є.В.		
7	Левченко Н.М.		
8	Якімцев Ю.В.		
9	Поснєва І. Є.		

Дата видачі завдання «__15___» __жовтня__2020__року.

КАЛЕНДАРНИЙ ПЛАН

№ з/п	Назва етапів дипломного проєкту (роботи)	Строк виконання етапів проєкту (роботи)	Примітка
1	Аналіз вхідних данних	2 тижні	
2	Огляд області розробки і постанова завдань	2 тижні	
3	Розробка фільтрів та видалленя шуму	4 тижні	
4	Тестування роботи фільтрів	3 тижні	
5	Розрахунок економічної ефективності	1 тиждень	
6	Охорона праці та безпека у надзвичайних ситуаціях	1 тиждень	
7	Аналіз вихідних данних	2 тижні	

Студент(ка) ____________(підпис) ______**Романов М.В.**_____ (прізвище та ініціали)

Керівник проєкту (роботи) ____________(підпис) _____ **Огренич Є.В.** _____ (прізвище та ініціали)

PROJECT OVERVIEW

Project: 84 p., 24 fig., 15 tab., 2 ref.

The main point of this project is to implement various algorithms to detect and remove powerline interference noise in ECG signals. We will use both linear time-invariant (LTI) filters (notch filters) and adaptive (LMS and/or RLS) algorithms. After the implementation, the comparison between the tested method will be performed based on several parameters like mean squared error (MSE) and segmentation ability of the relevant waveforms in the ECG.

Chapter 1 is the preface to the rest of the thesis. It comprises of a brief introduction to ECG denoising.

Chapter 2 explains the basics of electrocardiogram, the generation of the heart beat and the morphology of the ECG waveform. Artifacts that commonly appear in the ECG signal during acquisition are elaborately discussed.

Chapter 3 explains how ECG measurements may be corrupted by many sorts of noise. We will stop at the Power line interference noise and take it apart.

Chapter 4 Linian filter (notch filter) Non linian filter All the algorithms which are implemented in this thesis for ECG enhancement purpose are described here. For denoising purpose, the window based notch FIR filtering.

Chapter 5 This chapter will start with a brief presentation of signal processing methods and then the main focus will be the Adaptive Signal processing technique, based on LMS algorithm.

Chapter 6 This chapter will discuss a set of conclusions related to the evaluation and analysis of ECG denoising based on adaptive signal Processing technique.

Chapter 7 Also, some future work is presented that may enhance and increase the work developed.

ELECTROCARDIOGRAM, SIGNAL, FILTERING, POWERLINE INTERFERENCE, NOTCH , LMS ALGORITHM, NOISE

INDEX

ABSTRACT

1. Description

Biomedical signals are produced by physiological activities in the organism. All living organisms, from gene and protein sequences to neural and cardiac rhythms, are capable to producing signals. These signals can be observed or monitored to realize some aspects of a particular physiologic system. In medical assistance, the cardiac signal, ECG, is the more common signal used by doctors to evaluate heart anomalies. The ECG is a representation of the heart electrical activity in time, which is highly used to detect heart disorders. According to the most recent statistics, reported by the World Health organization, cardiovascular diseases remain the main specific cause of mortality in any region of the world[2]. Several studies demonstrate the importance of reducing the time delay to treatment for improving the clinical outcome of the patients in case of acute coronary syndromes[14]. Some of the most common cardiac problems are myocardial infarction (heart attack), ventricular tachycardia, ventricular fibrillation or atrial fibrillation, where the early detection of the first symptoms occurrence is significantly crucial to decrease the mortality rate and admission time in a hospital or medical centres. These are sufficient reasons for considering the ECG signal as a relevant signal to be monitored by portable systems.

The ECG signal is a low amplitude voltage signal, and due to the amount of noise sources that can destroy it, the ECG signal recording should take this problem into account. ECG noises sources are many; the most common noises arise from instrumentation, interference of power lines and biological systems nearby the heart. Organic systems like the heart are complex, and they are always affected by other organic systems or subsystems in their surrounding. Therefore, heart signals usually contain signals of other parts of the human body, e.g. electromyography (EMG) signals. Removing unwanted signal components from ECG signal can improve the

interpretation of the signal. Hence, signal processing is present in a vast number of ECG systems for noise reduction.

A fundamental method for noise cancelation analyzes the signal spectra and suppresses undesired frequency components. The problem is that noise can overlap the entire signal, and in these cases the classical methods for signal denoising are not adequate. To this difficulty new methods based on advanced signal processing techniques such as Adaptive Signal Processing have been developed. It should be taken into account that adaptive signal processing methods can perform some tuning in their filtering parameters in such a way that their performance will improve. These filters are defined as a self-designing system that relies on a recursive algorithm for its operation. This algorithm allows the filter to provide good accuracy for signals even when relevant signals statistics are not available.

One of the first algorithms used in adaptive signal processing was the Least Mean Squares (LMS) method developed by Widrow and Hoff in 1959 [18]. Nowadays this algorithm, which has many users is widely used due to its robustness and simplicity.

2. Methodology

This work implements different algorithms for removing powerline interference in ECG recordings using Matlab. On the first stage, we will download the ECG signals from PhysioNet (https://www.physionet.org/). PhysioNet is a repository of freely-available medical research data, managed by the MIT Laboratory for Computational Physiology[24]. We will select some clean ECG signals, like signal 118 from the MIT-BIH Arrhythmia Database (mitdb), and we will added powerline interference noise. As a basic noise removal method, we will first design a notch filter trying to optimize the design parameters. On the second stage, we will implement the estimation-substraction method and/or an adaptive filtering approach, comparing its performance with respect to the standard LTI filtering approach.

2. Tasks

The main Tasks witch we have done:

- download the clean ECG signals from PhysioNet and generate the synthetic powerline interference signals.
- design a notch filter (both FIR and IIR will be considered) with optimal specifications.
- program the Estimation-Subtraction method and/or adaptive filtering algorithms.
- compare the performance of the different algorithms in terms of MSE and other performance metrics.

4. Materials to be used

The following in materials have been used in this project:

- software: Windows 10 Enterprise x64 (1703 build 15063), MATLAB R2019b;
- hardware: Apple MacBook Pro 13 A1502.

1 INTRODACTION

1.1 Objectives

The main point of this project is to implement various algorithms to detect and remove powerline interference noise in ECG signals. We will use both linear time-invariant (LTI) filters (notch filters) and adaptive (LMS and/or RLS) algorithms. After the implementation, the comparison between the tested method will be performed based on several parameters like mean squared error (MSE) and segmentation ability of the relevant waveforms in the ECG.

1.2 Description

ECG (Electrocardiogram) signals are the most commonly known, recognized and used biomedical signals for medical examination of the heart. The ECG signal is very sensitive in nature, and even if small noise is mixed with the original signal, the various characteristics of the signal change. Data corrupted with noise must either be filtered or discarded. Therefore, filtering is an important issue for design consideration of real time heart monitoring systems.

A major problem in the recording of electrocardiograms is that the measurement signal is degraded by additive 50- or 60 Hz power line (AC) interference. In my project, it is 50 Hz, as this is the standard frequency in Spain and Europe. This AC noise is caused by improper grounding and interference from other electronic equipment.

Such narrowband noise renders the analysis and interpretation of the ECG more difficult, as the delineation of low-amplitude waveforms becomes unreliable and spurious waveforms may be introduced. Although various precautions can be taken to reduce the effect of powerline interference, for example,selecting a recording location with few surrounding electrical devices or appropriately shielding and grounding the location, it may still be necessary to perform signal processing to remove such interference. Several techniques have been presented for this purpose, ranging from straightforward LTI notch filtering to more advanced techniques that handle variations in the amount of powerline interference like adaptive filters:

Notch filter: This filter causes only minimal distortions of the power spectra and thus permits us to filter high-resolution ECG's without any appreciable changes in the frequency distribution of the original signal. Since the filter is based on an integer coefficient filter technique, the calculation time is relatively short and the programming effort comparatively low. Kumaravel N et.al. suggested this power line interference removal technique to enhance the signal characteristics for diagnosis[20]. They studies the performances of the linear FIR filter, Wave digital filter (WDF) and adaptive filter for the power-line frequency variations from 48.5 to 51.5 Hz in steps of 0.5 Hz.

The method of Estimation-substraction: Another approach to the removal of powerline interference is to estimate the amplitude and phase of the interfering sinusoid in an isoelectric segment, followed by subtraction of the estimated sinusoid within the entire heartbeat. Since it is only of interest to estimate the properties of the interference, the isoelectric segment can be made even more "silent" by appropriate use of bandpass filtering centered around the powerline frequency. The position of this segment can be defined by the PQ interval.[3]

Adaptive filtering method: This method uses a linear filter (IIR or FIR) plus some algorithm to update the coefficients of the filter, like the LMS (Least Means Squares) or the RLS (Recursive Least Squares) algorithms, to estimate the coefficients of the filter. The main features associated to the use of the LMS algorithm are its low computational complexity, the proof of convergence in a stationary environment, and its unbiased and stable behavior when implemented with finite precision arithmetic.

2 BIOMEDICAL SIGNALS

2.1 Introduction

This Chapter explains the basics of the electrocardiogram, the generation of the heart beat and the morphology of the ECG waveform. Artifacts that commonly appear in the ECG signal during acquisition are elaborately discussed. Different modes of lead placement and the MIT-BIH arrhythmia database are also described.

2.2 Function of the heart

The cardiac muscle is composed of two main cell types: cardiomyocytes, which generate electrical potentials during contraction, and cells specialized in the generation and conduction of the action potentials. At rest, cardiomyocytes are polarized with an electrical membrane potential of about - 90mV [4]. Excitation by an external stimulus can trigger a rapid reversal of the electrical potential of working myocardial cells (depolarization). Figure 2.1 shows the wiring diagram of the heart. Electrical impulses are generated in the Sino-Atrial (SA) node. As the SA node fires, which cannot be seen in the ECG signal, electrical impulses travel through the right and left atrium. As a consequence, the two upper chambers of the heart contract.

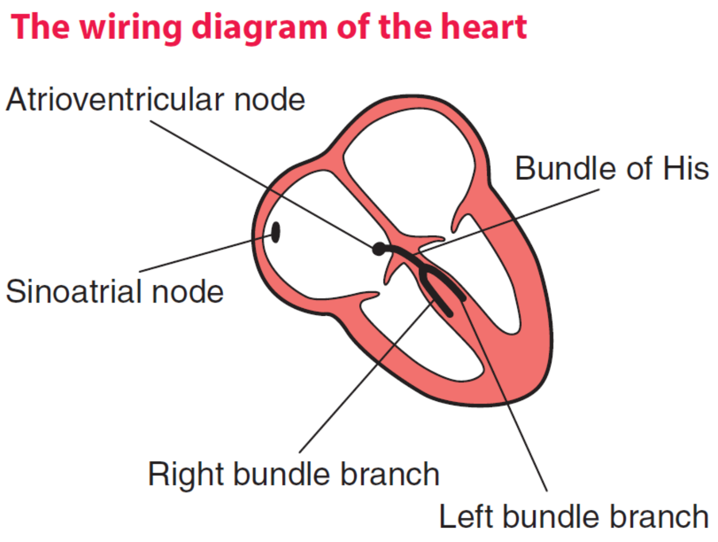

Figure 2.1 - The wiring diagram of the heart [5]

In the ECG signal this process is represented as the P-Wave, shown in Figure 2.2 Next, the impulse travels to the atrio-ventricular (AV) node, which is placed above the ventricles. The AV-node is the only electrical connection between atrium and ventricle and here the propagation of the electric signal gets delayed. This is reflected in the PR-interval in Figure 2.2 Subsequently, the electrical impulse travels through both ventricles, leading to contraction as represented by the QRS complex in

Figure 2.2 Since the muscle of both ventricles is bigger compared to the atria, the amplitude of the QRS complex is higher than the one of the P-wave. During relaxation of the muscle the ECG shows the ST segment and T wave in Figure 2.2.

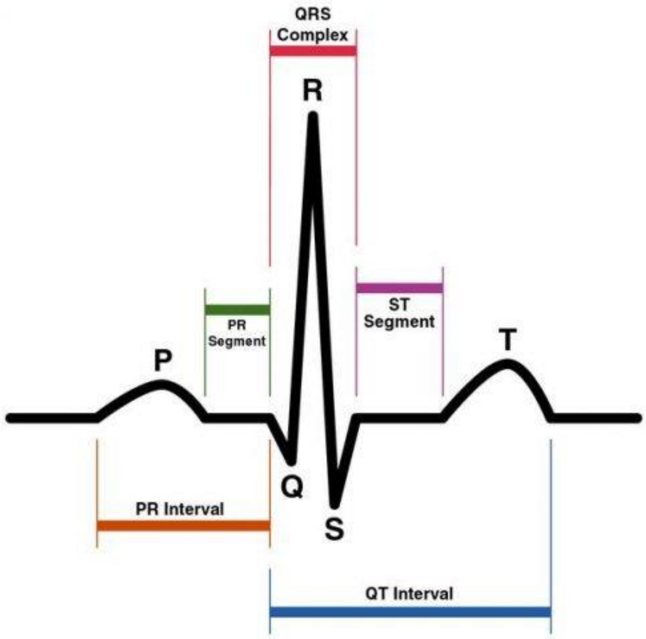

Figure 2.2 - Single ECG wave of a heart in normal sinus rhythm [11]

The length and height of the various parts of the ECG wave give information about the condition of the patient's health [5].

For example, if the PR interval is very short, depolarization might have accidentally been initiated by a cell close to the AV node, or there is abnormally fast conduction from the atria to the ventricles. The length of the QT interval can be in influenced by drugs which would lead to ventricular tachycardia, resulting in a higher than normal resting rate.

2.3 Leads

The electrical signal generated by the heart is detected by electrodes placed on the surface of the body. The ECG recorder compares the different electrical activities in the electrodes and creates a so-called lead.

Today a standard ECG consists of 12 leads, each of them determined by the placement and orientation of the electrodes on the body. This is necessary because the heart is a 3 dimensional organ and therefore it has to be viewed from different angles in order to recreate the full signal.

In Figure 2.3 the electrodes for a 12 lead ECG are spread as follows:

- 2 on the arms (Sec 2.3.1);
- 2 on the legs (Sec 2.3.1);
- 6 across the chest, forming the precordial leads (Sec. 2.3.2).

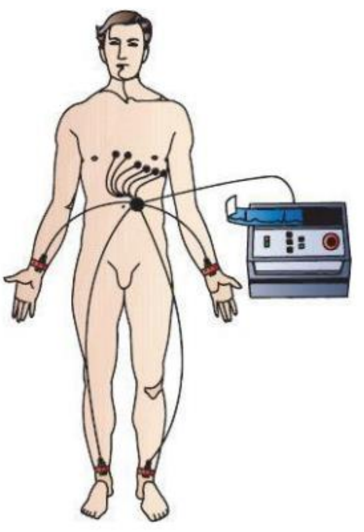

Figure 2.3 - Placement of the electrodes for a 12 lead ECG [12]

2.3.1 Limb leads

The six limb leads record the heart in a frontal vertical plane [5]. This can be pictured as a circle on the body as it is shown in Figures 2.4 and 2.5 To produce this six leads the electrodes on the arms and legs can be marked positive and negative, depending on which lead you want to observe. The angle of the lead can be illustrated by drawing lines from the negative to the positive electrode(s) as shown in Figures 2.4 and 2.5.

