CONTACTLESS HUMAN VITAL SIGN MONITORING SYSTEM USING MILLIMETER WAVE FMCW RADAR FOR HEALTH CARE APPLICATIONS.

An Undergraduate CAPSTONE Project
By

1. NEIR, SHILAMONI SHAHA	ID: 20-43640-2	Dept: EEE
2. SAGOR, MD. SHAKIL AHAMED	ID: 20-42444-1	Dept: EEE
3. NIHAL, NAZMUS SAKIB	ID: 20-44102-2	Dept: EEE
4. SAHA, SIMANTA	ID: 20-43652-2	Dept: EEE

Under the Supervision of

DR. MOHAMMAD HASAN IMAM
Associate Professor

Spring Semester 2023-2024
June, 2024

Faculty of Engineering
American International University - Bangladesh

CONTACTLESS HUMAN VITAL SIGN MONITORING SYSTEM USING MILLIMETER WAVE FMCW RADAR FOR HEALTH CARE APPLICATIONS.

A CAPSTONE Project submitted to the Faculty of Engineering, American International University - Bangladesh (AIUB) in partial fulfillment of the requirements for the degree of Bachelor of Science in their mentioned respective programs.

1.	NEIR, SHILAMONI SHAHA SAHA, SIMANTA	ID: 20-43640-2	Dept: EEE
2.	NIHAL, NAZMUS SAKIB	ID: 20-44102-2	Dept: EEE
3.	SAGOR, MD. SHAKIL AHAMED	ID: 20-42444-1	Dept: EEE
4.	SAHA, SIMANTA	ID: 20-43652-2	Dept: EEE

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DECLARATION

This is to certify that this project is our original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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Students' names & Signatures

1. **SAHA, SIMANTA**

   Simanta Saha

2. **NIHAL, NAZMUS SAKIB**

   Sakib

3. **SAGOR, MD. SHAKIL AHAMED**

   Shakil

4. **NEIR, SHILAMONI SHAHA**

   [illegible]

APPROVAL

The CAPSTONE Project titled **CONTACTLESS HUMAN VITAL SIGN MONITORING SYSTEM USING MILLIMETER WAVE FMCW RADAR FOR HEALTH CARE APPLICATIONS** has been submitted to the following respected members of the Board of Examiners of the Faculty of Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in the respective programs mentioned below on **June 6, 2024** by the following students and has been accepted as satisfactory.

1. NEIR, SHILAMONI SHAHA — ID: 20-43640-2 — Dept: EEE
2. SAGOR, MD. SHAKIL AHAMED — ID: 20-42444-1 — Dept: EEE
3. NIHAL, NAZMUS SAKIB — ID: 20-44102-2 — Dept: EEE
4. SAHA, SIMANTA — ID: 20-43652-2 — Dept: EEE

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Supervisor
DR. MOHAMMAD HASAN IMAM
Associate Professor
Faculty of Engineering
American International University-Bangladesh

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

External Supervisor
DR. MD. HUMAYUN KABIR
Associate Professor
Faculty of Engineering
American International University-Bangladesh

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Mr. Nafiz Ahmed Chisty
Head, Department of EEE
Faculty of Engineering
American International University-Bangladesh

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Prof. Dr. ABM Siddique Hossain
Dean
Faculty of Engineering
American International University-Bangladesh

ACKNOWLEDGEMENT

We humbly express our eternal appreciation to the divine Almighty, Allah, for bestowing upon us the resilience to surmount formidable obstacles. Each day granted us the invaluable opportunity to acquire knowledge, evolve personally and triumph over challenges. Through the gracious blessings of Allah, we accomplished the successful completion of our project. We count ourselves immensely fortunate to be surrounded by extraordinary companions and cherished family members who unwaveringly supported us throughout the journey of our project. We extend our sincere gratitude to our esteemed supervisor, **DR. MOHAMMAD HASAN IMAM,** Associate Professor, whose guidance and counsel proved to be invaluable during the development of our project. On top of that, we express our sincere gratitude to the esteemed members of the committee for their contribution to our defense, which has not only brought us great pleasure but also enriched our understanding with their erudite perspectives and innovative concepts. We would like to express our gratitude for the steadfast assistance and direction extended by our external supervisor, Sir **DR. MD. HUMAYUN KABIR**, throughout the investigative and innovative stages of our endeavor. The supplications you have offered have been vital in advancing our development. In conclusion, we would like to convey our profound appreciation to our esteemed teachers, whose extensive expertise and proficiency steered us into each subject matter during our undergraduate tenure.

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ABSTRACT

This project presents a contactless vital sign monitoring device designed for heart patients and the elderly. The device utilizes a combination of a 60 GHz FMCW radar and a thermal sensor to track skin temperature, heart rate, and respiration rate. This contactless approach offers advantages for monitoring during sleep and in situations with potential viral illnesses. The 60 GHz radar extracts heart and respiration rates, while the thermal sensor measures temperature. An ESP8266 Node MCU processes the radar data before transmitting it to a dedicated Android application (CVSMS) for visualization and data graphing. A LCD screen also integrated with system to see the result immediately in the screen. The data was taken on different age group and gender. Pulse oximeter and ADS1292R respiratory module is used to validate the data. After analyzing 20 data, evaluation results demonstrate an accuracy of approximately 88% for heart rate and 92% for respiration rate.

Chapter 1

INTRODUCTION

1.1. Overture

The evolution of ubiquitous sensing has led to millimeter wave frequency-modulated continuous waves in short FMCW radar technologies which is a special type of radar that can measure the range, velocity, and angle arrival of objects in front of it. While FMCW radars are widely utilized in automotive, industrial, and medical domains, their unique features make them suitable for contactless human vital sign detection. Generally, there are four types primary vital signs: body temperature, blood pressure, respiratory rate and heart rate. Any abnormal changes in vital signs have become an active area of concern that it can be early indicators of patient's deterioration and adverse events. The idea depends on the concept of the Doppler effect. Doppler effect is a phenomenon that is observed when the source of the waves changes its distance.**[1]** Our project's primary aim is to develop a contactless human vital sign monitoring system utilizing mm-wave FMCW radar for healthcare applications. The motivation for this project stems from the challenges faced by healthcare professionals during the COVID-19 pandemic in measuring vital signs through traditional methods, such as attaching probes to patients. This approach is uncomfortable for patients and increases the risk of healthcare staff contracting the virus. To address these issues, our project focuses on radar-based technology for non-intrusive and contactless human vital sign monitoring. The central objective is to implement an FMCW radar system for accurate and rapid detection of vital signs. This technology aims to enhance the safety and well-being of arrhythmia patients by enabling contactless monitoring for multiple individuals, eliminating the need for attaching probes to their bodies. The anticipated outcomes of this research are poised to significantly contribute to innovative solutions in eldercare and safety monitoring, particularly for patients with arrhythmia. The inclusion of a digital interface facilitates chip configuration and radar data acquisition. Additionally, the sensor incorporates optimized power modes to ensure efficient low-power operation, and it comes equipped with an integrated state machine, enabling independent operation. This sensor holds promise across various applications. Through the integration of these elements, the project aims to harness the advanced features of the radar sensor and the processing capabilities of the Arduino board to display real-time results wirelessly and effectively. This combination of technologies establishes a promising foundation for the development of a reliable and efficient contactless vital sign monitoring system. Certainly, employing FMCW radar for contactless vital sign detection encounters challenges in scenarios with multiple targets, such as objects or other individuals. The radar system may face difficulties in distinguishing between the specific individual's heart rate and respiratory rate and the movements of other nearby objects or people. This challenge has the potential to impact the accuracy and precision of the vital sign algorithm. In conclusion, utilizing millimeter-wave FMCW radar for vital sign detection aims to eliminate the discomfort associated with continuous monitoring of heart rate and respiratory rate in elderly, newborn or unwell patients, which is notably high when using probes attached to their bodies.

1.2. **Engineering Problem Statement**

The chosen topic was to design contactless human vital sign monitoring system using millimeter wave technology for eldercare and safety monitoring, particularly for patients with arrhythmia due to disease or any other reason. The major problem of some current technology like attaching probes to bodies which can be problematic for some reason. For instance, the discomfort associated with constant monitoring of the heart rate and respiratory rate in elderly or unwell patients is notably high when using probes attached to their bodies. Also, the leads used to attach the probes to patients' body is single use only which is costly and has some negative environmental impact as well as. The problem statements are,

Problem 1: The project under consideration is a radar-based initiative that will be controlled by a microcontroller (Arduino Mega, Arduino Uno, Arduino Nano), employing advanced programming languages such as C, C++, and Arduino IDE. Profound understanding of Frequency Modulated Continuous Waves (FMCW) and Millimeter wave is imperative to comprehend the intricacies of monitoring heart rate and respiratory rate using a high-frequency radar system. A comprehensive understanding of these concepts is essential for the successful implementation of the project.

Problem 2: A high-frequency operation is crucial for detecting the desired output as in high frequency if distance in antenna if change 1 mm. Its digital interface allows for chip configuration and radar data acquisition. Optimized power modes ensure energy efficiency, and an integrated state machine enables independent operation. The sensor's versatility extends to gesture sensing, high-resolution FMCW radars, short-range sensing, and hidden applications behind a random.

Problem 3: Numerous alternatives exist for detecting human vital signs, with ECG being one of the closest and highly effective technologies for monitoring the heart's rhythm and beating. However, the persistent discomfort linked to continuous monitoring of heart rate and respiratory rate in elderly or unwell patients is a significant drawback when utilizing probes attached to their bodies. This project can serve as a strong contender, aiming to limit the discomfort associated with probe attachments.

Problem 4: During any contagious virus outbreak like SARS-CoV-2 virus the measure the human vital sign with traditional methods contains a risk of healthcare staff contracting the virus. To prevent this type of unwanted situation this project can be a good solution for continuous monitoring.

Problem 5: Generally, in hospital general ward nurses take the vital signs manually after a certain time. But there is no cost-effective way to monitor them continuously as the ECG and other equipment are very high cost. But this product can be a cost-effective way to monitor them continuously.

1.3. Related Research Works

The research work has been divided into two sections for ease of usage. The earlier research area reviews literature published over five years ago, whereas the recent research section discusses papers, articles, and journals published in the recent five years or less. The design of millimeter wave FMCW radar-based contactless human Vital sign safety monitoring IoMT (Internet of Medical Things) has been the sole objective of the literature review.

1.3.1. Earlier Research

Fadel Adib et al. [2] has developed a device called vital radio which has the ability to monitor the vital signs of multiple people wirelessly without requiring the user’s physical contact. The device transmits low-power wireless signals, measuring signal travel time to compute distance to the human body, capturing minute changes in distance caused by breathing and heartbeats. The device consists of an FMCW radio operating within FCC regulations, transmitting signals sweeping from 5.46 GHz to 7.25 GHz every 2.5 milliseconds. Connected to a computer via Ethernet, the received signal undergoes real-time processing. Implemented in C++, the software utilizes shifted overlapping FFT windows, updating breathing and heart rate estimates every 30 milliseconds, while concurrently logging the data. Additionally, the code detects user motion, distinguishing between quasi-static and major motion states. In environments with various reflectors and multiple users, the operation involves three steps: Isolating reflections from different users and eliminating reflections off furniture and static objects, identifying signal variations related to breathing and heartbeats for each user, separate from variations due to body or limb motion and analyzing signal variations to extract breathing and heart rates. In challenging real-world conditions and multi-user environments, the device demonstrated a median accuracy of 99% for breathing and heart rate monitoring also can monitor vital signs from up to 8 meters or even from behind a wall, enabling remote monitoring of users' health. The device faces limitations like user separation requirements, limited monitoring range, quasi-static user necessity, potential non-human motion interference, and a need for further evaluation with larger, diverse populations.