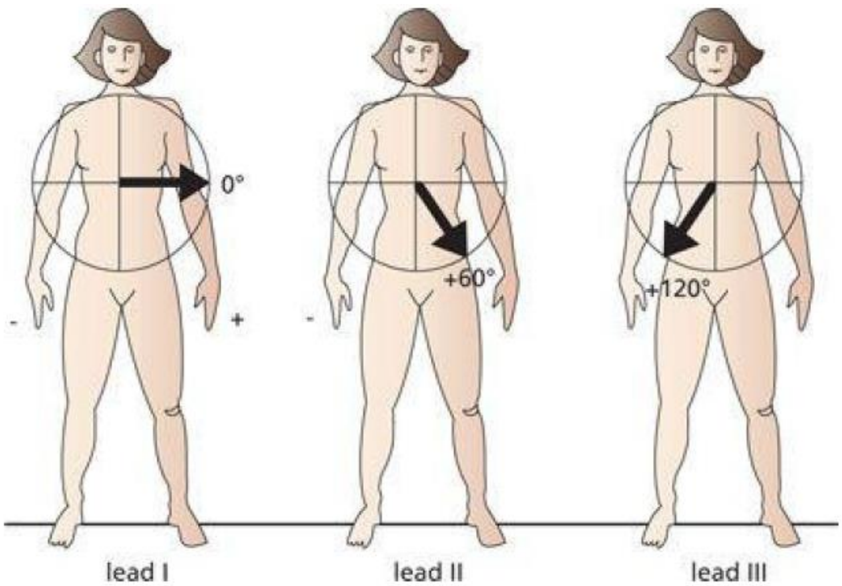

Figure 2.4 - Standard Limb Leads [12]

Standard limb leads:

- Lead I: right arm negative → left arm positive → Angle: 0°;
- Lead II: right arm negative → legs positive → Angle: 60°;
- Lead III: left arm negative → legs positive → Angle: 120°.

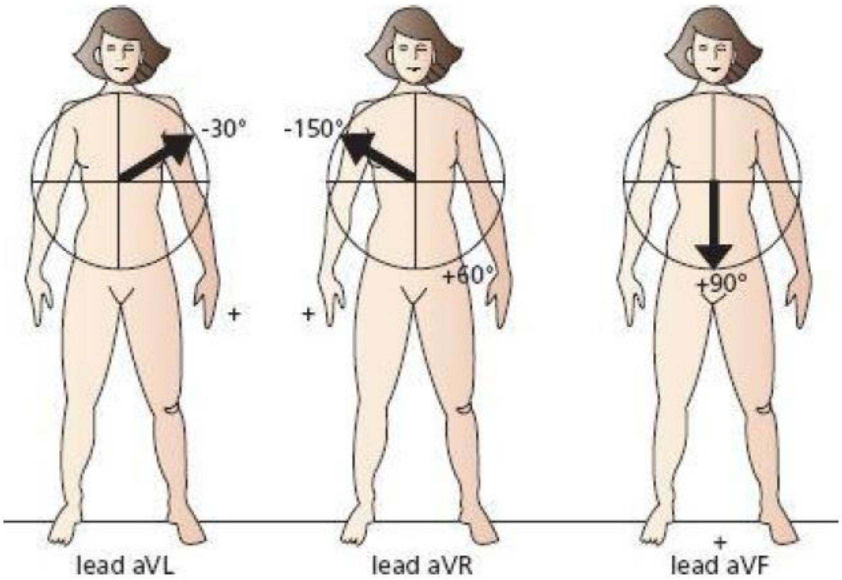

Figure 2.5 - Augmented Limb Leads [12]

3 augmented limb leads

In this case one electrode is chosen to be positive, all others are negative. The angle is now specified between the median of the negative electrodes and the positive one:

- Lead aVL: left arm positive → Angle: -30°;
- Lead aVR: right arm positive → Angle: -150°;
- Lead aVF: legs positive → Angle: 90°.

Each lead views the heart from its own particular angle of orientation. Leads I, II and aVL provide information about the left lateral surface of the heart, III and aVF about the inferior surface and aVR about the right atrium. [12]

2.3.2 Precordial Leads

These six electrodes are arranged across the chest to build the six precordial leads as seen in Figure 2.6 To obtain these six leads, one electrode is made positive and the body acts as common ground. This is done successively for all electrodes. They are positioned as follows:[12]

- V1 is placed right of the sternum in the fourth intercostal space;
- V2 is placed left of the sternum in the fourth intercostal space;
- V3 is placed between V2 and V4;
- V4 is placed in the fifth intercostal space in the imaginary line that extends downward over the trunk from the midpoint of the clavicle;
- V5 is placed between V4 and V6;
- V6 is placed in the fifth intercostal space in the line leading from the axilla down midway between ventral and dorsal surfaces of the body.

The precordial leads view electrical forces moving anteriorly and posteriorly. These six leads view the heart in a horizontal plane: where V1 and V2 provide information about the right ventricle, V3 and V4 about the septum between the ventricles and V5 and V6 about the anterior and lateral walls of the left ventricle.[12]

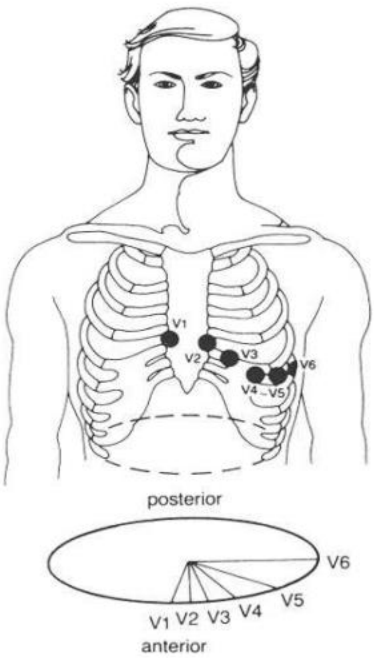

Figure 2.6 - Precordial Leads [12]

2.4 Abnormalities of the ECG wave

When interpreting an ECG signal, each section and possible abnormalities provide information about the underlying physiological condition the patient.

2.4.1 P-wave

The most common abnormality of the P-wave is its change of shape as the heart rhythm changes. Additionally, the P-wave exhibits a sharp peak instead of the usual wave when the right atrium is enlarged. Conversely, an enlargement of the left atrium manifests in a broad and split P wave.

2.4.2 QRS-complex

When the depolarization has spread through the ventricles by an abnormally slow pathway the QRS-complex is widened. There are also other reasons for widening, like the Wolff Parkinson-White syndrome. An enlargement of either ventricle results in a higher QRS-complex due to the increased electrical activity.

2.4.3 ST-segment

The ST segment is normally at the same level as the segment between the T wave and the next P wave. In abnormal signals, the ST-segment may be depressed or elevated. The reason for an elevation is mainly an acute myocardial injury resulting from either an infarction or an inflammation of the fibrous sac surrounding the heart. Depression of the ST-segment is mostly a sign of ischaemia, i.e a restriction of blood flow to tissues or organs causing a shortage of oxygen and glucose.

2.4.4 T-wave

Although in some leads, like in aVR or in V1 and sometimes also in III and V2, the T-wave can be inverted, it can also be a sign of abnormalities like myocardial infarction or ventricular enlargement. Another reason for T-wave deformation is the bundle branch block. This is caused by injury to the bundle branch, which forces the electrical impulse to use muscle fibres instead, resulting in a decceleration of the electrical movement and a deformation of the T wave. A bundle branch block can also be diagnosed when the QRS-complex is prolonged.

2.5 Discussion

Electrocardiography is the interpretation of electrical activity of the heart over a period of time, which produces a representation of ECG. The ECG is a crucial diagnostic tool in clinical practice. It is especially useful in diagnosing rhythm disturbances, changes in electrical conduction, and myocardial ischemia and infarction. In noninvasive electrocardiography, the signal is detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body. The sections of this chapter describe the methods used for recording Electrocardiograms. The locals of electrodes and the respective signal associated to those locals. Then will be presented a brief exposition about the instrumentation used in ECG field.

3 NOISE

3.1 Introduction

Noise is present in almost all environments, and can be defined as an undesirable signal that interferes with the desired signal. A noise itself is a signal that can be generated from several sources, and takes different spectrum distributions. In fact, biomedical electrical signals, which are the scope of this work, are always polluted with some kind of noise. These interference signals include interferences from power supplies, motion artefacts due to patient movement, radio frequency interference, defibrillation pulses, pacemaker pulses, interferences from other monitoring equipment, etc. The big challenge of noise in biomedical signals is closely related with the amplitude of the desired signals with respect to the noise, i.e. the Signal-to-Noise Ratio (SNR). For instance, an ECG measurement gets challenging due to the presence of the large DC offset and various interference signals. This potential can be up to 300 mV for a typical electrode, which is several times larger than the ECG signal. Noise reduction is an important task to solve in biomedical signals and for this reason, the understanding of noise characteristics is the focus of the contents in this chapter. The chapter will start discussion noise properties and characteristics, as SNR and separability, followed by the most common noise sources associated to ECG.

3.2 Noises in ECG

ECG measurements may be corrupted by many sorts of noise. The ones of primary interest are:

- Power line interference;
- Electrode contact noise;
- Motion artifacts;

- EMG noise;
- Baseline Wander;
- Chanel noise.

3.2.1 Power line interference

It consist of 50/60Hz pickup and harmonics. The interference is mainly caused by Electromagnetic interference by power line, Electromagnetic field (EMF) by the nearby machines, Stray effect of the alternating current fields due to loops in the cables, Improper grounding of patient or the ECG machine ,The electrical equipments induce 50 Hz signals in the input circuits of the ECG machine. Example, air conditioner, elevators and X-ray units which draw heavy power line current. [26]

3.2.2 Electrode contact noise

Electrode contact noise is caused by the loss of contact between the electrode and the skin, which effectively disconnects the measurement system from the subject. The noise is of duration 1s. [27]

3.2.3 Motion artifacts

Motion artifacts are transient base line changes caused by changes in the electrode-skin impedance with electrode motion. As this impedance changes, the ECG amplifier sees a different source impedance which forms a voltage divider with the amplifier input impedance therefore the amplifier input voltage depends upon the source impedance which changes as the electrode position changes[27].

3.2.4 EMG noise

The Electromyogram (EMG) noise is generated from electrical activity of the muscle. EMG consist of maximum frequency of 10 KHz. Sections of ECG may be interfered and corrupted by surface EMG which causes difficulties in data processing and analysis[26]

3.2.5 Baseline Wander

Baseline wander is a low-frequency noise component present in the ECG signal. This is mainly due to respiration, and body movement. Baseline wander have frequency greater than 1Hz. This low frequency noise, Baseline wander causes problem in detection and analysis of peak.[27]

3.2.6 Chanel noise

Channel noise introduces when ECG signal is transmitted through channels. This is due to the Poor channel conditions. It is mainly like white Gaussian noise which contains all frequency components [26]. E.g. AWGN

3.3 Noise Properties

Depending on its frequency or time characteristics, a noise process can be classified in several categories [26]: Narrowband noise, White noise, Band-limited white noise, Colored noise, Impulsive noise and Transient noise pulses. **Narrowband noise** is a noise process with a narrow bandwidth such as a 50Hz hum from the power lines. **White noise** is purely random noise that has a that power spectrum. White noise theoretically contains all frequencies in equal intensity. **Band-limited white noise** is a noise with **limited bandwidth** that spectrum usually covers the limited spectrum of the device or the signal of interest. **Coloured noise** it is nonwhite noise or any wideband noise whose spectrum has a non-flat shape; examples are pink noise, brown noise and autoregressive noise**. Impulsive noise** consists of short-duration pulses of random amplitude and random duration in time. And **transient noise** pulses consists of relatively long duration noise pulses.

3.4 Powerline Interference (50/60 Hz)

Electromagnetic fields caused by a powerline represent a common noise source in the ECG, as well as in any other bioelectrical signal recorded from the body surface. Such noise is characterized by 50 or 60 Hz sinusoidal interference, possibly accompanied by a number of harmonics. Such narrowband noise renders the analysis and interpretation of the ECG more difficult, since the delineation of low-amplitude waveforms becomes unreliable and spurious waveforms may be introduced. Although various precautions can be taken to reduce the effect of powerline interference, for example, by selecting a recording location with few surrounding electrical devices or by appropriately shielding and grounding the location, it may still be necessary to perform signal processing to remove such interference Several techniques have been presented for this purpose, ranging from straightforward linear, bandstop filtering to more advanced techniques which handle variations in powerline frequency and suppress the influence of transients manifested by the occurrence of QRS complexes.

3.5 Simple model for generating synthetic Powerline noise in ECG signals.

A Powerline Interference(PLI) noise w(n) can be generated as follows:

$$\mathrm{w(n)} = \mathrm{A} \times \cos(2\pi \times f_s \times t + 2\pi \times rand(1) \quad (3.1)$$

where t is time and f_r=50 Hz (Europe) or f_r = 60 Hz (USA) is the PLI frequency. Fs is the setting frequency in(Hz), and A is noise of amplitude.

Figure 7 shows on example of PLI noise generated with Fr=50 Hz, Fs=360 Hz and A=1.

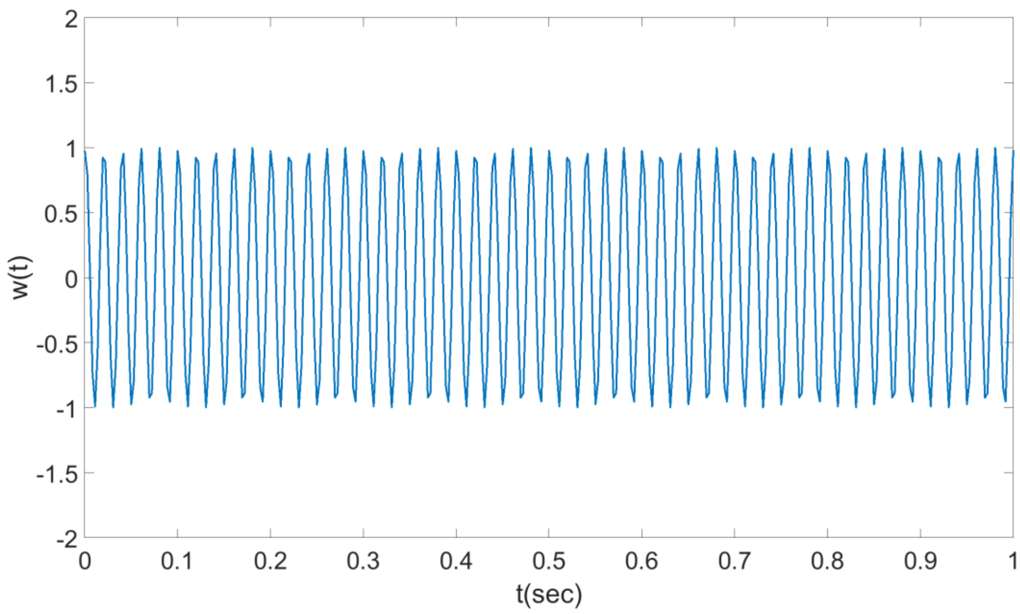

Figure 3.1 - Sinusoidal noise emulating mains at 50 Hz for 1 second

Figure 3.2 shows a example of on ECG signal (MIT-BIH signal 118m) Continued by the PLI noise in Figure 3.1.

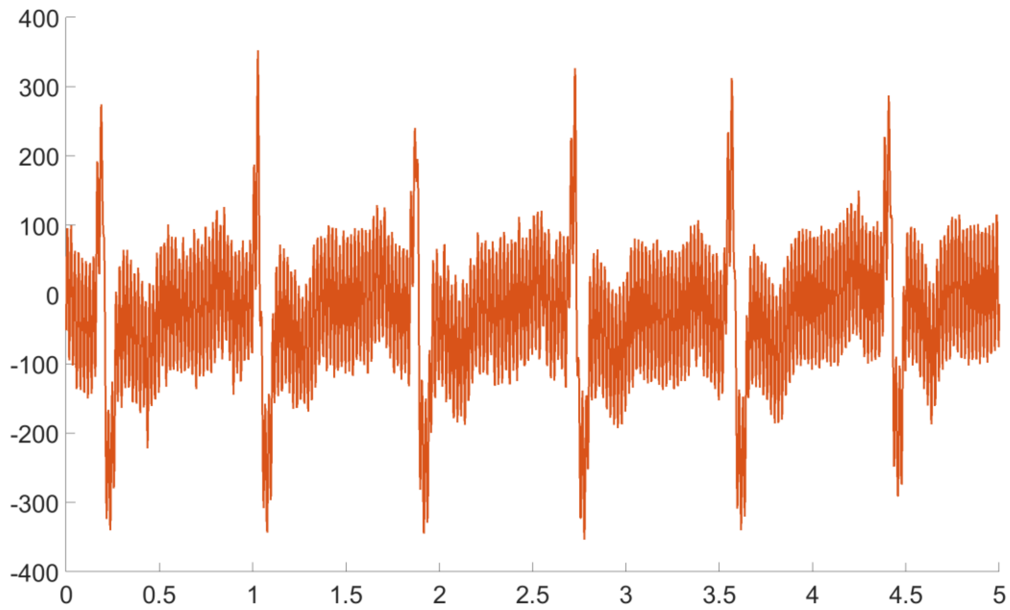

Figure 3.2 - Noisy ECG signal (5 seconds). SNR = - 40 dB

During the recording of an ECG signal, the part followed by of the signal between patient and ECG recorder cannot be completely shielded. Therefore, these fields produce significant interferences, which can be modelled with a sinusoid. The frequency spectrum of the power line interferences is quite narrow and centered around the frequency of the power supply, as show in Figure 3.3.

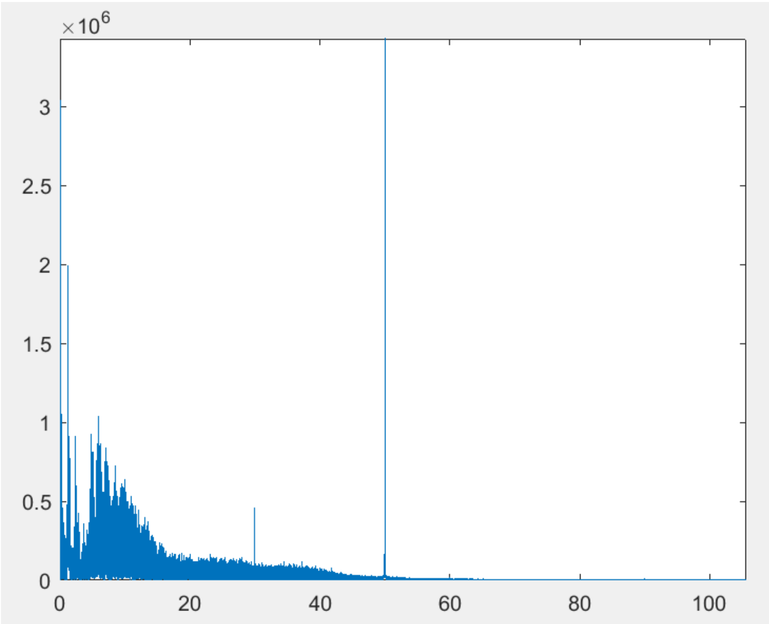

Figure 3.3 - Frequency spectrum of an ECG signal with frequency noise equally 50Hz

3.6 Discussion

Since noise can be generated by multiple sources, we differentiate between different types of noise. In order to create filter methods for single sources, we have to know the characteristics of the noise we want to create a filter for. Therefore it is an important task to create single noise models where we can test and improve the noise cancelling methods. The most important sources in ECG processing and their models are described in the following.

Denoising is used during preprocessing of the input signal. Since real-world ECG signals are often disturbed by noise and strongly depend on the individual patient, it is mandatory to perform denoising to get a robust recognition model. In section 3.3 - 3.4 we describe denoising for method frequency interference noise.

We are doing PLI (Power Line Interference) filtering. In a great, perfect world, it would be a sinusoid, but in reality, there are spikes sometimes, arcs, etc.

So, to test a denoising algorithm, we add a *known* noise to our signal, then pass it through our algorithm to get a denoised signal, then compare between original signal and denoised signal and look at performance parameters (SNR, distortion, etc).

4 LINEAR FILTERING (NOTCH FILTER)

4.1 Introduction

Filtering is closely related with signal processing discipline, and can be classified into two main categories, analogue signal processing and digital signal processing. Analogue signal processing is for signals that have not been digitized, which involves linear or nonlinear electronic circuits, such as passive or active filters. Digital signal processing is the processing of digitized discrete time sampled signals, where signal treatment is performed by computers or digital circuits, e.g. Digital Signal Processor (DSP) devices, running mathematical algorithms such as FIR or IIR. Additionally, filtering can be classified into linear or nonlinear process. If the filtered output is a linear function of the input observations, the filters is said to be linear, otherwise the filter is considered nonlinear. Moreover, filtering is directly related with spectral analysis, because the goal of filtering is to reshape the signal spectrum. For that reason, filtering techniques and filter types differing in the way that they reshape the signal spectrum.

4.2 Notch Filters

A very simple approach to the reduction of powerline interference is to consider a filter defined by a complex-conjugated pair of zeros that lie on the unit circle at the interfering frequency ω_0 = 2pi fo/Fs:

$$z_{1,2} = e^{\pm j\omega_0} \quad (4.1)$$

Such a second-order FIR filter has the following transfer function:

$$H(z) = (1 - z_1 z^{-1})(1 - z_2 z^{-1}) = 1 - 2\cos(\omega_0) z^{-1} + z^{-2} \tag{4.2}$$

Since this filter has a notch with a relatively large bandwidth, it will attenuate not only the powerline frequency, but also the ECG waveforms with frequencies close to ω_0. It is, therefore, necessary to modify the filter in (4.2) so that the notch becomes more selective, for example, by introducing a pair of complex-conjugated poles positioned at the same angle as the zeros $z_{1,2}$ but at a radius r,

$$p_{1,2} = re^{\pm;\omega 0} \tag{4.3}$$

where 0 < r < 1. Thus, the transfer function of the resulting IIR filter is given by

$$H(z) = \frac{(1 - z_1 z^{-1})(1 - z_2 z^{-1})}{(1 - p_1 z^{-1})(1 - p_2 z^{-1})} = \frac{1 - 2\cos(\omega_0) z^{-1} + z^{-2}}{1 - 2r\ \cos(w_0)\, z^{-1} + r^2 z^{-2}} \tag{4.4}$$

The notch bandwidth is determined by the pole radius r and is reduced as r approaches the unit circle. Figure 4.1 shows the impulse response and the magnitude function of the frequency es pause for two different values of the radius, r = 0.75 and 0.95. From Figure 4.1 it is obvious that the bandwidth decreases at the expense of on increased transient response time of the filter. The practical implication of this observation is that a transient present in the signal causes a ringing artifact in the output signal. For causal filtering, such filter ringing will occur after the transient, thus mimicking the low-amplitude cardiac activity that sometimes occurs in the terminal part of the QRS complex, i.e., late potentials.[1] Figure 4.1 shows one heartbeat without any contamination by powerline interference and the ringing artifact that results from processing with the IIR filter given in (4.4) using r = 0.97. This example clearly demonstrates that uncritical use of linear, time-invariant filtering can have a devastating effect on the ECG signal, significantly modifying its diagnostic content.

More sophisticated linear filters than the above second-order IIR filters can be designed for the removal of powerline interference, for example, by increasing the filter order to obtain a narrower notch or by employing filter design criteria involving both time and frequency properties. Since increased frequency resolution is always obtained to the detriment of decreased time resolution, it is impossible to design a linear, time-invariant filter which only removes powerline interference while not introducing a certain amount of ringing.

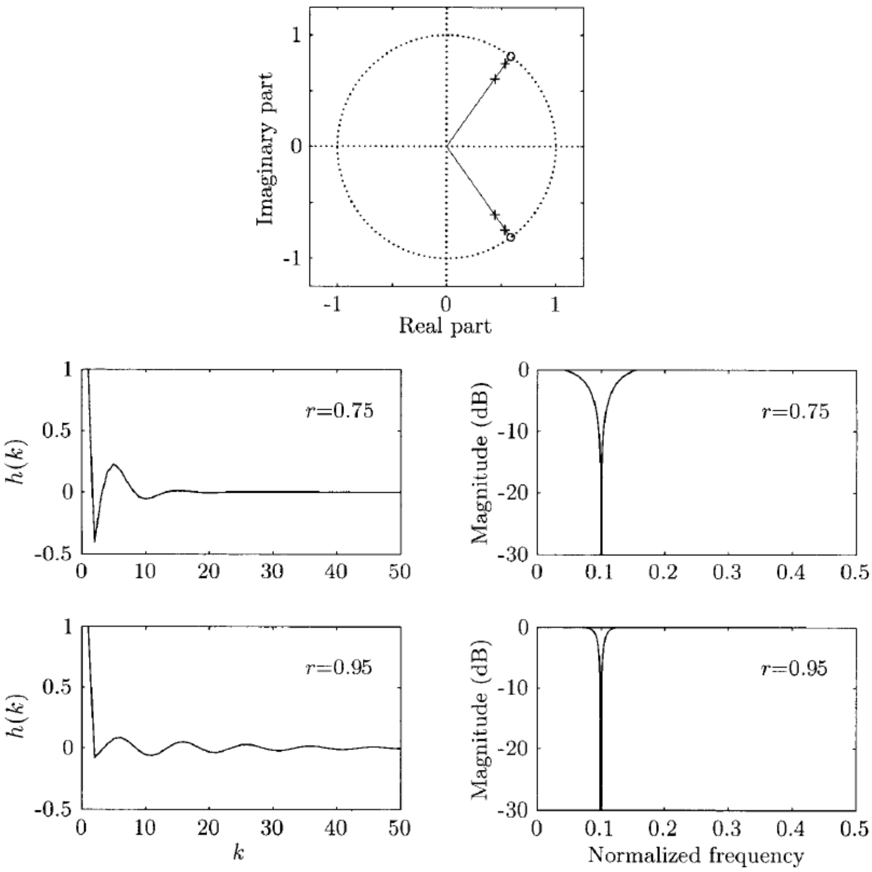

Figure 4.1 - Pole-zero diagram for two second-order [1]

IIR filters whose zeros are identically positioned but whose poles are at a radius r of either 0.75 or 0.95. The impulse response *h(k)* and the corresponding magnitude function are shown in the left and right panels, respectively.

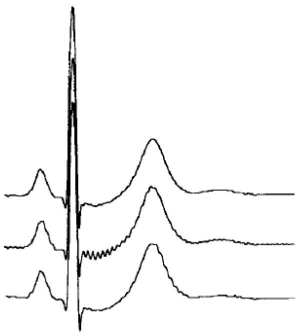

Figure 4.2 - Filtering of powerline interference. [1]

The original ECG signal without powerline interference (top), the output signal from the second-order IIR filter defined in (4.4) for r = 0.97 (middle), and the nonlinear filter defined with transient suppression using c~ = 10 pV (bottom).

4.3 Filter Design

Powerline interference as an example of frequency noise has a central frequency of 50 Hz with possible variations in a certain range in either direction. In case that the frequency range of the noise does not influence the frequency range of the ECG signal one effective method to filter this kind of noise is a simple notch filter. This allows to remove all signal components in the range around the centre frequency of the noise. In this work Notch Filter was used with the specifications shown in Figure 4.3 and Table 4.1. The advantage of a Notch filter compared to a low-pass filter is that possible signal frequencies higher than those of the frequency noise do not get filtered out and therefore the signal does not get distorted as much as it would with a low-pass filter.

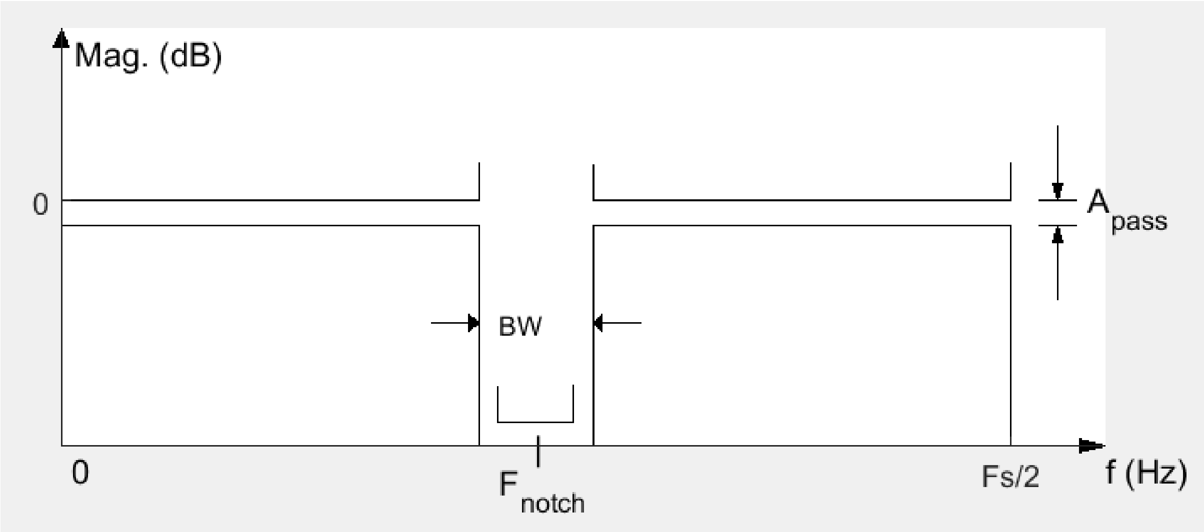

Figure 4.3 - Filter Specifications of a Notch Filter

The variables in Figure 4.3 have been chosen as described in Table 4.1, with f0 being the
central frequency and ±Δf describing the frequency range of the noise.

Table 4.1 - Filter Parameters used for frequency noise cancellation

Fs	360	Hz
Fnotch:	50	Hz
Bandwith	5	Hz
Apass	1	dB

The magnitude response of the filter is shown in Figure 4.5.