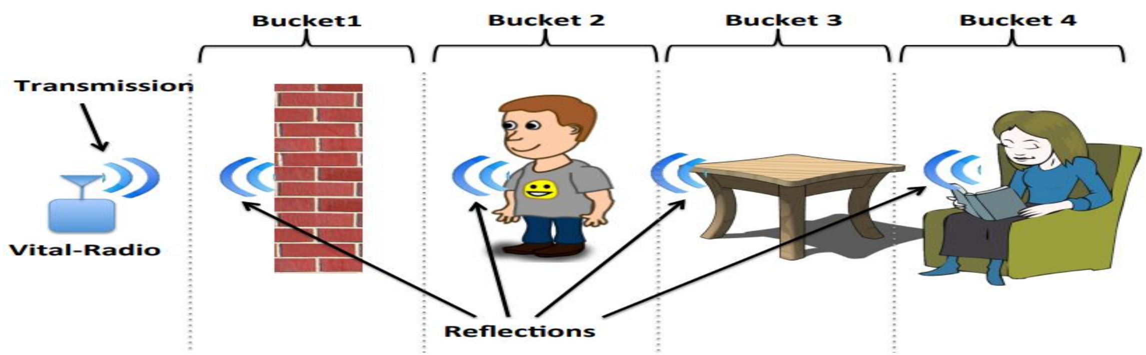


Figure 1.3.1: Separating Reflectors into Different Buckets [3]

Alizdeh et al. [4] investigated the respiratory rate and heart rate by 77 GHz Texas Instrument (TI) mm-wave radar (AWR1443). After collecting data for 40 minutes by device the data was analyzed by MATLAB signal analysis UART interface were found 94 % accuracy was found for breathing and 80 % for heart rate. The authors concluded the proposed system's heartrate estimation is more accurate than X-band FMCW radar and close to 80 GHz FMCW radar in case of respiratory rate accuracy it wasn't found in X band radar but improved compared to 80 GHz radar.

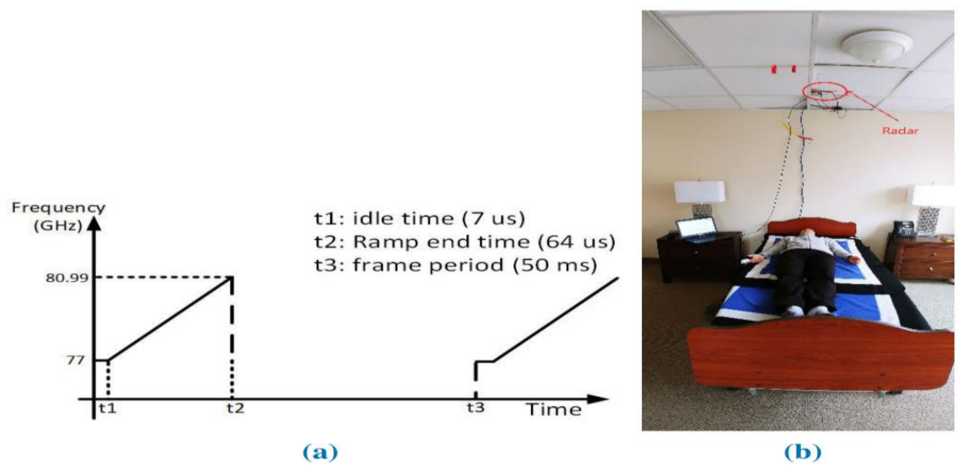


Figure 1.3.2: Chirp configuration (a), and the bedroom for the tests (b) [5]

Wang et al. [6] used a Texas instrument AWR 1642 77 GHz mm wave FMCW radar for heart rate and breathing rate measurement. For suppressing noise and harmonic interference two algorithms compressive sensing based on orthogonal matching pursuit CS-OMP and RA-DWT adaptive soft threshold noise reduction based on discrete wavelet transform (RA-DWT) to separate the signals of heartbeat and respiratory rate were used. With the two signals authors used frequency FFT algorithm and time domain autocorrelation algorithm for calculate the heartbeat and respiratory rates. The setup was 93% accurate. The author compared radar data with MI bracelet 3 and airflow sensors, addressing a significant limitation in traditional measurement accuracy.

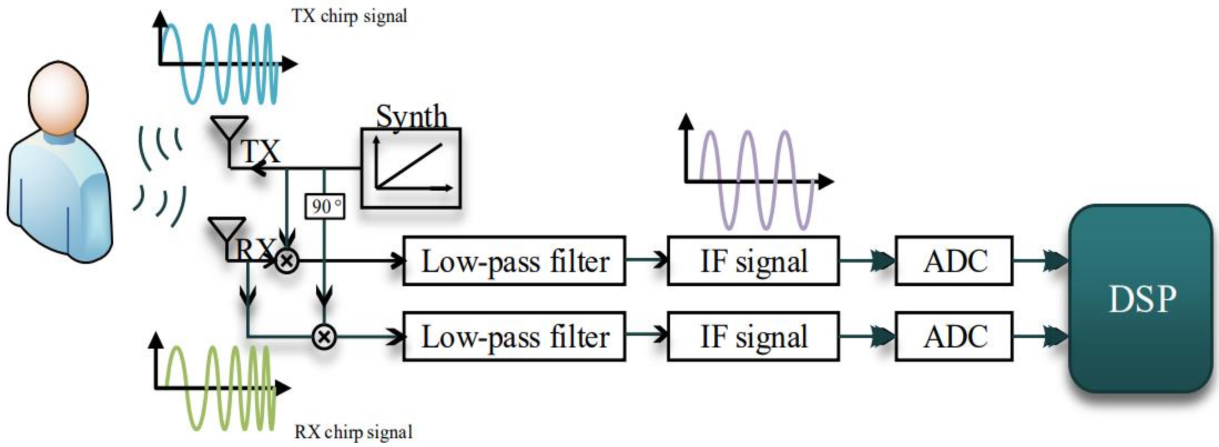


Figure 1.3.3: FMCW radar system block diagram [7]

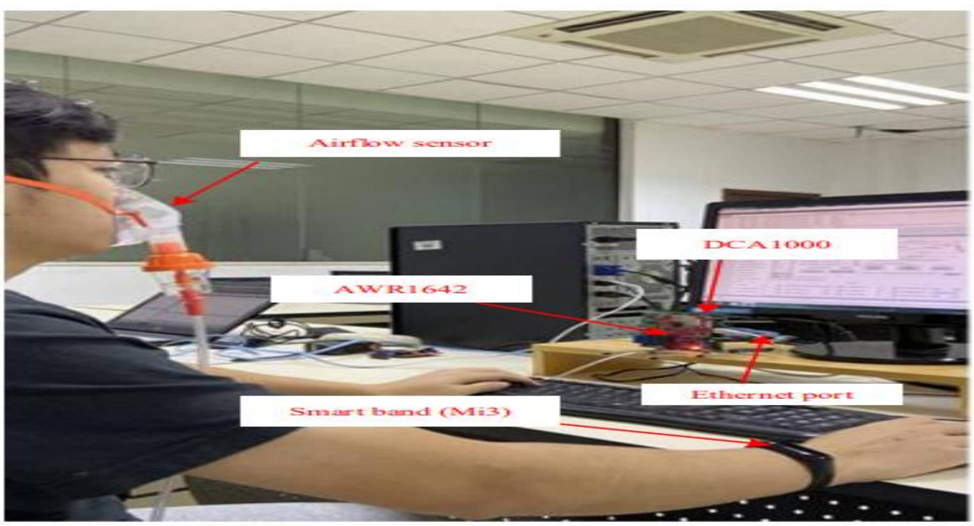


Figure 1.3.4: experimental scene[7]

Giulia Sacco et al. [8] proposed system aims to observe indoor human vital signs of multiple subjects in four different scenarios measuring respiratory rate and heartbeat of a subject in realistic and challenging indoor environments. The designed system is a single-input single-output (SISO) FMCW radar, working in the 5.8 GHz ISM band. To simulate a realistic configuration for ambient assisted living (AAL), the researchers considered four different orientation scenarios (chest, left side, back, right side) towards the antenna. The antenna is specifically designed for the proposed application. To increase the bandwidth, the receiving and transmitting antenna of two identical series-fed arrays composed of six suitably modified patches are used. The experimental results show the accuracy and ability of the radar to measure both the respiratory and heart rate independently of the chest orientation towards the radar antenna with maximum error in terms of BPM is 0.8 BPM and 3.1 BPM for the respiratory and heart rate, accordingly. The research paper successfully develops a low cost, compact, and well performing system using a FMCW radar with antenna of two identical modified series-fed arrays. The authors demonstrate that the radar can extract vital signals from different body orientations using the proposed signal processing thus ensure high accuracy in measurement.

Leem et al [9] proposed a IR-UWB radar based system for vital sign measurement, mobile phone usage detection for car crash prevention. They used a 6.8 GHz single-chip IR-UWB radar transceiver NVA6201 made by NOVELDA and set up in a car under the steering. After analizing in stationary, general movement and driving movements found that, And for mobile phone detection around 100%.

Table 1.3.1 Average error for respiration and heart rate of different human subjects (five humans)[9]

Movement Case		Average Error (Bpm) (Respiration Rate)	Average Error (Bpm) (Heart Rate)
stationary		almost zero	almost zero
general movements	hand motion near body	0.7	1.1
	gesture made by hand away from body	0.3	0.9
	lips motion during speaking	0.2	0.6
specific driving movements	lead movement to watch the mirror of the car	0.3	2.0
	turning the car	1.2	2.5
	applying the brakes	0.5	1.7
	accelerating the car	0.4	1.3

1.3.2. **Recent Research**

Fuchuan Du et al. [10] has developed an algorithm for an effective and practical multi-target vital sign signal extraction method using Infineon BGT60TR13C shield 60 GHz FMCW radar. the algorithm works in 3 major areas noise filtering, separation of breathing and heartbeat, and multi target monitoring. For filtering the noise clutter in radar data, which is caused by the static objects in the scene the authors used the DC offset method to filter. For separating the breathing and heartbeat, the authors developed an Empirical Mode Decomposition (EMD) method to decompose the signal with various frequency ranges. In multi target monitoring, the radar's L-shaped antenna configuration allows for only three sets of data, posing a challenge in analyzing target angles in both horizontal and vertical directions. Limited to two data sets, accurate spatial positioning of targets becomes challenging, so the authors proposed and used mathematical methods to improve frequency bandwidth with algorithms. The authors faced problems with the algorithm's detection range being restricted due to the radar's transmission power and the number of antennas, limiting its ability to differentiate between multiple individuals.

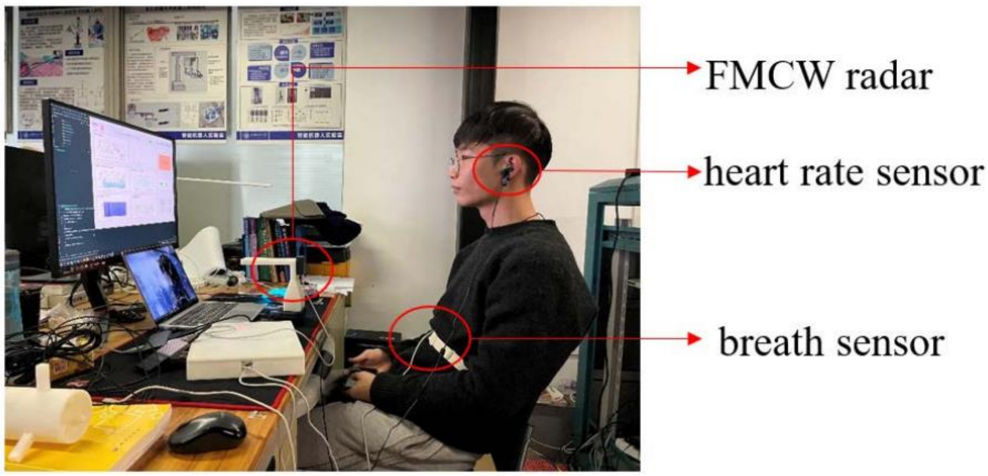


Figure 1.3.5: The experimental scene where sensors are used to compare with radar readings [5].

Yaokun Hu et al.[11] monitors vital signs of multiple moving targets using a millimeter-wave FMCW radar. FMCW radar has good range, speed measurement capability, high sensitivity, making it easy to detect tiny displacements on the surface of the skin. In previous method of monitoring vital signs the subject need to stay still for accurate heart and breathing measurements so authors proposed signal processing system and extraction system which emphasizes on improved adaptive range bin selection method that selects the optimal range bin cells to obtain high-quality phase-change information, and the reconstructed heartbeat signal and respiratory rate signal using ICEEMDAN (Improved Complete Ensemble Empirical Mode Decomposition with Additive Noise) method which shows very promising results that regardless of whether the subjects walked at 1 m/s or with the left side of their body facing the radar, the accuracy of the heart rate measurement remained high. In the fixed-route experiments, the root mean squared error (RMSE) for heart rate estimation was 4.09 bpm, with an accuracy of 95.88%. show the experiment's accuracy in fixed route and random walk. The authors faced challenges in measuring the right side of the human body and the presence of multiple targets in the same range bin cell for an extended period poses a classification problem. In future studies incorporating multiple radars can enhance the accuracy of the measurement system.