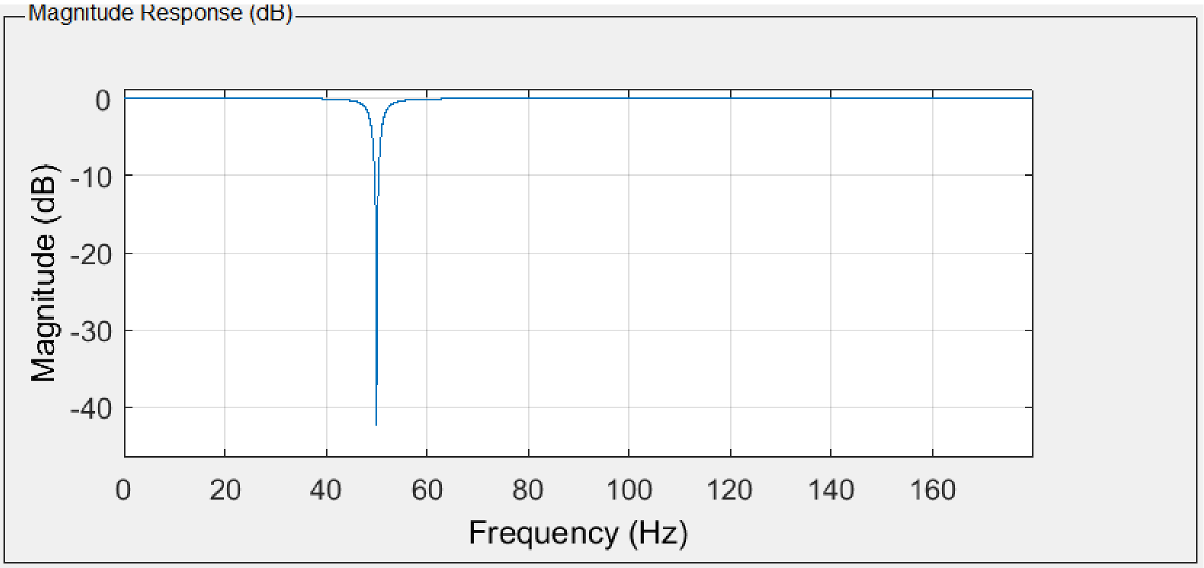

Figure 4.5 - Magnitude Response for attenuating frequencies of 50Hz ± 5Hz

The weakness of this method is that the clean ECG has some frequency components, such as those of the QRS complex, lying within the stopband of the filter used to remove the 50 Hz powerline interference with 50 Hz. Therefore, the QRS complex is distorted when filtered with a bandstop filter. One possible solution of this problem, is to preserve the QRS-complex, filter the remaining signal and then add the complex back to the filtered signal. [8]

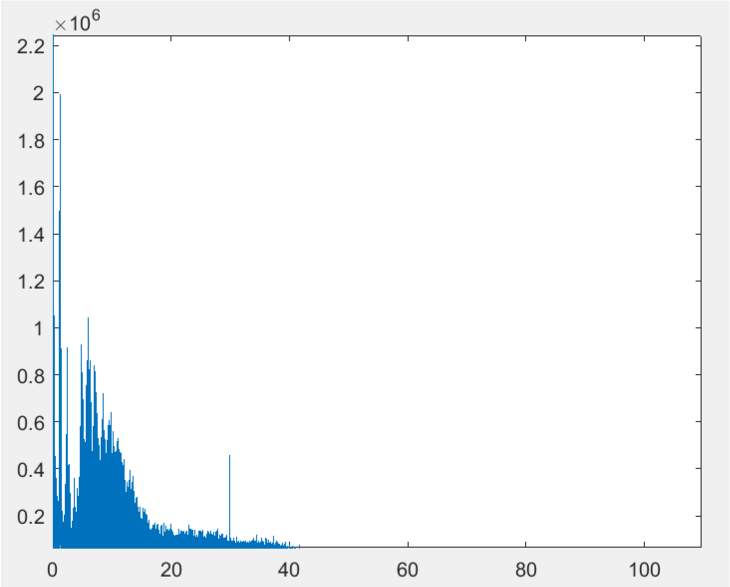

Figure 4.6 - FFT of the clean ECG Signal

We apply Matlab filtfilt function and return the 1-D digital filter of each row. Figure is Plots the original data against the filtered data.

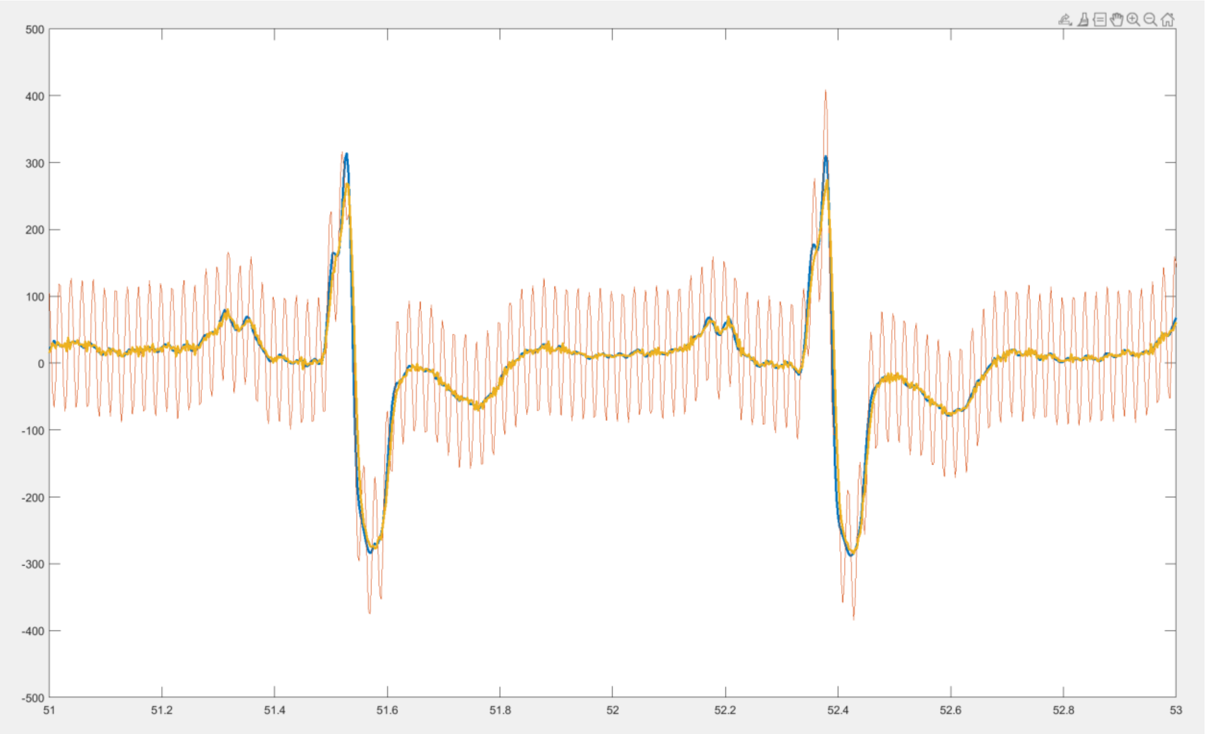

Figure 4.7 - blue) Real ECG signal, red) ECG signal with Powerline interference artefact, yellow) filtered ECG signal by notch filter

4.4 Non lineer filter

From the above observation, it is obviously desirable to develop a method for removal of powerline interference which is less sensitive to transients. We will now describe a nonlinear filter based on the idea of subtracting a sinusoid, generated internally by the filter, from the observed signal [12- 15]. The amplitude of the internal sinusoid is adapted to the powerline interference present in the observed signal x(n). The adaptation process is the key to making the filter less sensitive to transients and avoiding related filter ringing. The internal sinusoid is generated by.

Taking into account the fact that the amplitude A_0, in practice, is unknown and changing with time, it is preferable to generate the sinusoid recursively allowing us to update v(n) at every sample, so that amplitude changes can be tracked. The sinusoid can be generated by an oscillator defined by a pair of complex-conjugated poles located on the unit circle at frequency ω_0. The transfer function for the oscillator is

$$H(z) = \frac{V(z)}{U(z)} = \frac{1}{1 - 2cos\omega_0 z^{-1} + z^{-2}}, \quad (4.5)$$

and, accordingly, the sinusoid is generated by the following difference equation,

$$v(n) = 2cos\omega_0 v(n-1) - v(n-2) + u(n) \quad (4.6)$$

using the initial rest conditions, v(-1) = v(-2) = 0. The input signal *u(n)* is given by

$$u(n) = \delta(n) \quad (4.7)$$

where б*(n)* is the unit impulse function.

An error function *e(n)* is now introduced that indicates how well *v(n)* predicts the powerline interference contained in the signal x(n),

$$e(n) = x(n) - v(n) \qquad (4.8)$$

Since this error definition suffers from a dependence on the DC level of x(n), it must be modified so that it becomes insensitive to the DC level, for example, by computing the first difference of e(n),[1]

$$e'(n) = e(n) - e(n-1) = x(n) - x(n-1) - (v(n) - v(n-1)) \qquad (4.9)$$

We can, of course, use other types of filter to efficiently remove the DC level while retaining the sinusoidal interference; however, the first difference filter is extremely simple to implement. Depending on the sign of e’(n), the current value of *v(n)* is either updated by a fixed positive or negative increment α or kept constant to produce a new estimate v(n) of the powerline interference. The update equation is given by

$$v(n) = v(n) + a\ sgn\big(e'(n)\big) \qquad (4.10)$$

The output signal *y(n)* of the nonlinear filter results from subtraction of v(n) from *x(n)*

$$y(n) = x(n) - v(n) \qquad (4.11)$$

The nonlinear equation in (5.7) implements the transient suppression property of the filter since changes in amplitude are limited by the increment α. We note that too small a value of α causes the filter to poorly track changes in amplitude of the powerline interference, whereas too large a value of α causes the filter to introduce extra noise in y(n) because of the large step alterations which will occur in v(n).

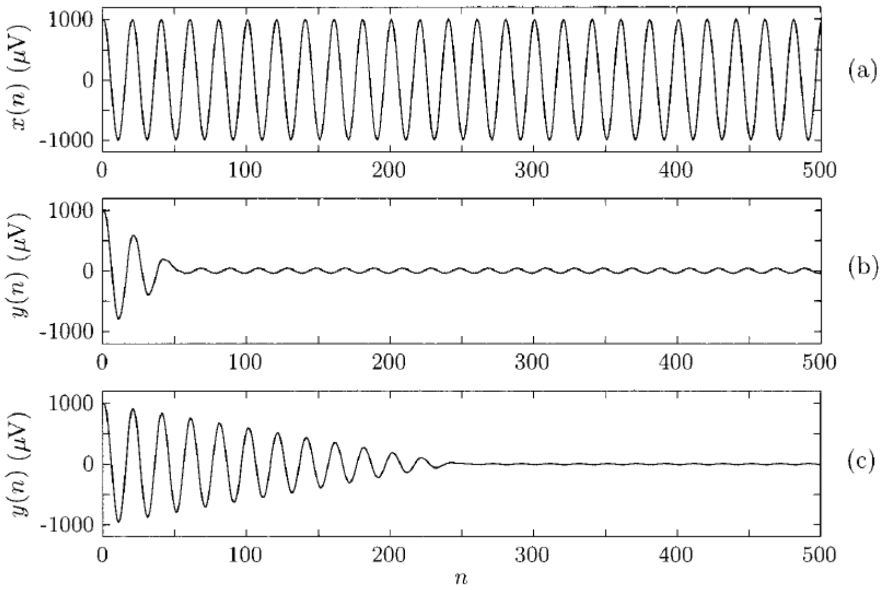

Figure 4.8 - Convergence properties of the nonlinear 50/60 Hz filter, illustrated by processing (a) a purely sinusoidal signal x(n) [1]

The output signal y(n) of the nonlinear filter is computed for a fixed increment of either (b) α = 10 μV or (c) α =2 μV.

Before the next sample at time n + 1 is processed, *v(n)* is replaced by its estimate in (4.10), and then used in the recursion (4.6) to generate *v(n* + 1), and so on. The performance of the nonlinear filter is exemplified in Figure 4.8. In contrast to the above-mentioned IIR notch filter, no ringing artifact can be discerned after the QRS complex when this filter is applied[1]. In the ECG signal, adaptation of the internal sinusoid primarily takes place during the isoelectric line and the T wave; the duration of the QRS complex is short enough not to significantly influence the interference estimate v(n) [15]. Figure 4.8 illustrates the convergence properties of the nonlinear filter: too large a value of α will produce an output signal in which a substantial part of the sinusoid remains. The frequency characteristics of this filter are not easily analyzed due to its nonlinear structure. By replacing the nonlinear update equation in (4.10) with a linear one,

$$v(n) = \hat{u}(n) \tag{4.12}$$

$$v(n) = v(n) + \alpha e'(n) \tag{4.13}$$

the resulting filter can be identified as an IIR notch filter with the transfer function [40]

$$H(z) = \frac{(1-a)(1-2cosw_0 z^{-1} + z^{-2}}{1-(a+2(1-a)cosw_0)z^{-1} + (1-a)z^{-2}} \tag{4.14}$$

This filter has a pair of zeros on the unit circle at w_0 and a pair of poles located inside the unit circle. The update parameter a in (5.11) determines the pole position and, thus, the bandwidth of the IIR filter. Clearly, the transient suppression property is lost when (5.7) is replaced by the linear update equation in (5.10), and thus, QRS-related ringing artifacts will occur in the filtered signal. It may be noted from the transfer function in (5.11) that the poles are not located at the angles +- w_0, but rather at positions modified by the increment α.[1]

5 ADAPTIVE FILTERS ESTIMATIONS – SUBTRACTION (LMS/RLS METHOD)

5.1 Introduction

Adaptive filters have 2 basic filter structures. One of the adaptive filter structures is shown in Figure 5.1 below,

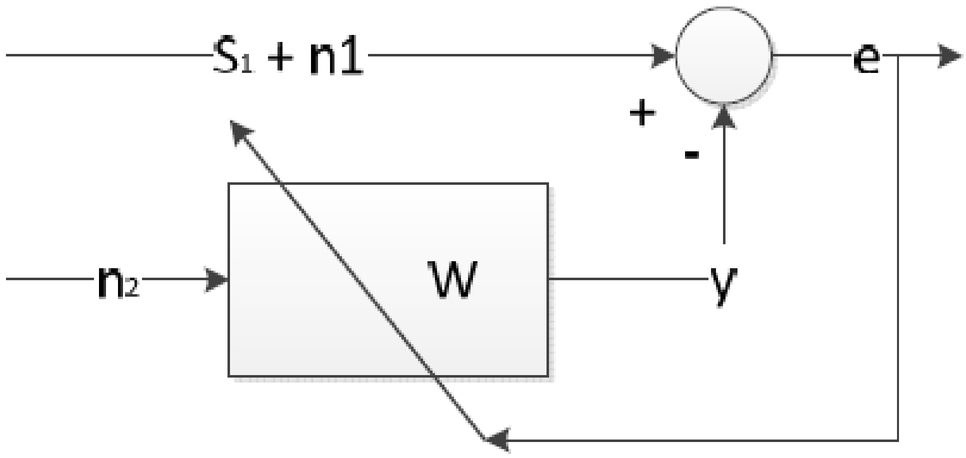

Figure 5.1 - Adaptive Filter Structure 1 (Type I) [28]

In this filter structure,the primary input is signal s1 with additive noise n1 and reference input is noise n_2, which can be any baseline wander, power-interference noise, etc. and it is correlated with n_1. Both noise sources n1 and n_2 should not be correlated with the signal s1. The filter output is y and the filter error is $e = (s_1 + n_1) - y$. W is the weight function that is updated every iteration and the basic structure for it is, New weight = old weight + adjustments.

The other basic adaptive filter stricture is shown in Figure 5.2 below.

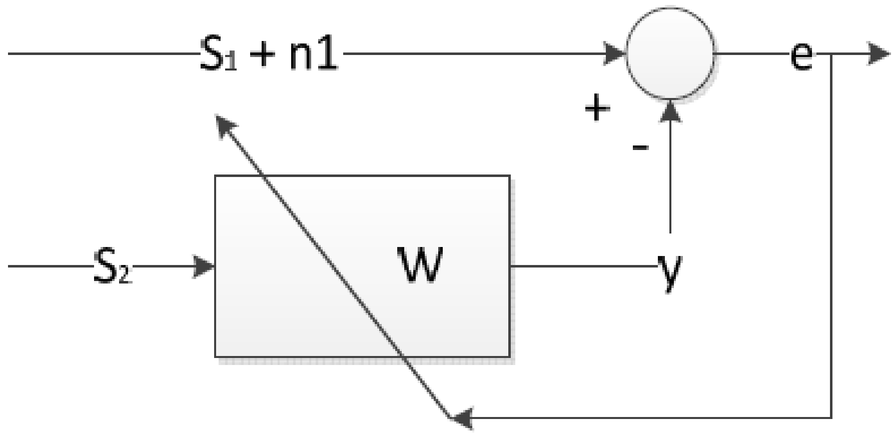

Figure 5.2 - Adaptive Filter Structure 2 (Type II) [28]

Unlike filter structure 1, this structure has s2 as its reference signal. In this filter structure, the primary input is signal s1 with additive noise n1 and reference input is the signal s2, which can be the clean ECG signal and it is correlated with s1. Because of the unknown nature of the clean ECG signal, this adaptive filter structure cannot be used to remove noise sources from the ECG signal.

5.2 Adaptive Signal Processing

Aiming to achieve the best filtering performance, signal processing methods have progressed considerably in algorithm is complexity. In general, the computational requirements for signal processing methods have increased exponentially w.r.t. algorithmic complexity. Therefore, finding an algorithm with the ability of filtering signals efficiently, with automatic performance adaptation, and at the same time offering a good balance between performance and computation requirements, becomes an interesting motivation to work with non-classical filtering schemes, such as adaptive signal processing techniques. Conversely to classical FIR and IIR filters, adaptive filters automatically change theirs characteristics, by optimizing the internal parameters. It is important to refer the close relationship of the adaptive signal processing technique with the Wiener filter. The Wiener filter is based on the minimization of the Mean Square Error (MSE) value of the signal that is defined as the difference between some desired response and the actual filter output. But it is only possible to design a Wiener filter with optimal performance if a priori information about the statistics of the data to be processed is known [18]. Adaptive filters are quite similar to Wiener filters they are based on the same concept, the minimization of the MSE. But unlike Wiener filters, the parameters of adaptive filters are constantly adapted to reach the MSE. Adaptive filters are widely used in several applications including the treatment of biomedical signals. Biomedical signals such as ECG, EMG and EEG are important in diagnosis and patient monitoring. But these signals have very small amplitude, and therefore they are commonly affected by noise. It is difficult to filter noise from these signals, and errors resulting from filtering may distort them.

5.3 Adaptive Filtering Scheme

The complete specification of an adaptive system consists of three main points: application, structure and algorithm [19].

Application: What is the application where the filter will be used? The type of application is defined by the signals applied to the input and the desired output signals. The number of different applications in which adaptive techniques are being successfully used increases every day. Some examples are echo cancellation, equalization of dispersive channels, system identification, signal enhancement, adaptive beam forming, noise cancelling, and control.

Structure: Which filtering structure better satisfies the characteristics of the application? Adaptive filters can be implemented in a number of different structures or realizations. The choice of the structure can influence the computational complexity and also the necessary number of iterations to achieve a desired performance level. Basically, the two major classes of adaptive digital filter realizations are the FIR and IIR filters.

Algorithm: What kind of algorithm should I use to update the filter parameters? The algorithm is the procedure used to adjust the adaptive filter coefficients in order to achieve the best filtering performance. Adaptation algorithms are typically based on the mean square error minimization criterion. This error is the difference between the output of the signal processing module and the reference signal. To achieve optimum parameters for the filter, two methods are commonly used: the Recursive Least Square (RLS) method, and the Least Mean Square (LMS) method.

5.4 Least Mean Squares (LMS) Algorithm

The LMS algorithm is a linear adaptive filter algorithm invented by B. Widrow and T. Hoff.[21] This filter is based on finding filter coefficients that lead to minimizing the mean square of the error which is the difference between the desired signal and error signal. Its stochastic gradient descent method adapts to instantaneous error. In order for the LMS filter to approach the optimum filter weights, the algorithm starts by assuming small weights (zero) and at each step, it finds the gradient of the mean square error and then updates the weights. If mean square is increasing, filter weights need to be reduced accordingly. And vice versa, if gradient is negative, filter weights need to be increased. The Weight update equation is shown below,

$$w(n) = w(n-1) + \mu\, e(n)\, x(n) \tag{5.1}$$

where e(n), x(n), μ and w(n) are the error, the input, step-size parameter, and weight

function respectively.

Under the assumption that the step-size parameter μ is significantly small, LMS algorithm converges in the mean square provided that μ satisfies the condition below,[21]

$$0 < \mu < \frac{1}{\lambda_{max}} \quad (5.2)$$

where λ_{max} is largest eigenvalue of the correlation matrix of input signal.

5.5 Variants of LMS

In adaptive filters, the weight vectors are updated by an adaptive algorithm to minimize the cost function. The algorithms used by us for noise reduction in ECG in this thesis are least mean square (LMS), Normalized least mean square (NLMS), sign data least mean square (SDLMS), sign error least mean square (SELMS) and sign-sign least mean square (SSLMS) algorithms.

5.5.1 Normalized LMS (NLMS algorithm)

The NLMS algorithm is a modified version of the standard LMS algorithm. The NLMS algorithm updates the coefficients of an adaptive filter by using the following equation

$$W(n+1) = W(n) + 2\,\mu \frac{x(n)}{\left||x(n)|\right|^2} e(n) \quad (5.3)$$

Equation 5.4 can be rewritten as

$$W(n+1) = W(n) + 2\,\mu(n)\,x(n)\,e(n), \quad (5.4)$$

Where $\mu(n) = \mu\, ||x(n)||^2$

From the equation 6.3 and Equation. 6.5, the NLMS algorithm becomes the same as the standard LMS algorithm except that the NLMS algorithm has a time-varying step size $\mu(n)$. This step size improves the convergence speed of the adaptive filter.

5.5.2 Sing-Data LMS (SDLMS algorithm)

In SDLMS algorithm, the sign function is applied to the input signal vector *x(n)*. This algorithm updates the coefficients of an adaptive filter using the following equation

$$W(n+1) = W(n) + 2\,\mu\, sgn(x(n))\, e(n) \tag{5.5}$$

5.5.3 Sign-Error LMS (SELMS algorithm)

In SELMS, the sign function is applied to the error signal *e(n)*. This algorithm updates the coefficients of an adaptive filter using the following equation

$$W(n+1) = W(n) + 2\,\mu\, x\,(n)\, sgn(e(n)) \tag{5.6}$$

5.5.4 Sign-Sign LMS (SSLMS algorithm)

Here, the sign function is applied to both $e(n)$ and *x(n)*. This algorithm updates the coefficients of an adaptive filter using the following equation

$$W(n+1) = W(n) + 2\,\mu\, sgn(x(n))\, sgn(e(n)) \tag{5.7}$$

5.5.5 Summary of LMS Verienrs

The main idea of LMS Verienrs:

- ‘LMS’ – Solves the Weiner-Hopf equation and finds the filter coefficients for an adaptive filter.
- ‘Normalized LMS’ – Normalized variation of the LMS algorithm.
- 'Sign-Data LMS' — Correction to the filter weights at each iteration depends on the sign of the input x.
- 'Sign-Error LMS' — Correction applied to the current filter weights for each successive iteration depends on the sign of the error, err.
- 'Sign-Sign LMS' — Correction applied to the current filter weights for each successive iteration depends on both the sign of x and the sign of err.

5.6 Recursive least squares filter (RLS)

In this section, we will look at the filters that are derived by minimizing a weighted least squares error, and derive an efficient algorithm for performing this minimization known as recursive least squares.

Recursive least squares (RLS) is an adaptive filter algorithm that recursively finds the coefficients that minimize a weighted linear least squares cost function relating to the input signals. This approach is in contrast to other algorithms such as the least mean squares (LMS) that aim to reduce the mean square error. In the derivation of the RLS, the input signals are considered deterministic, while for the LMS and similar algorithm they are considered stochastic. Compared to most of its competitors, the RLS exhibits extremely fast convergence. However, this benefit comes at the cost of high computational complexity.

The idea behind RLS filters is to minimize a cost function C by appropriately selecting the filter coefficients w_n updating the filter as new data arrives. The error signal e(n) and desired signal d(n) are defined in the negative feedback diagram below (figure 5.3),

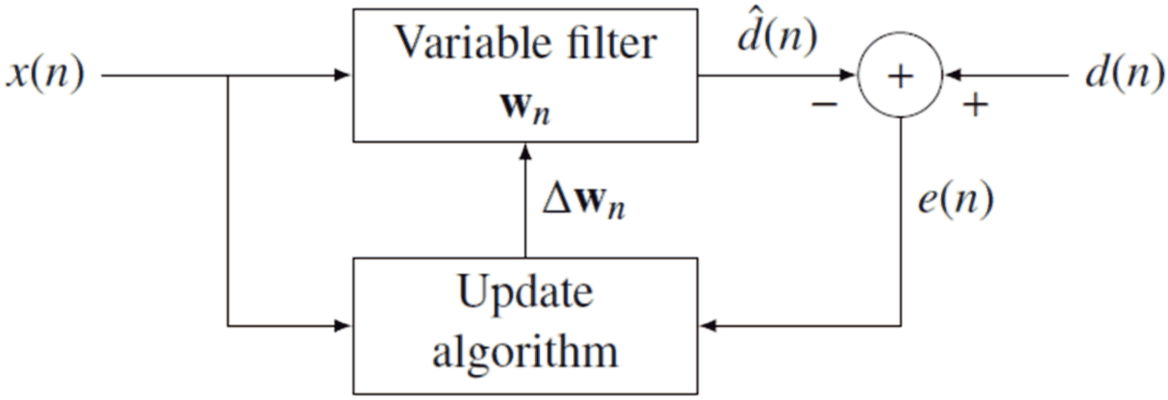

Figure 5.3 - Adaptive Filter RLS [28]

To allow for continuous operation, and thus actual implementation, the solution can be computed in recursive form.

5.7 Discussion

LMS and RLS can be considered the simplest forms of the steepest-descent search3. LMS was the first algorithm used to design a linear adaptive filter algorithm, when it was proposed by Widrow and Hoff in 1959. The LMS algorithm has established itself as the workhorse of adaptive signal processing for two primary reasons: computational efficiency and robust performance [21]. However, for signals with a large spectral dynamic range, the LMS has a no-smooth and slow rate of convergence. In addition if the signal is also non-stationary (e.g. speech and audio signals), then the LMS can be an unsuitable adaptation method. LMS algorithms are known as slowly converging algorithms. The speed of convergence defines the number of signal intervals that are necessary to obtaining reliable filter coefficients [21][19]. RLS type algorithms have much better starting convergence properties but they are much more complex, and for that reason, not so suitable for low computational devices. RLS method, has better convergence rate and less sensitivity to the eigenvalue spread than LMS.

6 NUMERICAL RESULTS

6.1 Introduction

Selecting the optimum filter parameters for Powerline cancellation is important. Generally, for ECG filtering. filter parameters calculated through approximation and then manually adjusted for best performance through trial and error. For PLI removal using adaptive filters, the smaller the step-size, the better the overall filter will perform. The filter will converge more slowly but fewer artifacts will go through.

6.2 Graphical and Numerical Results

The **mean squared error** (**MSE**) of an estimator (of a procedure for estimating an unobserved quantity) measures the average of the squares of the errors—that is, the average squared difference between the estimated values and the actual value. MSE is a risk function, corresponding to the expected value of the squared error loss. That MSE is almost always strictly positive can be attributed to either randomness, or the fact that the estimator does not account for information that could produce a more accurate estimate.[22]

We applied denoising methods described in chapters 4 and 5 to the contaminated. ECG signal generated as described in Section 3.5 The parameters for implemented filters and MSE are shown in Table 6.1 Figure 6.1 visualizes the processes of adding powerline interference noise to clean signal.

It shows an ECG signal with added powerline interference created as described in Section 3.5.

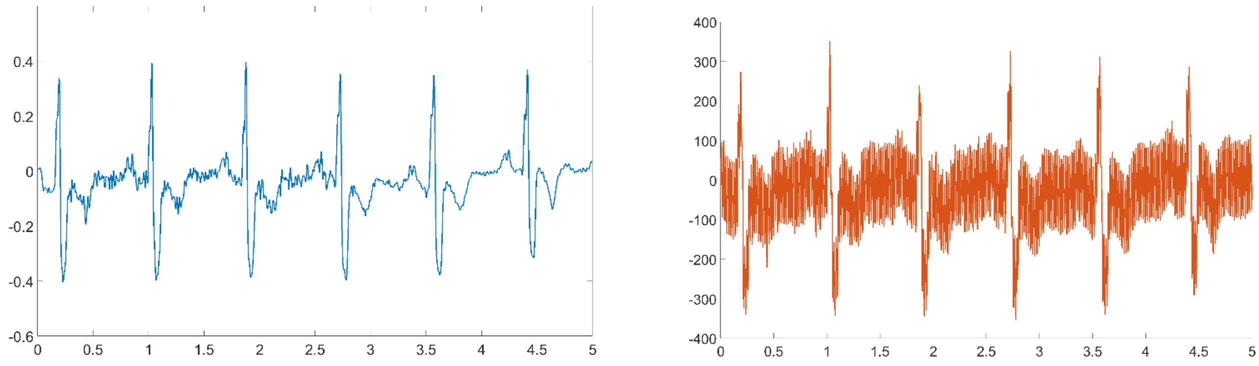

Figure 6.1 - Clean ECG signal (left), ECG signal with Powerline noise with a center frequency of 50 Hz ± 5 Hz SNR = -40db.(Right)

Figure 6.2 shows the results of filtering an ECG signal with frequency noise with a bandstop(notch) filter as described in Section 4.3.

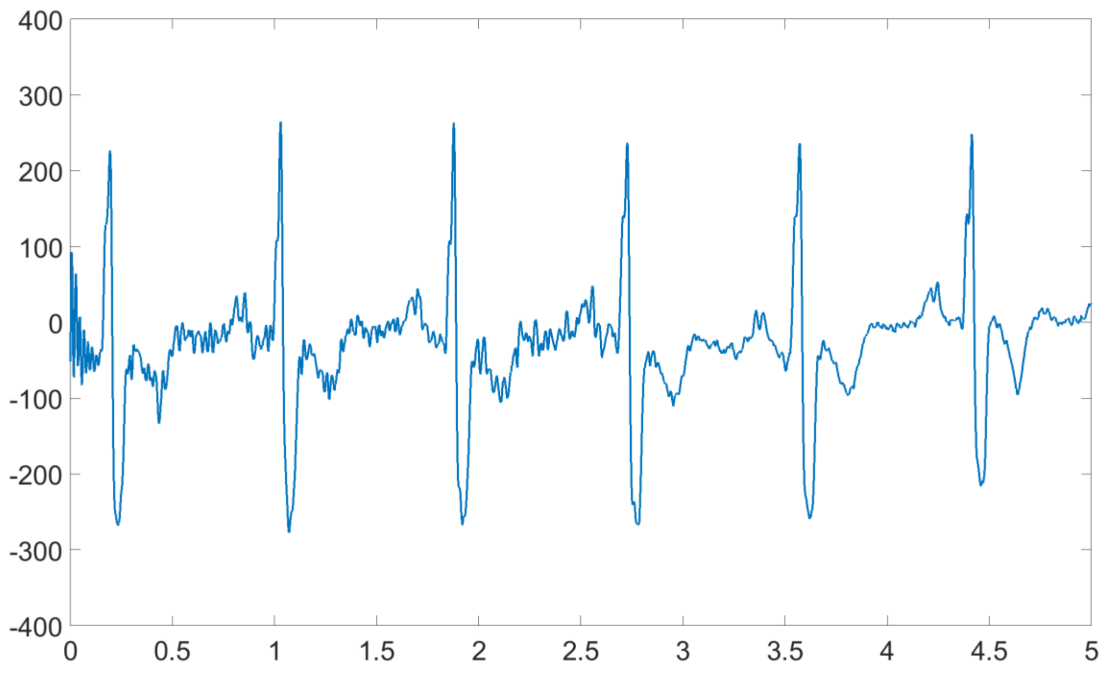

Figure 6.2 - ECG signal with notch filter removal (SNR= -40db)

The corrupted signals shown in Figures. 6.3-6.4 are obtained by passing the noisy signals through the adaptive filters.