Figure 1.3.6: Experimental setup for multiple moving targets vital signs monitoring [10]

Turppa et al [12] monitors vital sign with a 24 GHz FMCW radar in different scenarios. Authors measured 11 participants with three activities relaxed respiration, hypopnea simulation, and recovering after physical exercise. From the data they extract heart rate by cepstral analysis after getting IBI from the radar data. For the respiration rate auto correlation function is applied on the phase signal. After posting the processing of non-reliable estimates, we got the respiration rate. After comparing with traditional Embla titanium portable polysomnography (PSG) system and ECG they got accuracy of 91% for respiratory rate and 96% for heart rate.

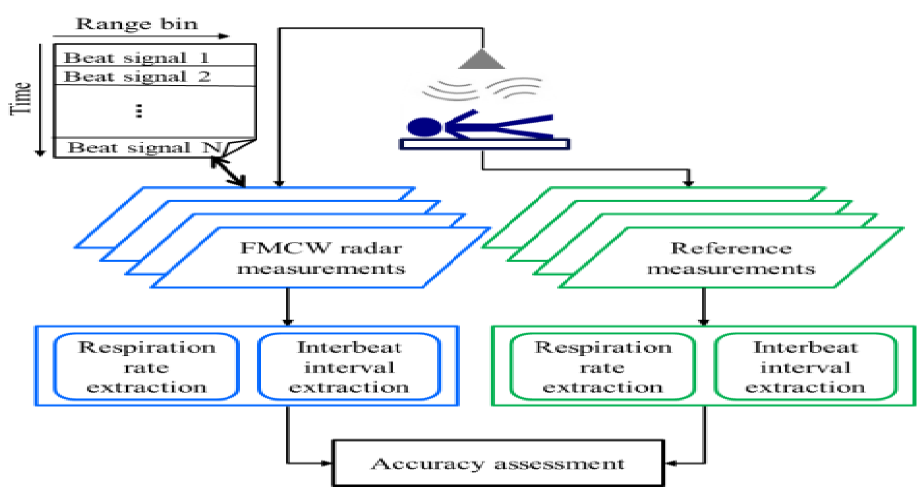


Figure 1.3.7: The overall measurement and evaluation workflow. The radar and reference data are processed separately. A beat signal describes the difference between the transmitted and received signals [12].

Xiang et al [13] proposed a system with 77 GHz Texas Instruments AWR1642 radar to measure the vital signs. First the signal is passed by bandpass and notch filter then used FFT-CZT hybrid algorithm to extract the heart rate and respiratory rate. After comparing PPG and ECG smart bracelet authors found around 98.67% accuracy for respiratory rate and 98.04% heart rate. They face problems with the noise of the hardware which leads to a low signal to noise ratio.

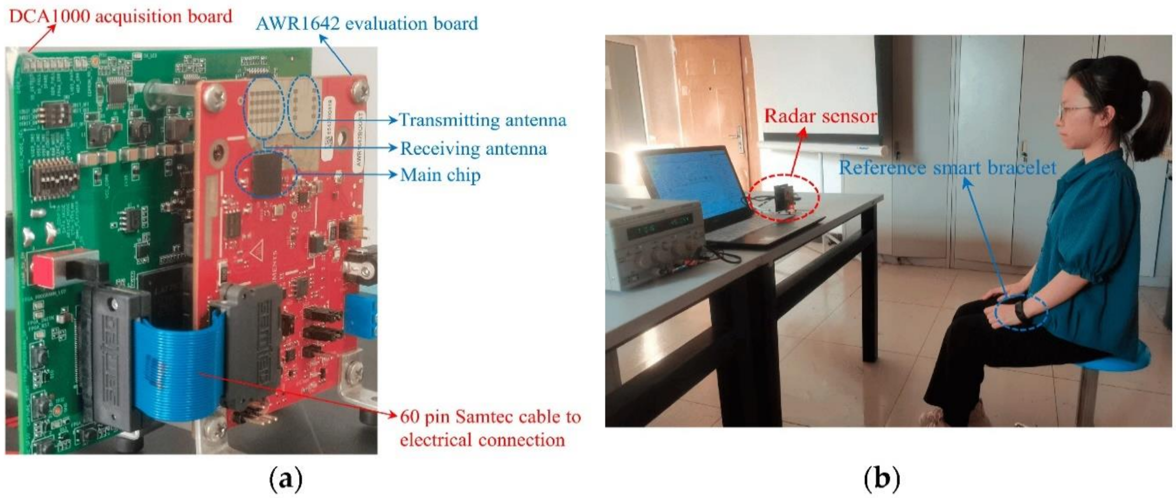


Figure 1.3.8: (**a**) TI AWR1642 sensor system; (**b**) Measurement scenario [13].

Choi et al [14] proposes a method to improve the heart rate measurement efficiency by FMCW radar. Authors used temporal phase coherency with the gather data. The proposed method had the lowest MD, -1.02 BPM with 95% confidence interval of -8.33/6.30 BPM where other methods have around

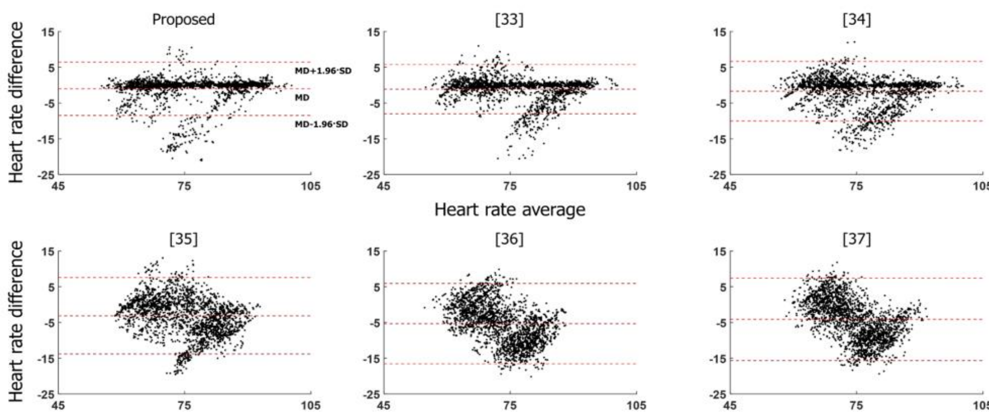


Figure 1.3.9: Bland-Altman plot of the extracted heart rates.[14]

Arsalan et al[15] improved the contactless heartbeat estimation. They used 60 GHz BGT60TR13C from Infineon Technologies radar for their analysis. The Kalman Filter Tracking method was used to improve the estimation. The resulting root-mean-square errors (RMSE) for the proposed algorithm are 5.3 bpm and 7.0 bpm compared to 17.6 bpm and 21.3 bpm for the heart rate and it found that the method is so efficient that it can decrease the RMSE by factor of 3 terms.

1.4. Critical Engineering Specialist Knowledge

The topic of the project needs special knowledge of critical engineering. This project is about detecting vital signs wirelessly. The specialized critical engineering knowledge about this module is necessary to understand the working procedure and the operation of this module for desired task. There are several issues for this module which need the special knowledge of critical engineering.Such as,

- **FMCW radar operation**: The main equipment of this system is FMCW Radar. The radar uses frequency modulated continuous wave to detect the movement of the skin and detects the heart rate and respiratory rate. Micro doppler effect along with FMCW can measure the vital signs. So critical engineering knowledge is required to understand the operation of the module.
- **Signal processing and Programming:** The radar is operated at 60 GHz frequency and the data will be processed and show real time data to the output device. The TX and Rx antenna will send and receive high frequency signal. There will be several objects so proper transmitting and receiving of reflected signal is needed. So, signal processing is one of the crucial areas of knowledge. As the radar will send the data to microprocessor for processing, differentiate between breathing, and heart rate data, check the normality, and alert if any abnormality is detected. All the things can be done by programming in the microprocessor. So, microprocessor programming knowledge is also needed for this project.
- **Antenna design:** Antenna is the main part of the radar. The module is integrated with the package chip which contains one Tx transmit antenna and three Rx receive antennas. For vital sign detection it is very important to transmit and receive the electromagnetic waves to the subject. Antenna gain is a factor for sensitivity of the radar. As this is a portable device the size is also important for the antenna. So, antenna design knowledge is also needed.
- **Embedded System:** The radar system is embedded with DEMOBGT60TR13CTOBO1 board.

There will be needed communication protocol between radar and microcontroller and the output devices. To use the microcontroller knowledge about microcontrollers is needed.

- **Biological Parameters:** This system will measure the data and transmit the data to the output device. For developing algorithms about any abnormality of the vital signs knowledge about biomedical parameters is needed.

1.5. Stakeholders

It is possible to identify different stakeholders and their requirements directly or indirectly for the project from research and publications. The development of millimeter wave FMCW radar-based vital detection system. By working together, these stakeholders can create technology that has the potential to improve the lives of millions of people.

- **Health Service Provider:** The primary beneficiaries of this project hospital authority who are involved in taking care of patients. This can be especially beneficial for the hospital ward and cabins. Generally, nurses manually monitor the patients in scheduled time. If similar devices installed in the hospital cabin this can be automated by this project again, they will be able to monitor more patients remotely and record the data for diagnosis.
- **Biomedical Instrument Manufacturer:** The companies which manufacture biomedical instruments will be benefitted from this project. As the FMCW technology in medical use is relatively new and has a robust and reliable operation there is a lot of scope for innovation for manufacturing devices performing similar operations like detecting vital signs.
- **Arrythmia and Asthmatic Patients:** The person who has an irregular heart rate and asthmatic patients will also be benefited from the project. Their heart rate and respiratory rate will be always monitored, and the data can also be used to diagnose their state. Any abnormality also can be detected real-time.
- **Biomedical Researcher and Engineers:** Researchers and engineers will also benefit from this project, as they will be able to use this technology to collect human vital rates without any interruption and measure other physical parameters. As this design is a solution to a complex engineering problem, the specifications must be met with absolute accuracy and in this field, the

manufacturers play a vital role. Engineers will benefit from this project, as it will provide them with an opportunity to develop modern technologies for monitoring the vital signs.

- **Regulatory Body:** Regulatory body will need to be involved in the regulation of this technology. For Bangladesh perspective Directorate General of Drug Administration (DGDA) will need to ensure that the mm Wave FMCW radar-based technology is safe and effective before it can be used for specific tasks.

In addition to these specific stakeholders, there are also a few other people who may be interested in this project, such as the public, investors, and the media.

1.6. Objectives

The main objective of the project is to measure vital signs remotely, which is highly helpful for patients and healthcare professionals. We developed a millimeter wave radar system that can detect human vital signs, record data and give emergency alert.

1.6.1. Primary Objectives

- To assess vital signs such as heart and respiratory rates remotely.
- To create an algorithm for real-time data processing.
- To transmit the collected data through Internet of Medical Things (IoMT) or cloud devices.
- To monitor the sleep state of individuals.
- To make decisions in case of detecting any abnormalities.

1.6.2. Secondary Objectives

- To utilize the collected data for automatic diagnosis.
- To store recorded data for post-processing analysis.
- To monitor emotional states.
- To measure body temperature without physical contact.
- To monitor patients with arithmetic conditions.

1.7. Organization of Book Chapters

The brief discussion of how the chapters of the book have been arranged is given below: Chapter-2: Project Management - The basic principles of project management are the main subject of this chapter. It covers topics like S.W.O.T. analysis, schedule management, cost analysis, P.E.S.T. analysis, professional responsibilities and management principles and economic models. The ideas presented in this chapter provide a foundation for the later chapters and a framework for effective project management.

Chapter-3: Methodology and Modeling - This chapter builds upon the project management principles discussed in Chapter 2 by delving into block diagram, hardware model and modeling techniques used in the projects. It covers topics such as system modeling and simulation.

Chapter-4: Implementation of Project - In this chapter the focus shifts to the practical aspects of implementing a project. It covers topics such required tools and components, implemented models like simulation and hardware models and engineering Solution in accordance with professional practices.

Chapter-5: Results Analysis & Critical Design Review - The analysis of project results and the critical design review process are discussed in this chapter. It covers topics like simulated results analysis, hardware results, and project results comparison.