They show the filtered output plot of the adaptive filters using the LMS and RLS algorithms respectively.

цWe have also considered other four adaptive filter: NLMS, SDLMS, SELMS, SSLMS, but are result is not showed because they are very similar to the first one (Figure 6.3).

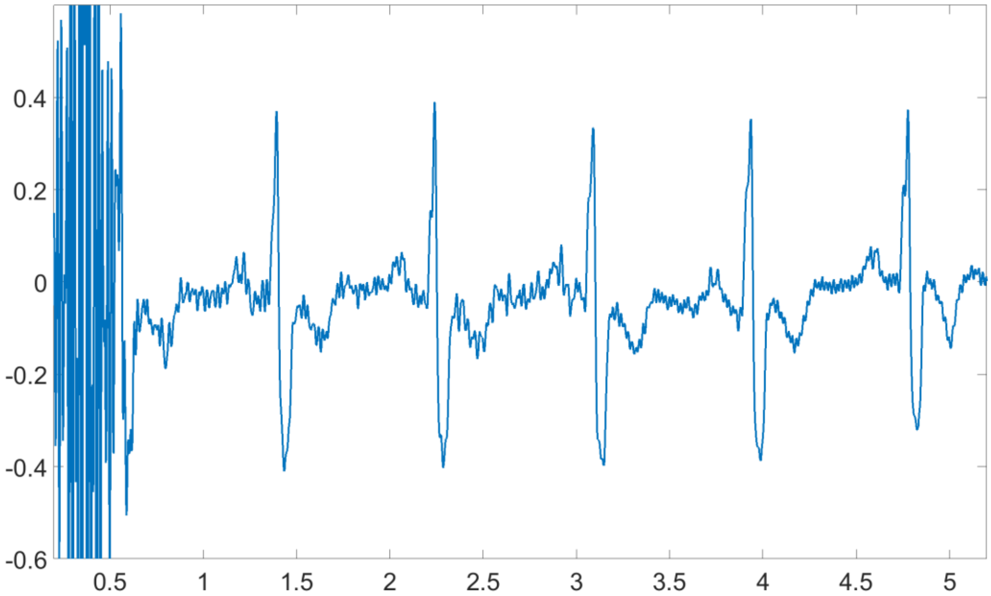

Figure 6.3 - ECG signal after passing through the LMS based filter. LMS parameters – mu = 0.0005, Stepsize = 12

The results for the notch IIR filter LMS, NLMS, SELMS, SDLMS, and SSLMS algorithms are shown Table 6.1.

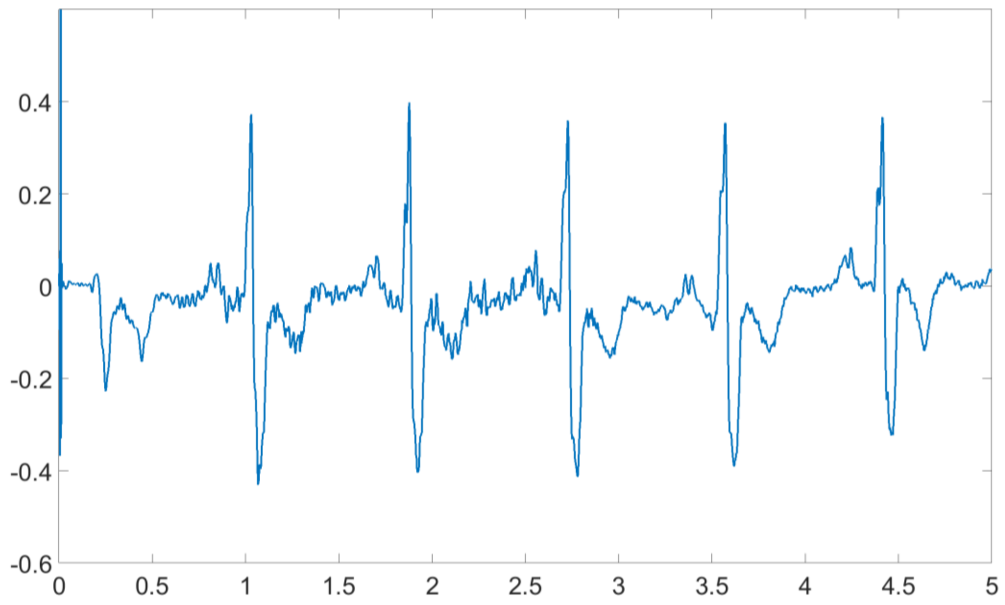

Figure 6.4 - ECG signal after passing through the RLS based filter

Table 6.1 - Summary of the mean squared error (MSE) for the tested algorithms

Denoise method	Filter Parameters	MSE
RLS	Stepsize 11	5.9539e-05
Notch IIR filter	Fnotch: 50, Bandwith 5 Apass 1	2.2008e-05
LMS	mu = 0.0005, Stepsize 12	5.0202e-04
Normalized LMS (NLMS)	mu = 1.4, Stepsize 12	6.4234e-04
Sign-Data LMS	mu = 0.009, Stepsize 12	4.4555e-04
Sign-Error LMS	mu = 0.00002, Stepsize 12	0.0029
Sign-Sign LMS	mu = 0.0004, Stepsize 6	0.0033

Based on results from graphs and tables, as for improving the results, one can implement variable step-size algorithm), which can help on faster convergence of the algorithm at the start. Faster adaptation allows the signal to be analyzed by smaller segments.

Table 6.2 - Summary of LMS algorithms

	LMS	**NLMS**
Data Modeling	Linear	Linear
Computation	Fast	Fast
Simplicity	Simple	Simple

6.4 Signal-to-Noise Ratio (SNR)

From previous notes at beginning of this chapter, signal and noise are relative terms: general speaking, signal is the waveform of interest while noise is everything else. The relative amount of signal and noise present in a waveform is usually quantified by the SNR. As the name implies, this is simply the ratio of signal to noise, both measured in Root-Mean-Squared (RMS) amplitude. The SNR is often expressed in decibel (dB).

As we can see below in Figure 6.5 curves for each Method.

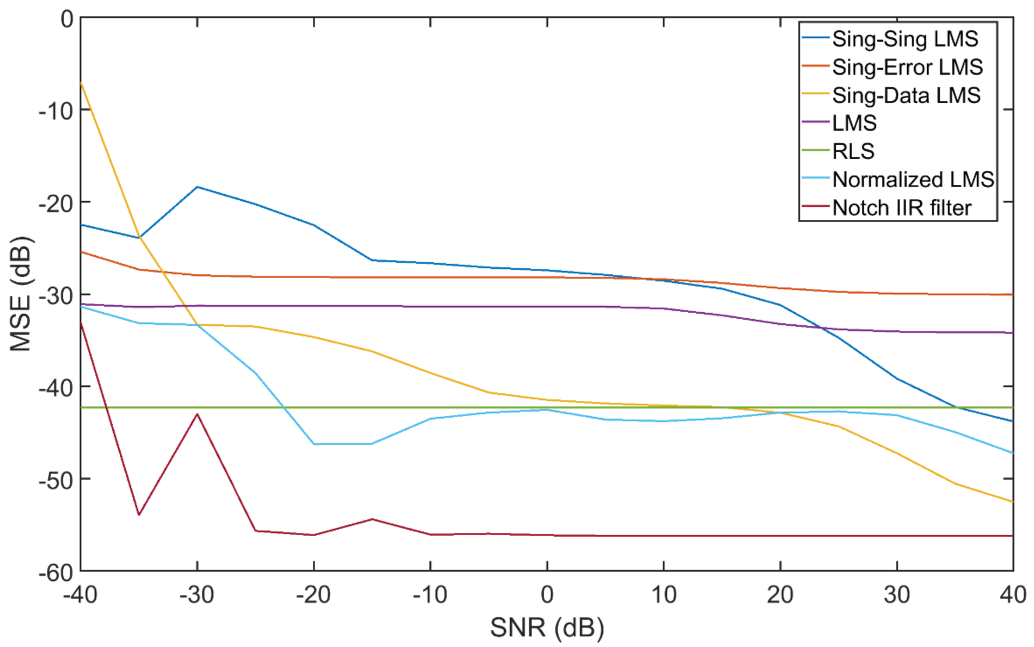

Figure 6.5 standard deviation for each SNR/MSE value for method used

As we can MSE decreases as the SNR increases, and then it gets stuck when we reach a certain SNR threshold. The curves also show that a properly designed notch filter is difficult to beat, and that is the reason why most people still use it to remove PLI.

6.5 Discussion

Noisy ECG signals were created by adding artifacts to the clean ECG signals. The clean ECG signal was 1 minute duration of the signal record 118 from the MIT-BIH database [21]. All artifacts were created as described in Section 3.5. Once the noisy ECG signals were created, they were fed into main MATLAB program. In the main program the performance of the notch IIR filter LMS, NLMS, SSLMS, SELMS and SDLMS algorithms on the noisy ECG signals were tested.

As a simple performance measure, we used the mean squared error (MSE). The results show that a properly designed filter is hard to beat when it comes to PLI removal.

7 CONCLUSION AND FUTURE LINES

7.1 Introduction

In the present work, the Notch IIR filter and LMS algorithm based adaptive filters have been used to remove power line interference artifacts.

7.2 Conclusion

Most of the work done in this master thesis has been rearming or conforming existing methods on measured raw data from several subjects. However, these methods are all done on a preexisting set of measurements, and a great motivation behind the origin of this thesis is to make these methods work as best you can. For that to happen, the first step must be real-time filtering of the signal. Luckily, Simulink in Matlab has excellent tools for handling real-time processing of signals, and since the NLMS-algorithm only minimizes the instantaneous cost at each iteration, the processing power needed for real-time implementation should be negligible, as long as care is taken in choosing proper step-sizes. Filtering using instead DWT, as mentioned earlier, will likely be just as effective, and as mentioned in the discussion, has several strengths that make it preferable to an NLMS-filter in a future implementation.

Additionally, other studies [16] [17] have approached filtering of ECG from several different angles, granting insight that may further improve the filter. It is worth mentioning, however, that even though Matlab is a powerful tool with excellent handling of large sets of data, it might be worth considering implementing these methods in another language (e.g. Python or C) in order to make it computationally easier on eventual hardware with sparse amounts of power. Next, a real-time implementation of baseline wandering removal shall be attempted. Though this is also a form of filtering the signal, it will be most likely be slightly harder than straight-forward high-frequency filtering. This is due to the need for a posteriori knowledge about trends in the signal, at least for any implementation.

It is nonetheless imperative that any method for baseline wandering removal is able to retain the information removed so it can be further analyzed. The algorithm for QRS-complex detection is, as of now, quite stable, and has performed outstandingly on the measurements used in this thesis. A more extensive testing on a more varied set of data from different subjects is desirable, however, for the sake of confirming the validity of the method in different situations, and an experimental design for this purpose is likely to be made in the future.

Furthermore, and as mentioned earlier, the criteria for artifact classification needs to be better defined. A simple way of doing this could be to combine the existing cross-correlating method with some other approach that would more precisely classify cycles. Also, more multivariate analysis should be done on the cycles with methods such as e.g. Principal Component Analysis(PCA) and Partial Least Square Regression(PLSR). Such analysis might give information about physiological phenomena based on the variance between cycles, and would be of utmost interest.

Lastly, more work should be done on determining the respiratory movement in the signal. The most critical part of this stage would be to set up an experimental design, in which the subjects would be equipped with an respiratory belt, and instructed to breathe in a certain pattern underway in the measurement. Thus, it would be possible, with a much higher degree of accuracy, to say whether or not the methods used in this thesis are adequate. An investigation should also be done on whether or not the EDR is a signal possible to identify from the aforementioned heart cycle variance. Any work beyond that other than refining what's already done, would likely be to look for signs of other physiological phenomena not typically considered in ECG-signals. One could also perhaps extend the part of the methods to other bodily signals such as, for example, EEG.

7.3 Future lines

As future work, it will be interesting to implement the LMS adaptive filter in hardware, using a low cost and low power microcontroller with signal processing capabilities. It will be also important to develop an algorithm to adjust the step-size dynamically, which could be useful to adapt the algorithm to different noise sources. In this work it was evaluated the performance of LMS adaptive filter to remove power line noises from ECG signal.

Improving LMS algorithm:

An idea that was proposed during our work was to apply the LMS algorithm in the frequency domain. This has been said to reduce computational complexity [29].

Improving RLS algorithm:

While researching different RLS filters a few other names popped up, for example. The Householder RLS, the Sliding Window RLS, a combination of these two: Householder Sliding Window RLS and QR decomposition [29]. There was not enough time to implement all of these different RLS filters, so the most promising two were chosen for this thesis. However, in future, it might be useful to implement these as well.

Finally, the computational requirements could be reduced if the process for Wiener tap-weights actualization is done in blocks instead of every sample. The performance will be affected, but depending on the purpose this could be a profitable solution for very low computational hardware systems.

The future developments to this work can be made as follows:

- Implementation of wavelet based denoising for the removal of base line wander;
- use of other adaptive methods like FT-RLS, QRD-RLS algorithms for ECG denoising;
- application of blind adaptive filtering for ECG enhancement;
- real time application of implemented algorithms.

8 ECONOMIC CHAPTER

Cardiovascular diseases (CVD) are one of the most dangerous of the diseases, as well as the most common. Such diseases can be detected by ECG. A large percentage of people suffer from strokes, heart attacks, coronary heart disease.

Moreover, it is proved that approximately half of the patients do not show visible changes even with regular ECG examination. Therefore more exact methods of processing of an ECG are required. can be useful to healthcare professionals to simplify and expedite work.

This topic is relevant in the field of medicine. It can be useful for health professionals to simplify and speed up work.

The idea of the project is that the processing of cardiographic information is necessary for a large number of medical institutions, doctors, etc., which is specified in table. 8.1 And the use of methods in the medical field will significantly increase the accuracy of the diagnosis of CVD.

Table 8.1 - Description of the project idea

The content of the idea	Areas of application	Benefits for the user
Using a new approach to noise reduction in ECG signals Suppression mains interference	1. Medicine	Easy access to the system. Relatively low cost of sales. The analysis is performed on real data.
	2. Educational laboratory	Availability and reusability using. The possibility of using the analyzed data in the study of biomedical disciplines
	3. Scientific	No need for special equipment, only programming skills

Conclusions: in Table 8.1 shows the main directions of use of the proposed solution. Consumers of these products can be both, and public health institutions.

Analysis of market launch opportunities

Table 8.2 - Preliminary description of the potential market

№ p / p	Market indicators (name)	Characteristic
1	Number of main players, units	10
2	Total sales, UAH / unit	40
3	Market dynamics (qualitative assessment)	is growing
4	There are restrictions for entry (specify the nature restrictions)	no
5	Specific requirements for standardization and certification	available
6	Average rate of return in the industry (or market),%	

The market is attractive for entry according to the preliminary assessment

Table 8.3 - Preliminary description of potential customers

/ p	The need that shapes the market	Target audience (target market segments)	Differences in the behavior of different Potential target customer groups	Consumer requirements for goods
	The need for filters that require a minimum of preparation before use and have good technical characteristics	Medical institutions, educational laboratories, home use	Focus on the availability and quality of software	- to products: reliability, access ibility - to the supplier company: Experienced, specialists, quality guarantee

Table 8.4 - SWOT analysis

Strengths: Reusability; Price per unit of software; Easy to use code	Weak sides: Developed filters are needed improve.
Opportunities: Availability of implementation; Good technical characteristics.	Threats: Individual noise level in different rooms; Technical characteristics are insufficient.