Chapter-6: Conclusion - The final chapter summarizes findings, novelty of the work, cultural and societal factors and impacts, limitations of the works, future scopes, economic and cultural factors, and sustainability.

Chapter 2

PROJECT MANAGEMENT

2.1. Introduction

The process of developing to with, planning, and executing ideas as well as monitoring the plan for carrying out the project in its whole is known as project management. Examine affected person issues and alert the attendee of the patient. Following that, the processes were carefully designed, and the project's resources, materials, cost analysis, and most importantly time management were ensured. Another important component of project management is developing and executing off project objectives and goals. These arrangements lead to risk as well as effective financial management, group member communication, and administrative resources.

2.2. S.W.O.T. Analysis

Strengths:

- The contactless vital sign monitoring system can be used easily from home. Also, in this project we used 60G FMCW radar which have a variety of functions and advantages.
- This project can detect the human movement also.
- This project will make it easier for women to checkup their vital signs
- There is a large market demand for such a product.

Weaknesses:

- It can measure the vital signs from a particular distance and one person at a time.
- The contactless vital sign monitoring system can show the heart rate accurately within 100 bpm and respiratory rate within 20 bpm.

Opportunities:

- It can be profitable to target particular age group, such as hospitals, old age homes.
- This FMCW contactless vital sign monitoring system not only for detecting the heart rate or respiratory rate but also for detecting human presence in a room, human movement.

Threats:

- Modifications to government rules or health policies may affect the development of contactless vital sign detection systems capacity to be produced and distributed.

2.3. Schedule Management

The schedule was managed using the Gantt chart formed below. The dates were all taken with a one or two days of tolerance.

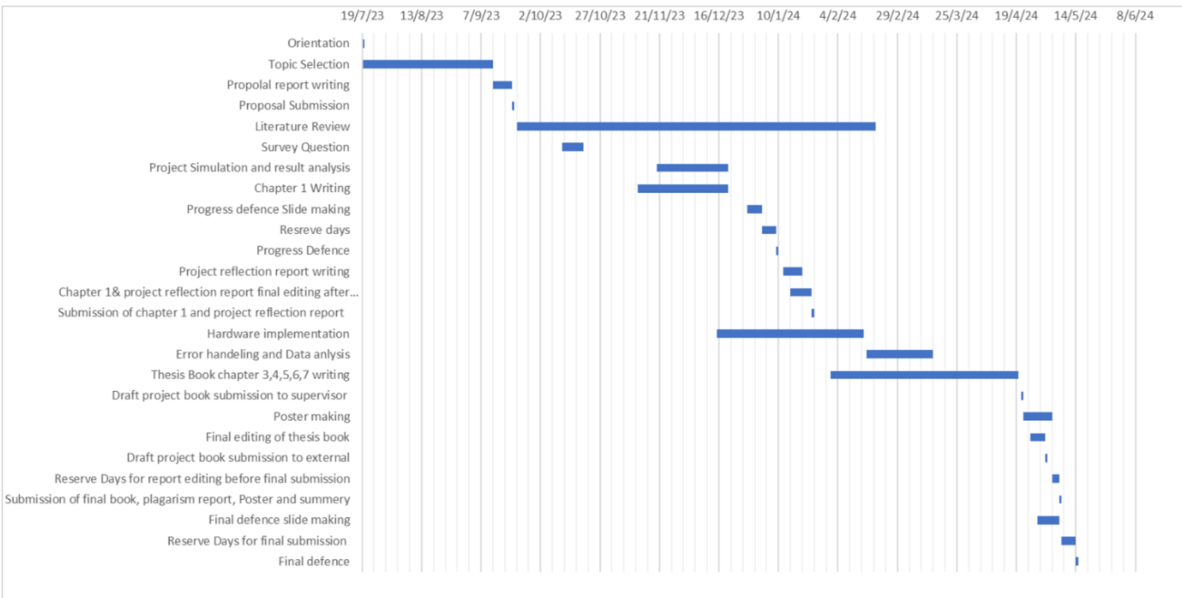


Figure 2.3.1: Gantt Chart of schedule management.

2.4. Cost Analysis

Table 2.4.1 Cost Analysis of the CVSMS

Components	**Quantity**	**Projected Price (Tk)**	**Total Price (Tk)**
60 GHz Radar	1	5500	5000
Thermal Sensor	1	6500	6700
ESP 8266 Node MCU	1	400	420
BMS Circuit	1	300	220

LCD Display with I2C module	1	600	550
Battery	1	400	350
ESP 8266 Node MCU Extension Base Board	1	250	260
Battery Adapter	1	350	350
3D printing		2000	1000
Miscellaneous		500	400
	Total	16800	15250

Total Estimated Project Cost = BDT. 16,800/-

Total Actual Cost of Project = BDT. 15,250/-

% of Error in Cost Estimation = (16800−15250)/15250∗100 %

% of Error = 10.16 %

The main and one of the expensive elements is the radar. Below table shows the other radar prices:

Table 2.4.2 Comparison table

Radar	Price (BDT)
Project Radar (Seed Studio MR60BHA1)	5000
Texas Instrument AWR 1443	73500
Texas Instrument AWR 1642	73000
Texas Instrument IWR 1443	72000
Infenion BGT60TR13C	23000

From the chart it is shown that selected radar is the most cost-effective radar from other available radars. With this radar made device more people can afford this system and use it for healthcare purpose.

2.5. P.E.S.T. Analysis

Political Analysis:

- The government's support for healthcare and heart care foundations.
- The import and export of this FMCW contactless vital sign detection systems may be impacted by international trade laws and regulations, which will have an effect on both suppliers and buyers.

Economic Analysis:

- The demand for contactless vital sign detection systems may be influenced by the general economic climate.
- There are no competitors in the market. So people will show interest to buy this product.
- The price of this system will depend on a variety of variables, including discretionary money, health insurance coverage, and income levels.

Social Analysis:

- The need for FMCW contactless vital sign detection systems will be impacted by factors like aging populations, rising heart disease.
- As this contactless vital sign detection system easy to use and low cost so people will show interest to buy this product for home and will rise in demand for this system may be attributed to better healthcare services and accessibility.

Technological Analysis:

- Investment in research and development within the sector may result in new technological developments, patent requests, and product innovations that could completely transform the contactless vital sign detection systems market.

2.6. Professional Responsibilities

Project implementers have to ensure that the end product is accessible and understandable to all stakeholders involved. Engineers ensure that methods, procedures, settings, and products are safe, usable, and effective. Effective management, communication, and teamwork are essential for engineers to achieve their goals. The engineers should develop plans and estimate a budget before starting this project. While doing the project maintain deadline and report the progress and the findings to the manager. After completing the project make as built sheet and technical reports for the customers and industry owners. The algorithms and program for the abnormal heart rate or respiratory rate notification should be accurate as many scenarios can arise. Engineers should build a string data security system to secure the customers data. This involves protecting data from unauthorized access, usage, or disclosure by utilizing encryption and other security methods.

2.6.1. Norms of Engineering Practice

The engineers should maintain the guidelines of norms provided by IEEE. When implementing a project engineers should look into the environmental, budget, and quality of the project. The FMCW radar is a cost-effective solution for continuous vital sign monitoring device. The traditional devices are so costly that only hospitals use it. Moreover, these devices are not used for normal ward patients These devices only used in ICU, CCU and other intensive care units. When designing the solution engineers must balance the quality and costing issue. As this is a biomedical device so reducing its quality may hamper the life. Here the quality of the equipment's was not minimized. This radar uses 60 GHz frequency. From Bangladesh National Frequency Allocation Plan (NFAP) it is found form 20.05-70 GHz is allocated for earth exploration satellite (passive), fixed inter-satellite (5.556a), mobile (5.558) space research.[16] As there is no military allocation so this device can get permitted easily from the government. In the USA, the 60 GHz spectrum allocation is interesting because it's designated for unlicensed use. This means anyone can use devices that transmit in this range without needing a specific license from the Federal Communications Commission[17]. In Europe, most countries allow unlicensed use of the 60 GHz band for high-speed wireless applications indoors, with some extending it outdoors. This unlicensed range sits alongside licensed allocations for other services, ensuring both innovation and control of the spectrum. [18]. Both USA and European chart says there is no license user for this spectrum. So this device can be operated most of the countries of the world without any kind of problem. A user-friendly interface, together with regulatory compliance such as medical device laws and RF standards, ensures usability and market access.

2.6.2. Individual Responsibilities and Function as Effective Team Member

Accountabilities:

Table 2.6.1 Individual Accountabilities

Name	Accountabilities
Simanta Saha	Book writing, Team managing, Equipment sourcing, MATLAB Simulations, Android App development
Nazmus Sakib Nihal	Book Writing, Data analysis, Simulation
Shakil Ahmed	Book Writing, Hardware setup
Shilamoni Shaha Neir	Book Writing, Data collecting

Individual Contribution:

Table2.6.2 Individual Contribution for the project

Name	Contribution
Simanta Saha	Topic selection, Component collection, Block diagram, Flow Chart, Book writing, Progress defense presentation, Temperature sensor calibration, MATLAB simulation, Android app development, Final Defense Poster and Presentation slide making
Nazmus Sakib Nihal	Topic selection, Component collection, Book Writing, Data Collecting, Data analysis, Cost Analysis, Progress defense presentation, 3D Design, 3D Printing, Project account management,
Shakil Ahmed	Book Writing, Hardware setup, Component selection,
Shilamoni Shaha Neir	Book Writing, Data collecting

The four team members' duties and responsibilities for creating a FMCW radar based contactless Vital sign monitoring device may be broken down as follows:

Each team member had specific duties and accountability in the project to create a versatile FMCW based contactless vital sign monitoring device for people, which helped the project get done. The performance of the FMCW based contactless vital sign monitoring device was designed and optimized by engineers, who used their technical knowledge to make sure issues like radar systems, and signal processing were taken into consideration. Designers and engineers worked closely together to translate functional requirements into aesthetically pleasing and user-friendly designs while taking user comfort, ergonomics, and visual aesthetics into account. Based on their knowledge, healthcare professionals were a crucial part of the process, contributing their insights into user demands, suggesting and ensuring that the FMCW based contactless Vital sign monitoring device design adhered to strict functional specifications. Project managers managed the project's execution by organizing tasks, keeping track of advancement, managing resources, and promoting effective teamwork. Effective team members actively participated in team discussions, spoke honestly, valued opposing points of view, and worked together to solve challenging problems. Their combined efforts made the best use possible of their group's expertise and abilities, which produced effective project results. While individual tasks may vary, the team's cohesiveness and collaboration ensured the project's smooth progress and achievement of its objectives. Each team member has worked well together, maintained clear lines of communication, and shown flexibility in responding to shifting needs and unforeseen difficulties. Each team member also shared their knowledge with others and was open to learning from their experiences. Our team has successfully created a versatile FMCW based contactless Vital sign monitoring device that is suited to the requirements of users by encouraging a culture of innovation and teamwork.

2.7. **Management Principles and Economic Models**

All the project management principles were used to run the project smoothly. The project was first reviewed clearly and as this is a radio wave device so first the frequency was checked clearly if this frequency is usable for the human being or not. As well as radio wave is used for communication such as broadcasting, military and personal communication and also in the airports to communicate with airlines. So, working with radio frequency is so critical. After reviewing the government rules and regulation for using radio wave frequency got the frequency clearance. After clearance of the frequency first the project was planned and simulated for more verification and then the project was implemented. In the terminology of economics, this project is much cost-effective solutions for continuous vital sign monitoring. The continuous vital sign monitoring device is so costly that it is used in the hospital ICU only. The cost of the available components was first and choose the most reasonable but devices to reduce the cost without sacrificing quality. And made a cost-effective device that it can be used for the hospital general ward and also for personal use such as elderly or heart patients. The impact of COVID -19 has also increased the demand of this product. As this is contactless so healthcare workers can measure the vital sign of the patient without any contact of the patient. Again, The COVID patients also need the vital sign measurements regularly. So, this can be done with this device.

2.8. **Summary**

This chapter presents a comprehensive analysis of the project's viability. Cost analysis, schedule analysis, the project's strengths and weaknesses. This chapter also addresses the contributions of each team to the overall project. With a comprehensive examination, it is possible to conclude that the project deserves to be a significant contributor to the environment and our society. The timing, budget, cost, quality everything was considered carefully when developing the project. The system was tested several times and ensured best quality and functionality. Careful management enabled the completion of the project in right time.

Chapter 3

METHODOLOGY AND MODELING

3.1. Introduction

This project uses several engineering theories and principles, most of them revolving around communications and sensing. The evolution of ubiquitous sensing has led to millimeter wave frequency-modulated continuous waves in short FMCW radar technologies which is a special type of radar that can measure the range, velocity, and angle arrival of objects in front of it. The FMCW radar transmits a sinusoidal wave called chirp whose frequency increases linearly with time. Utilizing FMCW radar and an IR thermal camera module alongside ESP 8266 Node MCU, the project is built to efficiently transmit real-time human vital signs such as heart rate, respiratory rate, and body temperature to our designated Android application named CVSMS. This enables remote monitoring of vital signs through IoMT environment.

3.2. Block Diagram and Working Principle

This is the graphic representation of the system's steps or actions, made with symbols and arrows. It offers a clear and straightforward synopsis of the process flow, making comprehension and analysis simple. The project's block diagram is shown in Figure 3.2.1

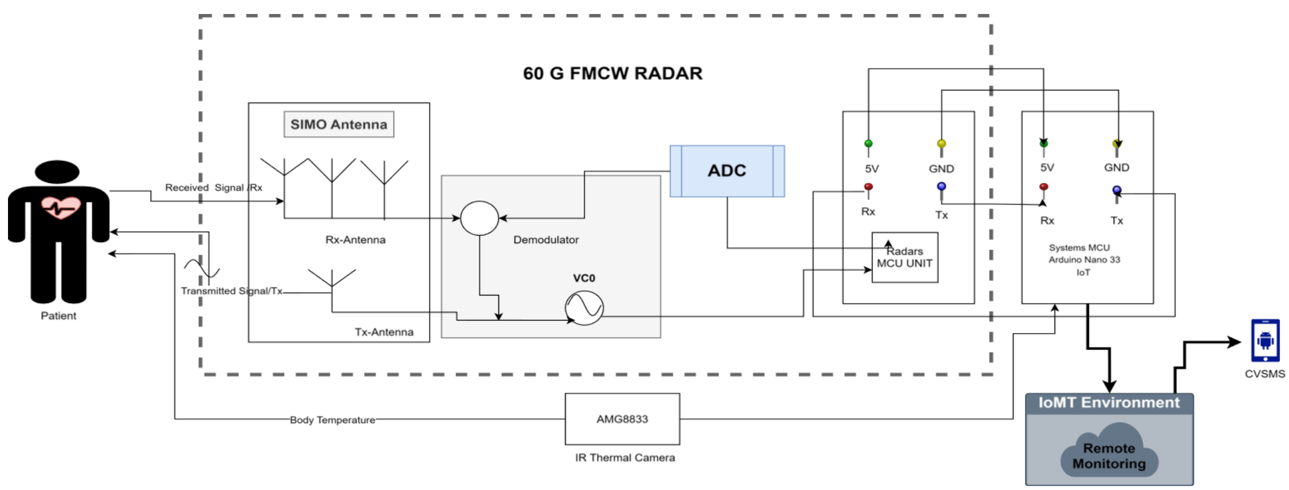


Figure 3.2.1: Block diagram of the of the contactless vital signs monitoring system.

The main component of the project is 60G band millimeter wave FMCW radar. Our particular radar has transmitter antenna and two receiving antennas. The transmitter transmits a 60G band millimeter wave signal and the measured target reflects the electromagnetic wave signal and demodulated the transmitted signal and process it through amplification, filtering and phase of the eco signal data. Then the data is sent to microcontroller unit in short MCU unit. In our case for measuring breathing and heart rate the system relies on the observation that when an individual inhale, their chest expands, bringing it closer to the antenna. Conversely, during exhalation, the person's chest contracts, moving away from the antenna, which increases the distance between the chest and the antenna and prolongs the reflection time. The MCU unit then calculate the amplitude, frequency and phase of the eco signal and measured the targeted parameter heart rhythm and respiratory rate. To measure body temperature, an IR thermal camera module (Model no. AMG8833) is connected to a microcontroller unit (MCU). This setup allows for the accurate measurement of human body temperature.

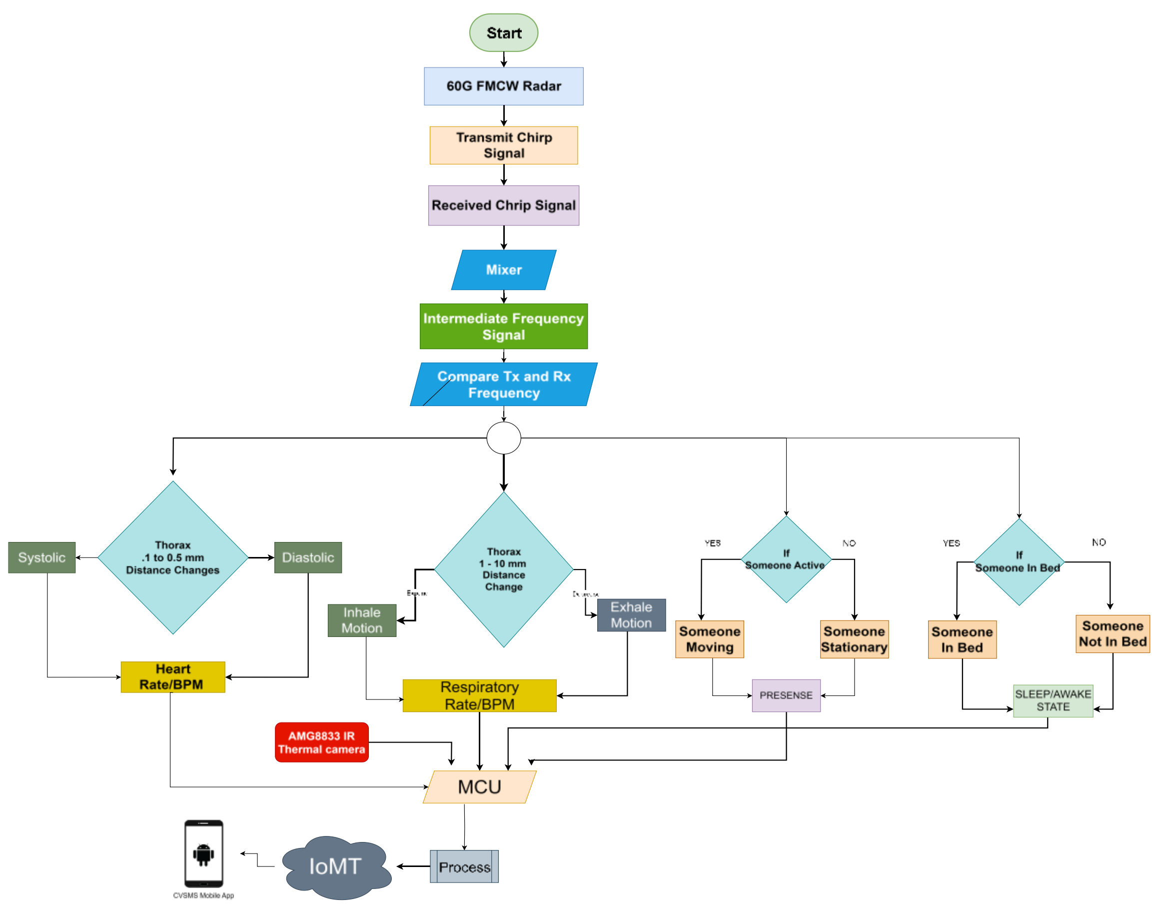
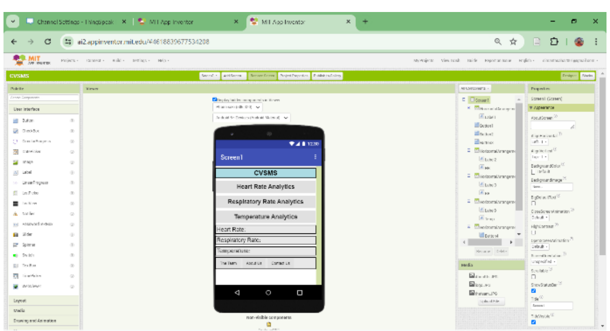


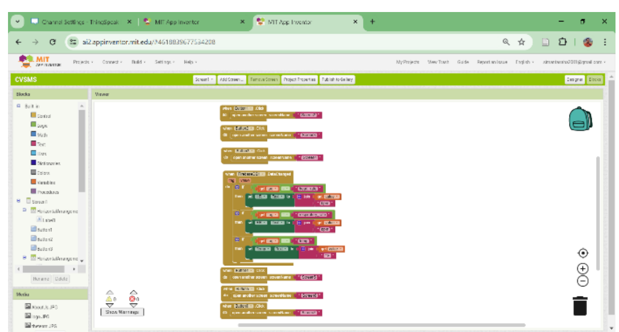
Figure 3.2.2: Flowchart of the of the contactless vital signs monitoring system.

The system tracks human vital signs like heart rate, respiratory rate, movement, and human presence using an FMCW radar. The synthesizer emits a chirping signal that transmits outside and is reflected by everything in its path. The original signal is combined with this reflected signal to produce an IF signal that contains a pack of environmental data. From this IF signal, the MCU extracts important information like angle, velocity, and range, and compares it to predetermined thresholds and successfully delivers the heart rate and respiratory rate. To measure body temperature, an IR thermal camera module (Model no. AMG8833) is connected to a microcontroller unit (MCU). This setup allows for the accurate measurement of human body temperature. Once the vital signs are successfully measured, the MCU unit of the system sends the data to the IoMT (Internet of Medical Things) environment. From there, the system displays the data in real-time on our developed Android application named CVSMS, providing graphical analysis alongside.

IoMT Based App Development:

The CVSMS Android app was created using the MIT App Inventor platform, a high-level, block-based visual programming language. Initially developed by Google and now managed by the Massachusetts Institute of Technology, this platform enables beginners to build applications for both Android and iOS. The app consists of multiple screens, each with various buttons and visual logic blocks to display real-time data. To achieve this, MATLAB's cloud-based service, ThingSpeak, was utilized. The system's MCU unit, specifically the Node MCU 8266, first collects heart rate and respiratory rate data from the 60G band radar sensor, and temperature data from the AMG8833 sensor. It then sends this data to the ThingSpeak server, where three different graphs are generated. These graphs are subsequently linked to our CVSMS app, enabling users to remotely access patient data. The following images illustrate the process of developing the Android app.