Development of market strategy of the project

Table 8.5 - Selection of target groups of potential consumers

p / p	Profile description target group of potential customers	Readiness of consumers to accept product	Approximate demand in within the target group (segment)	Intensive st competition in the segment	Easy to enter the segment
1	Medical institutions	Not ready yet	Demand is large	Average	Complex Exit
2	Educational laboratory	Ready	Demand is average	Average	Wednesday ease of entry
3	Used at home conditions	Ready	Demand is average	Small	Medium ease of entry
Which target groups are selected: Home use and training laboratories.					

Target groups selected: Home use and training laboratories. Since the company focuses on one segment - we choose a strategy of concentrated marketing.

The project at this stage is scientific, with virtually no modifications for the consumer market. In this regard, the main stakeholders will be individuals and organizations that directly use the system. In the first stage, the project will be directly influenced by students and laboratory technicians, and cardiac surgeons will implement it, as well as educational institutions that will use it. their main interests will be the cost of work and infrastructure complexity of the system in the case of application. An important group of stakeholders after the project will be students, for whom the main evaluation criteria will be the simplicity of the interface and the variability of usage scenarios. In the medical field, stakeholders will be distributed according to a similar mechanism - from organizations at the implementation stage, to patients and health professionals after the integration of the system. Stakeholders in the field of indirect influence are line ministries and international organizations, the main requirements of which will be the protection of personal data and the ability to integrate the system with existing medical information infrastructure.

Table 8.6 - Composition, number and salary fund of production workers

Categories of employees	Available number, persons		Tariff rate for the category of work performed, UAH / hour	Effective fund of working hours, hours	Tariff earnings, UAH	Premium interest on tariff earnings	The amount of the award, UAH	Annual salary fund, UAH	SSC , UAH
	per shift	per day							
1	2	3	4	5	6	7	8	9	10
Production workers, in including: 1.Main employees	1	1	63	8	10215	10%	1021.50	137253.60	30195.80
Together production workers	1	1	X	X	X	X		137253.60	30195.80

Table 8.7 - Composition, number and salary fund of administrative staff

Position	Keel - number of persons	Salary, UAH	Premium percentage to salary,%	Sum awards UAH	Monthly salary, UAH	Annual fund wages, UAH	SSC, UAH
1	2	3	4	5	6	7	8
Professor (Head of Scientific Department)	1	12258	10%	1225.80	13483,80	161805.60	35597.23
Together Managerial staff	1		X			161805.60	161805.60

Calculation of material costs

The cost of purchased materials used during R&D to ensure the normal passage of the technological process and packaging of products or spent on other production and economic needs

Table 8.8 - Calculation of material costs

Material costs	Standard per one. product. (services)	Production program	Volume of raw materials	Price	Sum UAH
1	2	3	4	5	6
Per a personal computer (Laptop)	1	-	1	12600	12600
Mathlab License	1		1	USD 940.00	26320
Table	1		1	1000	1000
Chair	1		1	500	500
Together					40420

The project development and implementation period is 3 months. According to DBN B.2.2-3: 2018 "Buildings and structures. Institutions of education", the area of the laboratory of general theoretical profile in institutions of higher education and

institutions of postgraduate education should be not less than 40 m2, with a ceiling height of not more than 3.8 m, namely in such a room is planned to develop and use the project.

According to the National Commission for State Regulation of Energy and Utilities, the electricity tariff for enterprises and government agencies of «Zaporizhoblenergo» is UAH 7.7 per kWh of electricity consumed. According to the concern "City Heating Networks" of Zaporozhye, the tariff for hot water supply is 83.54 UAH per m3, the tariff for heat supply is 1216.83 UAH per Gcal. Recalculation of the tariff for premises, according to the order of the State Committee of Ukraine for Energy Conservation "On approval of intersectoral norms of electricity and heat consumption for institutions and organizations of the budget sphere of Ukraine" from 25.10.99, Table 8.10. - "Heat consumption norms for heating public buildings and structures", should be carried out taking into account the coefficient of heat use per m3 of premises, which is 0.026 per m3 per year, for the Zaporozhye region. According to Table 8.8 - "Norms of electricity consumption for educational and laboratory buildings of higher and secondary special educational institutions" of the above order, the consumption rate for air-conditioned premises is 45 kW per m2 of floor space per year. Tariffs for water supply and sewerage are UAH 12.05 per m3 and UAH 5.26 per m3, respectively, according to the National Commission for Water Supply and Sewerage for Vodokanal. According to DBN B.2.5-64: 2012 , DBN B.2.5-74: 2013, the average values of drinking water consumption for educational institutions are 10 liters per day for one person.

Table 8.9 - Calculation of the cost of consumed services

Type of services	Standard per one. product. (ser vices)	Production program	Scope of services	Tariffs	Sum UAH
Power supply	-	-	450 kW	7.7 UAH / kW	3456
Water supply	-	-	1.8 m3	17.31 UAH / m3	31.16
Heat supply	-	-	1.31 Gcal	1216.83 UAH / Gcal	1594.04
Together	-	-	-	-	5081.2

Depreciation should be calculated by the straight-line method (formula 1), taken from the order of the Ministry of Finance of Ukraine "On approval of Regulation (standard) of accounting 7" Fixed assets ", from 27.04.2000, as they are electronic devices that do not have effective repair methods and therefore their economic effect directly depends on their service life. The service life of a laptop is usually 3 years.

$$A = Ca : T \qquad (1)$$

where A is the annual amount of depreciation; Ca - the value of the depreciable health facility; T is the useful life of the health facility (years).

The monthly amount of depreciation is calculated by dividing the annual amount by 12.

Table 8.10 - Depreciation calculation

Group of fixed assets	Depreciation rate	The initial cost of health on 01.01	OZ arrived		OZ was dropped		Sum UAH
			date	lane. var.	date	lane. var.	
1	2	3	4	5	6	7	8
Laptop	-	12600	09/28/20	12600	12/24/20	0	1050
Together							1050

Table 8.11 - Cost estimates

Costing articles	Costs
Raw materials	40420
Power supply	3456
Water supply	31.16
Heat supply	1594.04
others	
Together	45501.20

Wages of key production workers	137253.60
SSC	30195.80
amortization	1050
Costs for maintenance and operation of fixed assets current repairs	-
Total expenditures	-
Production cost	-
Administrative expenses	-
Other expenses	-
Full cost	167 449.40

This work is not a marketable product. The assessment of the financial value of the designed system as well as the assessment of the feasibility of selling software should be carried out only after the implementation of this system within at least one medical institution . This means that at the time of initial implementation, the project will require a sunk investment in the amount of the cost of developing the designed system. But such an implementation may not be useful in commercial activities.

As for the financing of this project, the required amount is 167449.40, which is approximately equal to 6000 thousand dollars. This amount can be taken from the Ukrainian Fund of Startups, which covers up to 75,000 thousand dollars, which is much less than the amount needed for the project.

According to the Ukrainian Foundation of Startups "The funding will be for startups that work with artificial intelligence, augmented reality, open data, cybersecurity, as well as in the field of defense, healthcare, travel, financial technology, education, robotics, e-commerce and services."

My project is a medical scientific activity.

This project is a system whose software can be changed as needed. But the use of the project is not possible for the purposes of all medical institutions within the country, as specializations differ from each other. This project is the implementation of a system of noise suppression and ECG signal analysis , the concept of which is not new in the study area. However, the use of different filters , the ability to operate the system at home and the ability to modify the parameters of the analysis give reason to believe that this work will help to supplement the knowledge about the nature of the studied processes.

Conclusion

As a result of writing this section I can draw the following conclusions:

- Market commercialization of the project is possible due to the fact that there is demand;
- market dynamics and profitability of work in the market;
- Implementation is promising given the potential customer groups, barriers to entry, the state of competition, the competitiveness of the project;
- Further implementation of the project is appropriate;

Technological implementation of the project is possible through the development of filters .

The technological path includes several stages:

- Removal of the electrocardiogram signal;
- technical signal analysis;
- development of a digital filter;
- filtration of the ECG signal.

Market commercialization of the project is possible due to the existing demand, market dynamics and profitability in the market. Implementation is promising given the potential customer groups, barriers to entry, the state of competition, the competitiveness of the project. Further implementation of the project is appropriate. Target groups selected: Home use and training laboratories.

9 OCCUPATIONAL HEALTH AND SAFETY DURING EMERGENCIES

9.1 Analysis of potential hazards

Master's thesis on "Investigation of powerline interference suppression algorithms for ECG recording" is research in nature. The workplace is a small laboratory equipped with computers and various electrical equipment and measuring equipment.

The set of general adverse factors due to the nature of the production process and working conditions include:

- electric shock due to malfunction of electrical equipment and violation of electrical safety rules, absence or malfunction of the grounding circuit, which can lead to electrical injuries;
- electromagnetic radiation from the computer, include various types of radiation from the display (X-ray, ultraviolet, infrared) and as a result of possible diseases of the eyes, skin, decreased immunity. It should be noted that in modern monitors based on LED screens, X-rays are absent;
- increased load on the musculoskeletal system, due to long sitting at the workplace (as a result - diseases of the musculoskeletal system);
- mechanical injuries due to improper installation of furniture, improper equipment and equipment of workplaces;
- unsatisfactory parameters of the microclimate (low or high humidity, high or low air temperature, etc.), which can lead to ill health, deterioration of health;
- insufficient lighting of work premises due to incorrect calculation of the number and power of lighting devices or their malfunction;
- overstrain of visual and auditory organs, as well as emotional stress (overstrain); (As a result - mental and physical)

- the possibility of ignition of electrical appliances due to violation of fire safety rules, which leads to damage to equipment and burns to workers;

- misconduct of personnel in emergency situations, due to ignorance of personnel, or their wrong actions.

Since the theme of the diploma project " Investigation of powerline interference suppression algorithms for ECG recording " is research (study of properties on mathematical models) and involves work in a laboratory equipped with personal computers with visual display terminals, so consider the measures to ensure safety, industrial sanitation, occupational health and fire safety for the laboratory with personal computers.

9.2 Measures to ensure electrical safety

To ensure electrical safety, it is necessary to connect separately or in combination one of the following technical means and means: safe construction of electrical installations; protective earthing; electrical network separation; insulation of current-carrying parts; preliminary alarm.

Insulation of live parts (working, additional, reinforced, double) must comply with NPAOP 40.1-1.21-98 SSBT "Rules for safe operation of electrical installations of consumers".

Elements for the use of protected earthing of non-conducting metal parts of products, which can be described under voltage (when creating insulation, mode of operation of the product, etc.), must be performedin accordance with GOST NPAOP 40.1-1.21-98 SSBT "Electrical products. General safety requirements ".

Protective earthing (zeroing) must comply with PUE (Rules for the introduction of electrical installations). The resistance of the earthing device to which the neutral generators or transformers or the terminals of the single-phase current source are connected must at any time be not more than 2, 4 and 8, according to the line voltages 660, 380 and 220. 127 In single-phase current sources.

Artificial and natural grounding conductors can be used for grounding electrical installations. When using natural earthing conductors, the description of earthing devices or contact voltage is not allowed, and the normalized values of voltage on earthing devices and allowable density of structures in natural earthing conductors are performed by artificial earthing conductors in an electrical installation up to 1 kV. The use of natural earthing conductors as elements of earthing devices does not cause them to be determined when determining the short-circuit currents or disruption of the devices to which they are connected.

Electrical networks must be protected against short-circuit currents, which is provided by the shortest possible tripping time and selectivity requirements. Protection must be used to disable harmful areas in the event of a short circuit at the end of the protected lines.

The type of insulation of laboratory equipment will be chosen by workers (which makes electrical insulation of live parts of the electrical installation, which ensures its normal operation and protection against electric shock) in accordance with DSTU 7237:2011"SSBT. Electrical safety. Terms and definitions".

Class of electrical manufacturers to protect people from electric shock in accordance with the same DSTU choose I - products that have at least a working insulator and elements for grounding. In case you decide the class I have a wire to connect to the source of life, this wire must have a ground wire and a plug with a ground contact.

To ensure the safety of work in various electrical installations and the spread of injury situations, perform the following organizational measures in accordance with DSTU ISO 3864-1:2005

"Electrical safety. General requirements and nomenclature of protection protection ":

- appointment of persons, responsible organizations and works;
- registration of work by an outfit or an oral order;
- admission to work;
- inspection during work.

Implementation of the exclusion of mechanical injuries, in accordance with GOST 12.2.061- 81 "Association of production. General safety requirements for the workplace ": the workplace, its equipment and equipment provided in accordance with the nature of work must ensure safety, health care and practical personalization.

The level of electromagnetic radiation does not need to violate the requirements of GOST 12.1.045-84 "Electrostatic fields. Permissible levels at workplaces and requirements for control": permissible levels of electrostatic levels are determined depending on the time spent by staff at workplaces. The maximum allowable voltage level of electrostatic levels is set equal to 60 kV / m for 1 year. When the voltage of electrostatic levels is less than 20 kV / m, the residence time in electrostatic fields is not regulated.

9.3 Measures to ensure industrial sanitation and occupational health

According to DSanPiN 3.3.2.007-98 "State sanitary rules and regulations for work with visual display terminals of electronic computers" sanitary and hygienic requirements to the parameters of the production environment of premises with computer equipment (CE).

Optimal values of microclimate parameters must be provided in production premises at workplaces with computer equipment: temperature, relative humidity and air velocity in accordance with the requirements of LTO 3.3.6.042-99 "Sanitary norms of microclimate of industrial premises" and GOST 30339-95* "SSBT. General sanitary and hygienic requirements for the air of the working area."

To minimize the negative impact of specific work and maintain efficiency, throughout the working day should provide: ensuring the correct "working posture" in the "sitting" mode, regulated breaks, space and conditions for minimal warm-up and rest. (SNiP 2.2.2.542-96, as well as Annex 15 "Time of regulated breaks depending on the duration of the work shift").

The design of the desktop should provide optimal placement on the work surface of the equipment used, taking into account its quantity and design features (size of VDT and PC, keyboard, music stand, etc.), the nature of the work performed. At the same time use of working tables of various designs meeting modern requirements of ergonomics is allowed.

The design of the working chair (chair) should provide support for a rational working posture while working on VDT and PC, allow you to change posture to reduce static tension in the muscles of the neck and shoulders and back to prevent fatigue.

The working chair (chair) should be lifting-rotating and adjustable on height and angles of inclination of a seat and a back, and also distance of a back from a forward edge of a seat, thus adjustment of each parameter should be independent, easily carried out plus reliable fixing.

The screen of the video monitor should be from the user's eyes at the optimal distance of 600 - 700 mm, but not closer than 500 mm, taking into account the size of alphanumeric characters and symbols.

The design of the VDT must allow frontal observation of the screen by rotating the housing in the horizontal plane around the vertical axis within ± 30 ° and in the vertical plane around the horizontal axis within ± 30 ° with fixation in a given position. The design of VDT should provide for painting the body in calm soft tones with diffuse light scattering. The VDT and PC case, keyboard and other PC units and devices must have a matte surface of the same color with a reflection coefficient of 0.4 ... 0.6 and have no shiny parts capable of creating glare. It is not recommended to place controls, markings, any auxiliary inscriptions and markings on the front side of the VDT case. If it is necessary to place the controls on the front panel, they must be closed with a lid or recessed in the housing.

The level of the eyes with a vertically located screen VDT should be in the center or 2/3 of the height of the screen. The line of sight should be perpendicular to the center of the screen and its optimal deviation from the perpendicular passing through the center of the screen in the vertical plane should not exceed ± 5 degrees, allowable ± 10 degrees.