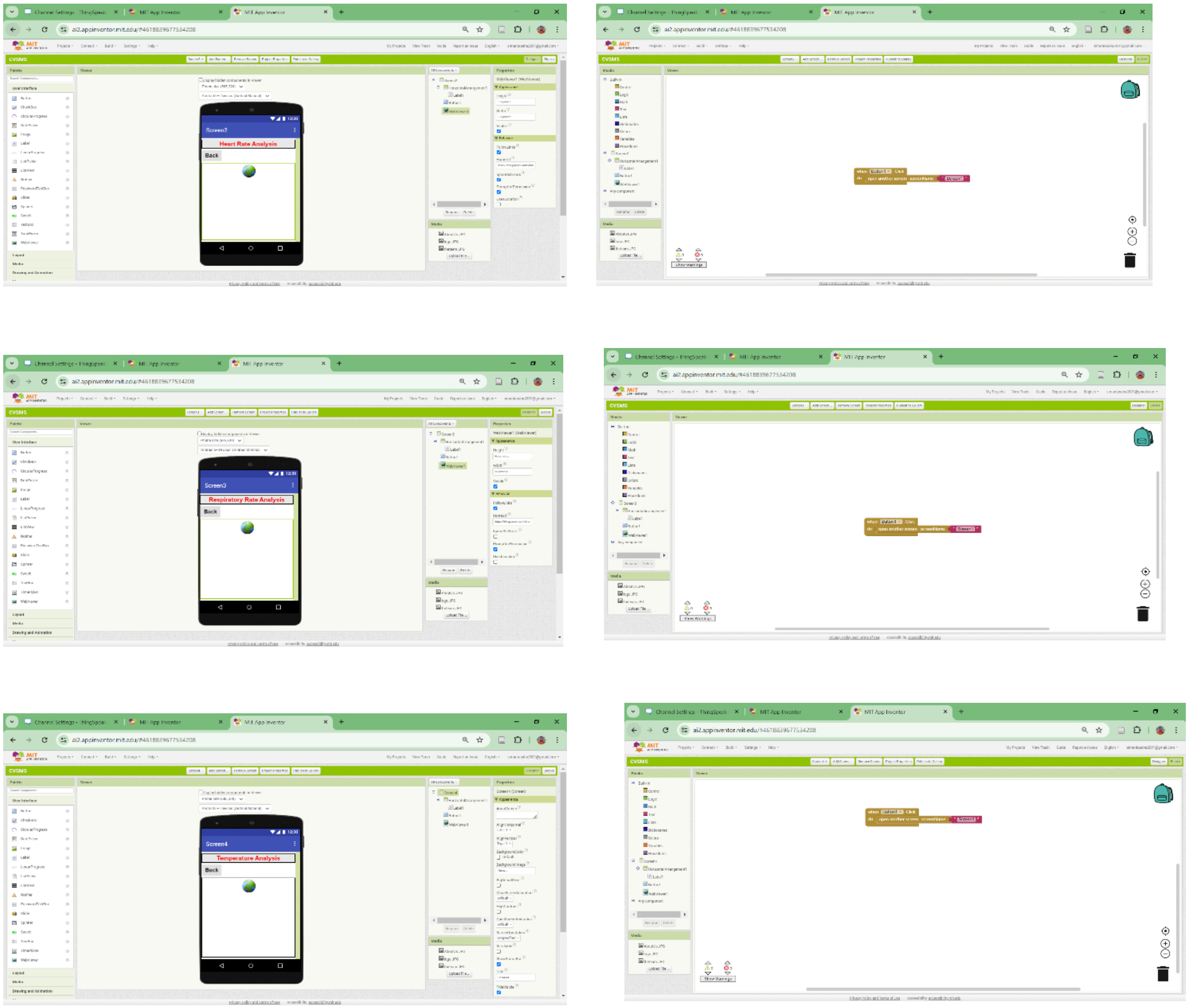


Figure 3.2.3: Visual representations of the app's interface and functionality

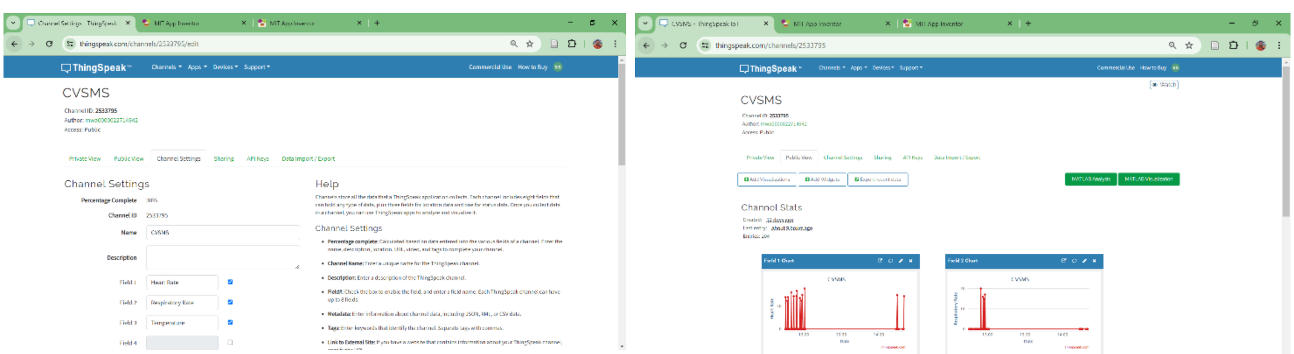


Figure 3.2.4: Visual representations of ThingSpeak server

3.3. **Modeling**

The 3D model shows the casing of the project. The shape has been built in a way that the inner and outer view can be seen and planned accordingly. The below box have only one cut which will have a switch. At the upper surface of the box there is a big cut for the display. Another cut is for temperature sensor. The radar is on the box. As visibility is not needed so no cut is not provided. The body dimension is 7.5”X4.5”X3.5” the big cut for screen which is 98 mm X60 mm and the temperature sensor cut is 17.5mm X 17.5 mm. The radar and battery module will be inside the box. The switch controls the Rx-Tx of the radar.

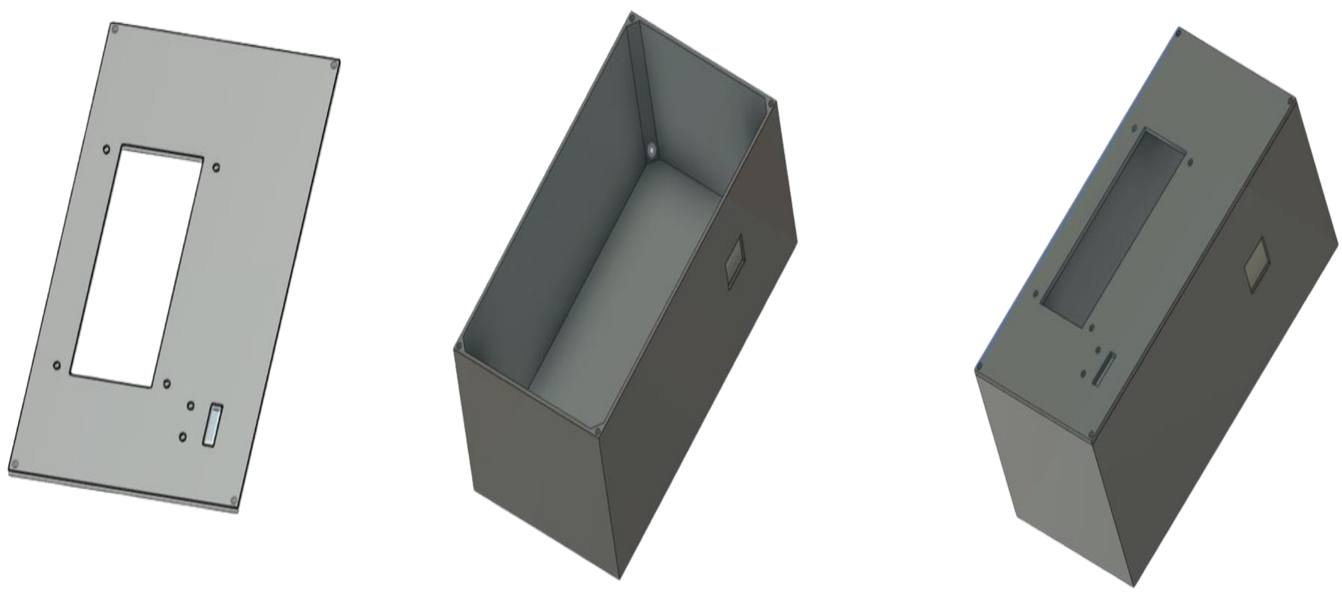


Figure 3.3.1: Inside and outer view of the contactless vital signs monitoring system.

Figure 3.3.2: Inside and outer view of the contactless vital signs monitoring system.

3.4. **Summary**

This chapter includes the project's operational block diagram, flowchart, 3D models as well as a clear analysis of its functionality to build this project. The block diagram gives an overview of features that are carried out in this project as well as flowchart gives an overview of running the project and 3D model gives the whole overview of the project. Finally, a brief description of the block diagram and some massive features of this project were highlighted in this chapter.

Chapter 4

PROJECT IMPLEMENTATION

4.1. Introduction

This chapter describes the steps used to implement the project, including the assembly and placement of all required parts. The individual components also discussed in this chapter. At every step of the procedure, there are simulations of the various hardware components. The Project mainly used radar and one thermal sensor for collecting the data. The sensors are connected to ESP 8266. The ESP 8266 process the data and also send the data to IoMT environment.

4.2. Required Tools and Components

- MR60BHA1 60GHz mm Wave Module - Respiratory Heartbeat Detection
- ESP 8266 Node MCU
- 16x2 LCD screen with I2C Module
- Lithium Ion Battery
- Buck-boost converter
- AMG8833 Thermal Sensor
- Connection Wire

4.2.1. MR60BHA1 60GHz mmWave Module - Respiratory Heartbeat Detection

The MR60BHA1 radar sensor is highly effective in measuring both respiratory rate and heart rate, even in noisy places. The radar use FMCW to precisely detect the movement of chest to detect the heart rate. The MR60BHA1 is small and easy to install into a variety of devices and systems, providing a non-contact method for monitoring vital signs that eliminates the need for bulky wires or sensors attached to the body. Its real-time monitoring capabilities are invaluable to healthcare practitioners, allowing for continuous testing of patient health and early diagnosis of abnormalities.

Table 4.2.1 MR60BHA1 60GHz mmWave Module Technical Specification[19]

Parameter content	Minimum	Typical	Maximum	Unit
Detection distance (thoracic)	0.4		1.5	m
Respiratory measurement accuracy		90		%
Heartbeat measurement accuracy		85		%
Refresh time	1		30	S
Observation set-up time		20		S

Operating Parameters:

Content	Minimum	Typical	Maximum	Unit
Operating voltage (VCC)	4.6	5	6	V
Operating current (ICC)		150		mA
Operating temperature (TOP)	-20		60	℃
Storage temperature (TST)	-40		80	℃
Launch parameters				
Operating frequency (fTX)	58	60	63.5	GHz
Transmitted power (Pout)		6		dBm

Antenna Parameters:

Content	Minimum	Typical	Maximum	Unit
Antenna gain (GANT)		4		dBi
Horizontal beam (-3dB)	-20		20	O
Vertical beam (-3dB)	-20		20	O

Figure 4.2.1: MR60BHA1 60GHz mmWave Module - Respiratory Heartbeat Detection[19]

4.2.2. **ESP 8266 Node MCU**

The ESP8266 Node MCU is a popular low-cost microcontroller and Wi-Fi module intended for IoT (Internet of Things) applications. It is based on Espressif Systems' ESP8266 Wi-Fi SoC (System on Chip) and comes in the form of a development board to facilitate prototyping and development. Node MCU combines the capabilities of a microcontroller with integrated Wi-Fi, allowing for simple wireless communication and internet access.

Table 4.2.2 Technical Specification ESP 8266 Node MCU [20]

Content	Description
Drive Type	Dual high-power H-bridge
Power Input (V)	4.5 to 9
CI Voltage (V)	3.3
Flash size (MB)	4
Operating Temperature (C)	-40 to 125
Transfer Rate (Kbps)	110 to 46800
AD0	1 Channel ADC
Length (mm)	49
Width (mm)	24.5
Height (mm)	13
Shipment Weight	0.06 kg
Shipment Dimensions	6 X 4 X 2 cm

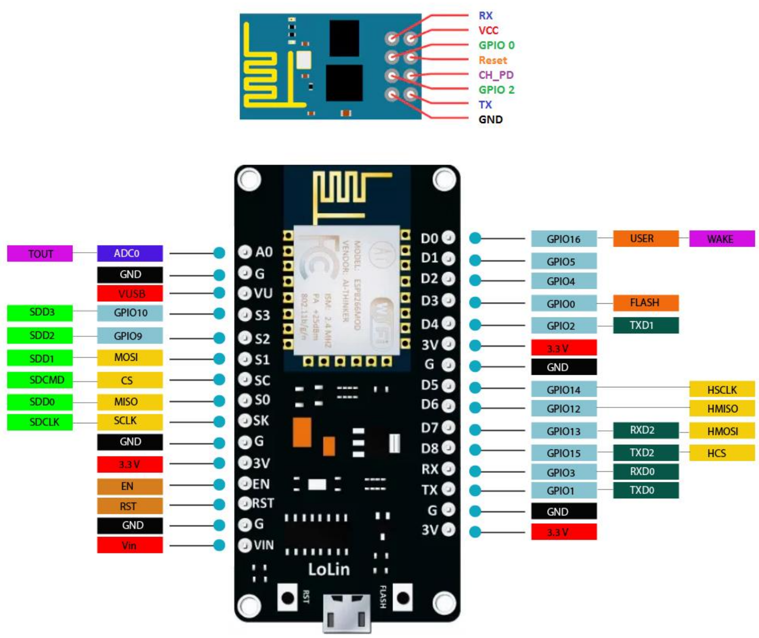


Fig4.2.2: ESP 8266 Node MCU with Pin diagram [20]

4.2.3. **Lithium Ion Battery**

Lithium-ion (Li-ion) batteries are widely recognized for their superior energy density, lightweight, and rechargeability, making them an excellent choice for a variety of applications, especially in portable electronics, Internet of Things (IoT) devices, and robotics.

Table 4.2.3 Technical Specification 3.7 Volt 18650 Battery[21]

Parameters	Specification Value
Current Capacity(mAh)	2000
Output Voltage(V)	3.7
Cell Type	Lithium Ion
Length(mm)	55
Diameter (mm)	30
Width(mm)	88
Shipment Weight	0.0035 kg
Shipment Dimensions	12 X 8 X 2.5 cm

Figure 4.2.3: Lithium Ion battery [21]

4.2.4. TP4056 Lithium Battery Charger with Boost Converter

The TP4056 chip is a popular choice for creating a simple lithium battery charger. It offers features like adjustable charging current and automatic termination at 4.2V, ideal for safely charging single-cell lithium ion batteries. However, for projects that need both charging and boosted voltage output, there are combination modules available that integrate the TP4056 charger with a boost converter. This eliminates the need for separate circuits and simplifies your design. These modules typically offer adjustable boost outputs, allowing you to power your project directly from the charged lithium battery.

Table 4.2.4 Technical Specification of TP4056 [22]

Parameters	Specification Value
Input voltage	3.7 V
Output Voltage	2-24 V
Dimensions in mm(L×W×H)	10 × 10 × 5 cm
Shipment Weight	0.002kg

Figure 4.2.4: Lithium Ion Battery charger with boost converter[22]

4.2.5. 20X4 LCD screen with I2C Module

It is a display consists of 16 columns and 2 rows of characters, allowing you to display up to 16 characters per row. It uses a serial communication protocol I2C, reducing the number of pins needed for communication. The contrast of the screen can be adjusted by potentiometer of the I2C module.

Table 4.2.5 Technical Specification 20×4 LCD screen with I2C Module[23]

Model	LCD1602
Characteristics	16
Interface type	I2C
I2C Address	0x27
Character Color	Black
Backlight	Blue
Input Voltage	5 V
Length	36 mm
Width	80 mm
Height	18 mm
Weight	35 gm
Shipment Weight	0.037 kg
Shipment Dimension	8 X 5 X 3 cm

Figure 4.2.5: 20X4 LCD screen with I2C Module[23]

4.2.6. 3D Printed Casing

A box is designed for the project. It has two parts. This two-part design, currently being prepared for printing, utilizes the combined strengths of PLA+ filament for durability and PLA+ transparent filament for clear visibility. Created within Fusion 360 software, the model undergoes slicing with Cura software specifically for an Ender 3 V2 printer. The upper portion is designated for a 20% infill, achieving a balance between weight reduction and structural integrity. In contrast, the box section receives a solid 100% infill, maximizing its strength and minimizing any potential flexing. This strategic approach allows for a clear view of the contained objects while ensuring the overall structure remains robust.

4.2.7. **ThingSpeak**

ThingSpeak is an open-source software written in Ruby which allows users to communicate with internet enabled devices. Our device uses ThingSpeak platform where data sent form the node MCU and visualized. Once the data is sent to ThingSpeak from the devices, it creates instant visualizations of live data without having to write any code. For sending the device's data to our developed app, MATLAB's cloud-based service, ThingSpeak, was utilized. The system's MCU unit, specifically the Node MCU 8266, first collects heart rate and respiratory rate data from the 60G band radar sensor, and temperature data from the AMG8833 sensor. It then sends this data to the ThingSpeak server, where three different graphs are generated. These graphs are subsequently linked to our CVSMS app, enabling users to remotely access patient data. The following images illustrate the process of developing the Android app.

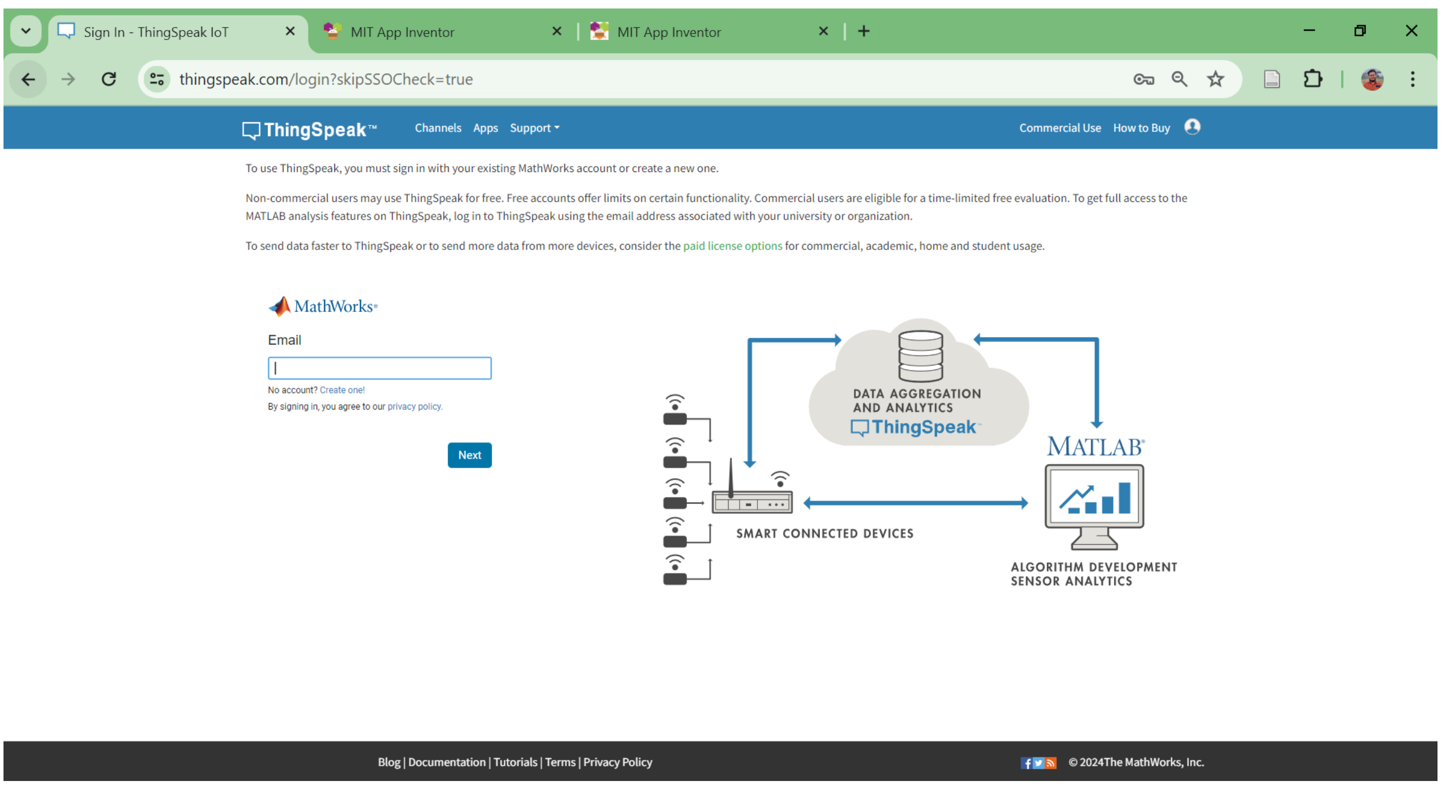


Figure 4.2.6: MATLAB cloud service ThingSpeak Interface

4.2.8. **MIT App Inventor**

The CVSMS Android app was created using the MIT App Inventor platform, a high-level, block-based visual programming language. Initially developed by Google and now managed by the Massachusetts Institute of Technology, this platform enables beginners to build applications for both Android and iOS. The app consists of multiple screens, each with various buttons and visual logic blocks to display real-time data.

Figure 4.2.7: MIT app inventor high level block based visual interface

4.3. Implemented Models

The implementation phase of the Contactless Vital Sign Monitoring System project has resulted in the realization of the final models, both in terms of hardware and software components. We have designed the circuit diagram using the circuit designer tools. To understand the radar system we have performed a MATLAB simulation where we transmit Tx and Rx signal and received IF signal. We visualize result and spectrogram which helps to understand the radar signal behavior in different scenarios and they can be proceed to extract information like distance and velocity. Below, we provide a brief overview of these implemented models, accompanied by pictures and figures for visual reference.

4.3.1. Simulation Model

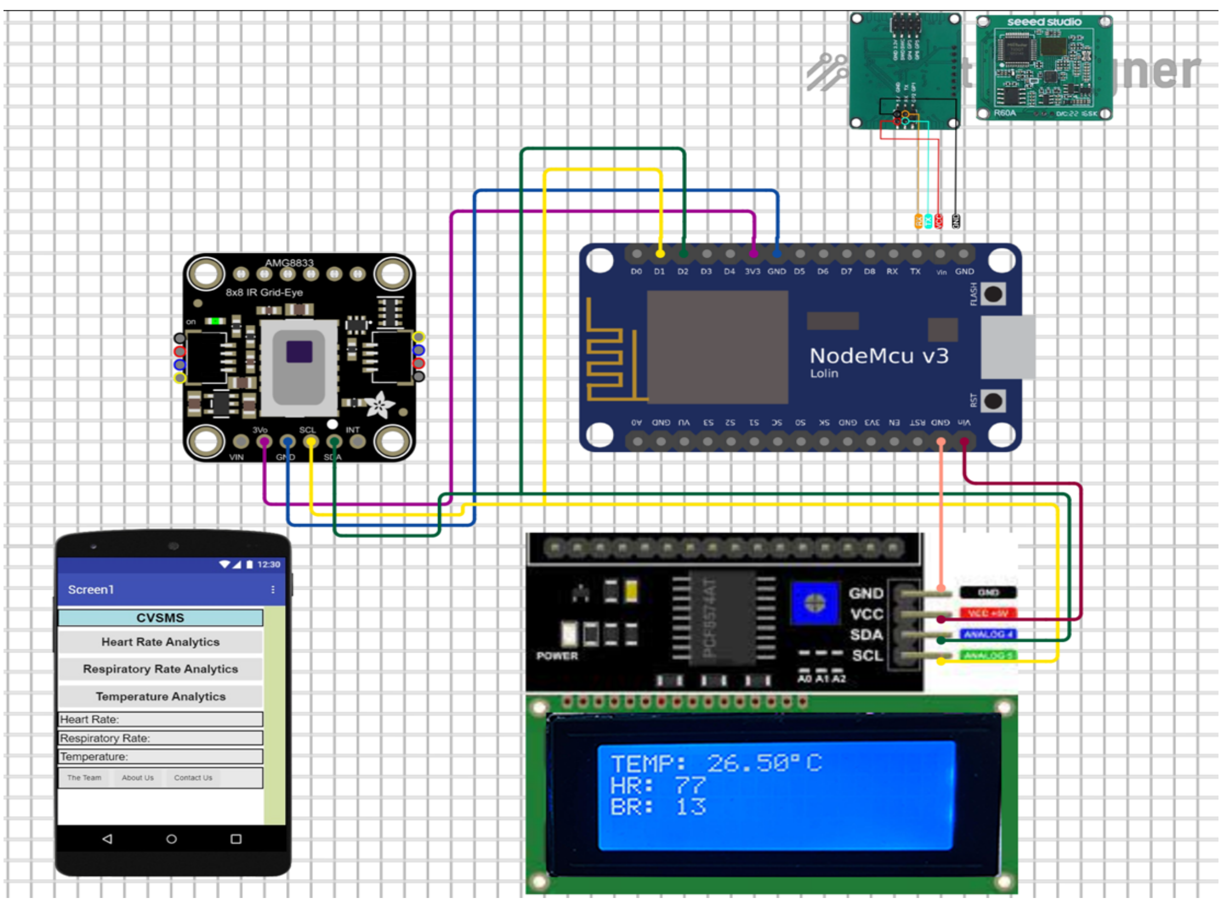


Figure 4.3.1: Circuit Diagram of the Designed Project

Step_1: Radar parameters setting

This step will set the basic parameters in a radar system,

```
% Radar parameters setting
maxR = 200; % Maximum range
rangeRes = 1; % Range resolution
maxV = 70; % Maximum speed
fc = 60e9; % Carrier frequency
c = 3e8; % Speed of light

r0 = 100; % Target distance
v0 = 70; % Target speed
% Calculate bandwidth, chirp time, and other parameters
B = c/(2*rangeRes); % Bandwidth
Tchirp = 5.5*2*maxR/c; % Chirp time
endle_time = 6.3e-6; % Endle time
slope = B/Tchirp; % Chirp slope
f_IFmax = (slope*2*maxR)/c; % Maximum IF frequency
f_IF = (slope*2*r0)/c; % Current IF frequency
Nd = 128; % Number of chirps
Nr = 1024; % Number of ADC sampling points
vres = (c/fc)/(2*Nd*(Tchirp+endle_time)); % Speed resolution
Fs = Nr/Tchirp; % Sampling rate
```

Bandwidth(B):

$$B = \frac{c}{2.range\ Res} \tag{1}$$

The bandwidth B is calculated based on the desired range resolution range Res. A higher bandwidth allows for finer range resolution. The speed of light c is divided by twice the range resolution to determine the required bandwidth.