To ensure optimal performance and maintain the health of professional users, regulated breaks should be established during the work shift. During the regulated breaks in order to reduce nervous and emotional stress, fatigue of the visual analyzer, eliminate the effects of hypodynamics and hypokinesia, prevent the development of positonic fatigue, it is advisable to perform sets of exercises.

For work that is performed with a heavy load, it is recommended to take a 10-15 minute break after each hour of work, and for intensive and monotonous work 10-15 minutes every 2 hours. The number of micropauses (lasting up to 1 minute) is regulated individually.

Exercising with a dosed load during the working day is recommended individually, depending on the feeling of fatigue. Gymnastics is aimed at correcting the forced posture, improving venous blood circulation, partial filling of the deficit of motor activity. Muscular efforts of a set of exercises - moderate, average pace. After gymnastics, passive rest is required, lasting 2-3 minutes before work.

In all cases where production circumstances do not allow the use of regulated breaks, the duration of continuous work with VDT should not exceed 4 hours.

In rooms with CE should be provided 3 times the air exchange per hour. To ensure constant parameters of the microclimate (temperature, humidity, speed and air purity), indoor air conditioners. can be installed in the premises.

CE rooms should have natural and artificial lighting. Unsatisfactory lighting reduces the productivity of CE users, the possible appearance of myopia, fatigue.

Natural lighting in rooms with CE must meet the requirements of DBN B.2.5-28-2006 "Engineering equipment of buildings and structures. Natural and artificial lighting ". Natural lighting should be carried out through light slots, oriented mainly to the north or northeast and provide a coefficient of natural light (KPO) of not less than 1.5%. To protect from direct sunlight, which creates direct and reflected glare on the surface of screens and keyboards, sun protection devices should be provided, the windows should be blinds or curtains. Satisfactory natural light is easier to create in small spaces for 5-8 jobs.

Artificial lighting in rooms with workstations equipped with computer PCs should be carried out by a system of general uniform lighting. In industrial and administrative-public premises, in case of predominant work with documents, the use of a combined lighting system is allowed.

For the general illumination it is necessary to apply fixtures of the LPO 36 series with mirror lattices completed with high-frequency starting regulating devices (HF PPA). The use of luminaires without diffusers and shielding grilles is not permitted.

The brightness of general lighting luminaires in the area of radiation angles from 50 ° to 90 ° with a vertical in the longitudinal and transverse planes should be not more than 200 cd / m, the protective angle of the luminaires - not less than 40 °.

Sound pressure levels in octave bands, sound levels and equivalent sound levels at workplaces equipped with PCs must meet the requirements of DSanPiN 3.3.2.007-98 "State sanitary rules and regulations for working with visual display terminals of electronic computers" and LTO 3.3. 6-037-99 "Sanitary standards of industrial noise, ultrasound and infrasound".

When performing work with a PC in production facilities, the values of vibration characteristics at workplaces should not exceed the permissible according to DSanPiN 3.3.2.007-98 "State sanitary rules and regulations for work with visual display terminals of electronic computers" and LTO 3.3.6-039- 99 "State sanitary norms of industrial general and local vibration".

Heating and air conditioning systems should be installed so that neither warm nor cold air is directed at people. It is recommended to create a dynamic climate with certain differences in production. The air temperature at the floor surface and at head level should not differ by more than 5 degrees. In industrial premises, in addition to natural ventilation, supply and exhaust ventilation is provided. The main parameter that determines the characteristics of the ventilation system is the frequency of exchange, ie how many times per hour the air in the room will change.

The following is the calculation of air exchange:

V_1 - the volume of air required for exchange;

V_2 - the volume of the working space.

For calculation we will accept the following sizes of a working room:

length B = 7,35;

width A = 4.9 m;

height H = 4.2 m.

Accordingly, the volume of the room is equal to:

$V_2 = A \cdot B \cdot H = 151{,}263$ sq. m.

The volume of air V_1vent necessary for an exchange is defined proceeding from the equation of thermal balance:

$V_1 \cdot C \cdot (t_{ух} - t_{пр}) \cdot Y = 3600 \cdot Q_{над}$,

where $Q_{над}$ - excess heat (W);

C = 1000 - specific thermal conductivity of air (J / KGK);

Y = 1,2 - air density (mg / cm);

$t_{ух}$ - exhaust air temperature, deg;

$t_{пг}$ - temperature of incoming air, deg.

The temperature of the air is determined by the formula:

$t_{ух} = t_{рм} + (H - 2)\ t$,

where t = 1-5 degrees - exceeding t per 1 m of room height;

$t_{рм}$ = 25 degrees - the temperature at the workplace;

H = 4.2 m - height of the room;

$t_{пр}$ = 18 degrees.

Then:

$t_{ух}$ = 25 + (4.2 - 2) 2 = 29.4

After:

$Q_{над} = Q_{над1} + Q_{над2} + Q_{над3}$

where $Q_{над1}$ - excess heat from electrical equipment and lighting.

$Q_{над1} = E \cdot p$,

where E is the coefficient of electricity loss for heat dissipation (E = 0.55 for lighting);

p - power, p = 40 W · 15 = 600 W.

Then

$Q_{над1}$ = 0.55 · 600 = 330 W.

where $Q_{над2}$- heat from solar radiation.

$Q_{над2} = m \cdot S \cdot k \cdot Q_c$,

where m is the number of windows, take m = 4;

S - window area, S = 2,3 · 2 = 4,6 sq.m;

k is the coefficient that takes into account the glazing. For double glazing k = 0.6;

Q_c = 127 W / m - heat from the windows.

Then

$Q_{над2}$ = 4.6 · 4 · 0.6 · 127 = 1402 W.

where $Q_{над3}$ - heat dissipation of people.

$Q_{над3} = n \cdot q$,

where q = 80 W / person,

n is the number of people, for example, n = 15.

$Q_{над3}$ = 15 · 80 = 1200 W.

As a result we receive:

$Q_{над}$ = 330 + 1402 + 1200 = 2932 W.

Then the equation of heat balance follows:

V_1 = 3600 · 2932/1000 · (29.4 - 18) = 926 cu. m.

Multiplicity calculation

Multiplicity = V_1 / V_2 = 6.12.

9.4 Fire safety measures

According to SNiP 2.09.02-85 "Industrial buildings" production laboratory building must have a degree of fire resistance not lower than III. Explosion and fire safety category - D.

For evacuation of people in case of fire SNiP 2.09.02-85 allows the organization of one evacuation exit from the room located on any floor (except basement and basement), if this exit leads to two evacuation exits from the floor, the distance from the most remote working places before leaving the premises do not exceed 25 m and the number of employees in the most numerous shift does not exceed 25 people.

The distance from the most remote workplace to the nearest evacuation exit from the premises directly to the outside or to the stairwell for category D buildings is not regulated.

According to DBN B.2.5-56: 2014, fire safety of the object should be provided by fire prevention systems, fire protection and organizational and technical measures.

Fire safety systems must be characterized by the level of fire safety of people and property, as well as perform one of the following tasks: to exclude the occurrence of fire; ensure fire safety of people and / or property.

Facilities must have fire safety systems aimed at preventing people from being exposed to dangerous fire factors, including their secondary manifestations at the required level.

Under active fire fighting is understood extinguishing a fire with the use of fire extinguishers. These means include various fire extinguishers, they are divided by type of filling into powder and carbon dioxide, sand, non-combustible materials, any materials and means that prevent the spread of fire and combustion of materials.

Dangerous factors of fire that affect people and property are: flames and sparks; elevated ambient temperature; smoke; reduced oxygen concentration.

Secondary manifestations of dangerous factors of fire, which affects people and property, include: fragments, parts of destroyed devices, units, installations, structures; toxic substances and materials coming out of the destroyed devices and installations; electric current, which arose as a result of high voltage on the conductive parts of structures, devices, units; fire extinguishers substance.

Electrical wiring in the building must be insulated, as this reduces the risk of short circuits and the occurrence of this fire. The cable, wire must be laid on a non-combustible base. In order to reduce the risk of short circuit, RCD devices, automatic, fuses are installed. Gas and electric stoves must be insulated from wooden furniture. Sockets on the exterior walls of the building and in the bathrooms must be insulated from moisture.

Since the PC uses electronics, the fire can not be extinguished with water, as this can lead to a short circuit and the emergence of new fires. Carbon dioxide, foam or powder formulations are used to extinguish electrical installations. The primary means of extinguishing with carbon dioxide are manual fire extinguishers such as ВВК-1.4, ВВК-3.5. These types of fire extinguishers must be used to extinguish the fire.

Automatic fire alarm systems (APS) are used to detect the initial stage of fire and alert the fire service. In addition, they can independently start the fire extinguishing system when the fire has not yet reached a large size. APS systems consist of fire detectors, communication lines and receiving consoles (stations).

The effectiveness of APS systems is determined by the correct choice of the type of detectors and their locations. When choosing fire detectors, specific conditions of their operation were taken into account: features of the room and air environment, the presence of fire materials, the nature of possible combustion, the specifics of the technological process, etc.

According to the "Standard rules of fire safety for industrial enterprises", the rooms, as well as adjacent rooms, are equipped with smoke alarms, because in the premises at the beginning of the fire when burning various plastic, insulating materials and paper products emit a significant amount of smoke and heat.

The objects of the building in which the room is located, in addition to the APS, are equipped with stationary automatic fire extinguishing systems. It is most expedient to use gas fire extinguishing systems, the action of which is based on the rapid filling of the room with a fire-extinguishing gas substance with a sharp decrease in oxygen content in the air.

9.5 Emergency safety measures

One of the most important measures to ensure safety in emergencies is to inform the public and production staff about the occurrence of an emergency.

Alert signals are used for timely delivery to the civil defense of orders and information about evacuation, enemy air attack, radiation danger, developed and approved (biological) infection, the threat of flooding, the beginning of dispersal, and others.

The latest technology allows you to immediately determine not only the location and direction of movement of the carrier (aircraft, helicopter, missile, etc.) of the attack weapon, as well as the time of its approach. Such technology provides signal transmission through the alert system to civil defense headquarters and facilities.

Alert signals are used mainly in the event of a sudden attack by the enemy, when the real time to warn the population will be extremely limited and calculated in minutes.

It is known that timely notification of the population makes it possible to shelter it for 10-15 minutes immediately after the notification. As a result, casualties are reduced from 85% to 4-7% with the sudden use of weapons of mass destruction by the enemy. Therefore, the protection of the population, first of all, depends on a well-organized warning system, the organization of which is entrusted to the civil defense headquarters.

Notifications are made by all types of communication: television, radio, the use of special equipment and tools for sound and light signals. Immediately instructions are given on the order of actions of the population and their formations, the approximate time of the beginning of precipitation of radioactive precipitations, time of approach of the polluted air, and also a kind of poisonous substances is stipulated. The signals announced by the higher headquarters are duplicated by all subordinate headquarters.

There are a number of signals that serve to alert the population of cities and rural settlements about the imminent danger of the enemy using nuclear, chemical, bacteriological (biological) or other weapons: "Air alarm" "Air alarm response"; "Radiation hazard"; "Chemical alarm".

Various signaling devices and means of communication are installed in cities. Thanks to them with the help of the remote control it is possible to include loudspeaker communication and the apartment radio broadcasting network, and also to make a call of the management of the city and objects of a national economy on a circular telephone network. With the help of such equipment, orders are issued by higher headquarters.

"Air alarm" signal. A similar signal is given to the entire population. This signal warns of the danger of defeat by the enemy of the city. The text is transmitted on the broadcasting network: "Attention! Attention!

Citizens! Air alarm! Air alarm! "This broadcast is accompanied by the sound of sirens, beeps of factories and vehicles. The duration of the signal is 2-3 minutes. transport is stopped and individual shelters are hidden in shelters.

The signal "Refusal of air alarm", this signal is alerted by civil defense. The following text is broadcast: "Attention! Attention, citizens! Air alarm response. Air alarm response." Upon receipt of this signal, the population is allowed to leave the shelter with the permission of the commandants, and workers can begin to continue their abandoned work. In places where the enemy has struck with weapons of mass destruction, the population is provided with information about the situation, the modes of behavior of the population, about the measures taken to eliminate the consequences of the attack.

"Radiation hazard" signal. The purpose of this signal is to alert the settlements and areas to which the radioactive cloud formed during the explosion of nuclear munitions is moving. Having heard this signal, it is urgent to put on a respirator, a cotton gauze bandage, in the absence of these items to put on a gas mask. Collect pre-prepared stock of products, personal care equipment, essentials and hide in the Radiation Shelter.

The "Chemical Alarm" signal, alerting such a signal indicates the threat or detection of a chemical or bacteriological attack. It is necessary to put on a gas mask immediately and to hide in a protective construction, in the absence of similar constructions it is necessary to use inhabited, industrial or auxiliary premises. When used by the enemy bacteriological weapons, the public address systems will immediately receive additional information about further action. All requirements of civil defense bodies must be complied with, as well as their orders must be followed even after the danger has passed.

The main way to warn the public about the danger is mainly through radio and television. Here are some examples of alerts about various dangers.

In the event of a flood, information about the danger will be announced as follows: "Attention! The district's civil defense headquarters says. Citizens! these streets and villages to collect the necessary things, food for 3 days, water, turn off gas and electricity and go to the school area № 7 to register at the prefabricated evacuation center and send to safe areas. " In the event of an accident at a nuclear power plant, information about the danger will be reported as follows: "Attention! The district's civil defense headquarters says. Citizens! There was an accident at a nuclear power plant. Radioactive substances are expected to fall near the city of Zaporozhye. prepare for evacuation. Continue to act in accordance with the instructions of the NGO headquarters. "

In the event of an accident at a chemical facility: "Attention! The city's civil defense headquarters says. Citizens! There was an accident at the plant with the release of a toxic active substance - ammonia. A cloud of contaminated air spreads in the direction of Zarichny village. Carry out sealing of their homes. Immediately leave the houses of Zavodska and Kovalska streets, houses, institutions, educational institutions and go to the area of Lake “Slavutych”. Continue to act in accordance with our instructions. "

When there is a threat of an enemy attack by local authorities and NGO headquarters through the media are transmitted to the population of the resolution or the order on the order of actions. From now on radio stations, TVs must be constantly switched on to receive new messages. As soon as possible, the population should take the necessary protection measures and be involved in the implementation of measures taken by NGOs. It is very important to immediately clarify the location of the nearest shelter (shelters) and ways to approach it. If there are no protective structures nearby, you need to immediately begin construction of the simplest shelter or adaptation of deep rooms (even the 1st floor of a stone house) for shelter. Senior students should also take an active part in this work. It is necessary to prepare personal protective equipment, adjust the means at hand, get a home medicine cabinet. In living quarters it is necessary to carry out sealing of windows, doors, to carry out fire-prevention measures; take measures to prevent food and water from possible contamination (contamination). It is necessary to prepare everything necessary in case of evacuation.

In the future, with the imminent danger of enemy strikes from the air, the signal "Air alarm!" It is preceded by a signal "Attention to all!", And then by means of radio and television will be transferred: "Attention! Attention! The headquarters of civil defense speaks. Citizens! Air alarm! Air alarm! Turn off light, gas, water, extinguish fire in furnaces. Take means personal protection, documents, food and water supplies. Warn neighbors and, if necessary, help the sick and elderly to go outside. Get to the shelter as soon as possible or hide in the area. Keep calm and order. Pay attention to civil defense messages! " Signal "Attention everyone!" May indicate, for example, a rapid threat of radioactive or bacteriological contamination. In this situation, there will be a brief message about the procedure and rules of conduct.

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