Chirp time (Tchirp):

$$T = 5.5\frac{2maxR}{c} \tag{2}$$

The chirp time is based on the maximum range max R that the radar should detect. The factor 5.5 is a design parameter ensuring the chirp time accommodates the round-trip time for the signal to travel to the maximum range and back.

Chirp slope:

$$slope = \frac{B}{T_{chirp}} \tag{3}$$

The chirp slope is the rate of change of frequency over time. It is calculated as the bandwidth B divided by the chirp time T_{chirp}

Maximum Intermediate Frequency (f_{IFmax}):

$$f_{IF_{max}} = \frac{slope.2.maxR}{c} \tag{4}$$

The maximum intermediate frequency IF max is the beat frequency corresponding to the maximum range maxR. It is calculated using the chirp slope, the maximum range, and the speed of light.

Current Intermediate Frequency (f_{IF}):

$$f_{IF} = \frac{slope.2.r_0}{c} \tag{5}$$

Similar to IF_{max} this is the beat frequency corresponding to the current target range r_0

Speed resolution (vres):

$$v_{res} = \frac{\frac{c}{f_c}}{2.N_d(T_{chirp}+endl_{time})} \tag{6}$$

The speed resolution v_{res} determines the smallest detectable change in velocity. It depends on the speed of light carrier frequency, number of chirps, chirp time and a parameter end time.

Sampling rate (F_s):

$$F_s = \frac{N_r}{T_{chirp}} \tag{7}$$

The sampling rate is the rate at which the ADC samples the received signal. It is determined by the number of ADC samples divided by the chirp time T_{chirp}.

Step_2: Signal of Tx:

Assuming that the Tx signal is a cosine signal whose frequency varies linearly with time,

```
Editor - C:\Users\user\Documents\CAPSTONE PROJECT\Simulations\mainfmcw.m
newplotwrapper.m  mainfmcw.m  Heart.m  Untitled8.m

    % Tx waveform parameters
    t = linspace(0, Nd*Tchirp, Nr*Nd); % Sampling time for Tx and Rx signals
    angle_freq = fc*t + (slope*t.^2)/2; % Angular frequency
    freq = fc + slope*t; % Frequency
    Tx = cos(2*pi*angle_freq); % Tx waveform

```

Tx waveform angular frequency (angle$_{freq}$):

$$angle_{freq} = f_c\,.t + \frac{slope.t^2}{2} \tag{8}$$

This represents the angular frequency of the transmitted signal, incorporating the carrier frequency and the frequency modulation over time due to the chirp slope.

Tx waveform (Tx):

$$Tx = \cos(2\pi.angle_{freq}) \tag{9}$$

The transmitted signal Tx is a cosine wave with the calculated angular frequency.

Step_3: Signal of Rx:

The Rx waveform can be calculated from the Tx waveform and the delay time,

```
Editor - C:\Users\user\Documents\CAPSTONE PROJECT\Simulations\mainfmcw.m
newplotwrapper.m  mainfmcw.m  Heart.m  Untitled8.m

    % Update target distance for Rx waveform
    r0 = r0 + v0*t;

    % Rx waveform parameters
    td = 2*r0/c; % Time delay
    freqRx = fc + slope*t; % Frequency for Rx
    Rx = cos(2*pi*(fc*(t-td) + (slope*(t-td).*(t-td))/2)); % Rx waveform

```

Target Distance(r_0):

$$r_0 = r_0 + v_0.t \tag{10}$$

The target distance r0 is updated over time as the target moves with velocity v0

Time delay(td)

$$t_d = \frac{2.r_0}{c} \tag{11}$$

The time delay td is the round-trip time for radar signal to travel the target and back, calculated using current target distance r_0.

Rx wave form frequency:

$$freqRx = f_c + slope.t \tag{12}$$

Similar to the transmitted signal the frequency of the received signal increase linearly over time due to the slope.

Rx Wave form:

$$Rx = \cos(2\pi\left(f_c(t - t_d) + \frac{slope(t-t_d)^2}{2}\right)) \tag{13}$$

The received signal Rx is a cosine wave with the angular frequency considering the time delay td.

Step_4: IF signal

According to the processing, assuming the IF signal can be represented by cos((2*pi*wt*t-2*pi*wr*t)),

```
Editor - C:\Users\user\Documents\CAPSTONE PROJECT\Simulations\mainfmcw.m
newplotwrapper.m | mainfmcw.m | Heart.m | Untitled8.m

% Intermediate Frequency (IF) signal parameters
IF_angle_freq = fc*t + (slope*t.^2)/2 - ((fc*(t-td) + (slope*(t-td).*(t-td))/2)); % Angle frequenc
freqIF = slope*td; % Frequency for IF
IFx = cos(-(2*pi*(fc*(t-td) + (slope*(t-td).*(t-td))/2)) + (2*pi*angle_freq)); % IF waveform
```

Intermediate Frequency (IF) signal angular frequency

$$IFangle_{freq} = f_c\,.t + \frac{slope\,.t^2}{2} - (f_c.(t - t_d) + \frac{slope\,.(t-t_d)^2}{2} \tag{14}$$

The equations are representing the angular frequency difference between the transmitted the received signal which corresponds to the beat frequency.

IF wave form

$$IFx = \cos(-2\pi(f_c(t-t_d) + \frac{slope(t-t_d)^2}{2} 2\pi.angle_{freq}) \tag{15}$$

The IF signal IFx is difference between the transmitted and received signals resulting in a beat frequency

IF signal frequency

$$freqIF = slope.t_d \tag{16}$$

The frequency of the intermediate frequency (IF) signal is determined by the product of the chirp slope and time delay td

Step_5: FFT of IF signal

In this step, we calculate the frequency of IF signal by the FFT of IF signal,

```
Editor - C:\Users\user\Documents\CAPSTONE PROJECT\Simulations\mainfmcw.m
newplotwrapper.m  mainfmcw.m  Heart.m  Untitled8.m  +

    % Range FFT
    doppler = 10*log10(abs(fft(IFx(1:1024)))); % Doppler signal
    frequency = fftshift((-Nr/2:Nr/2-1)*(Fs/Nr)); % Frequency
    range = frequency*c/(2*slope); % Range
```

Doppler Signal:

$$doppler = 10.\log_{10}(|fft.\left(IFx(1:1024)\right)|) \tag{17}$$

The Doppler signal is obtaining by taking the fft of the IF signal and converting it to a logarithmic scale to analyze the frequency components

$$frequency = fftshift(\left(\frac{-N_r}{2}:\frac{N_r}{2}-1\right).\left(\frac{F_s}{N_r}\right)) \tag{18}$$

The equations generate the frequency axis for the FFT result shifted to center around zero

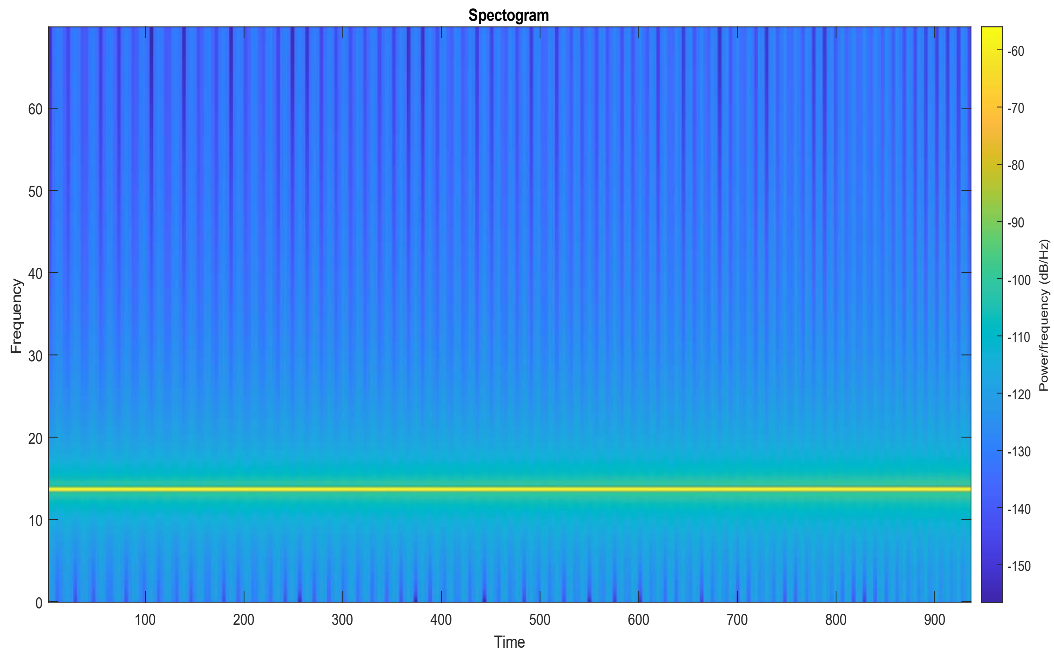
Range

$$range = frequency\,.\frac{c}{2.slope} \tag{19}$$

The range is calculated form the frequency axis of the FFT result, using the speed of light and the chirp slope which translates the frequency components into distance measurements.

Step_6: Spectrogram with time

In this step, Spectrogram with time change will be calculated.



We can see that the IF signal frequency change due to target displacement within a single FRAME cycle is difficult to distinguish within the spectrogram, so we need to detect small displacements and velocities by phase changes.

Table 4.3.1 Radar Signal Processing Parameters

Parameter	**Name**	**Value**
Maximum range	Max R	200 m
Range resolution	Range Res	1 m
Maximum speed	Max V	70 m/s
Carrier frequency	fc	60 GHz (60 × 10^9 Hz)
Speed of light	c	3 × 10^8 m/s

Parameter	Name	Value
Target initial distance	r_0	100 m
Target speed	v_0	70 m/s
Bandwidth	B	150 MHz (150 × 10^6 Hz)
Chirp time	T_{chirp}	7.33 µs (7.33 × 10^-6 s)
Endle time	End time	6.3 µs (6.3 × 10^-6 s)
Chirp slope	slope	20.46 THz/s (20.46 × 10^12 Hz/s)
Maximum IF frequency	f_{IFmax}	27.28 kHz (27.28 × 10^3 Hz)
Current IF frequency	f_{IF}	13.64 kHz (13.64 × 10^3 Hz)
Number of chirps	N_d	128
Number of ADC samples	N_r	1024
Speed resolution	v_{res}	0.1706 m/s
Sampling rate	F_s	139.66 MHz (139.66 × 10^6 Hz)
Sampling time	t	linspace(0, Nd × Tchirp, Nr × Nd)
Tx waveform angular freq	angle_freq	fc × t + (slope × t^2) / 2
Tx waveform frequency	freq	fc + slope × t
Tx waveform	Tx	cos(2π × angle_freq)
Updated target distance	r_0	r0 + v0 × t
Time delay	t_d	(2 × r0) / c
Rx waveform frequency	Freq Rx	fc + slope × t
Rx waveform	Rx	cos(2π(fc(t - td) + (slope(t - td)^2)/2))
IF signal angular freq	IF_angle_freq	fc × t + (slope × t^2) / 2 - (fc(t - td) + (slope(t - td)^2) / 2)
IF signal frequency	Freq IF	slope × td

Parameter	Name	Value
IF waveform	IF x	cos(-2π(fc(t - td) + (slope(t - td)^2)/2) + 2π × angle_freq)
Doppler signal	Doppler	10 × log10(
Frequency	frequency	fftshift((-Nr/2 : Nr/2 - 1) × (Fs / Nr))
Range	range	frequency × c / (2 × slope)

4.3.2. **Hardware Model**

Figure 4.3.2.1: Hardware Model: Outer view of the device

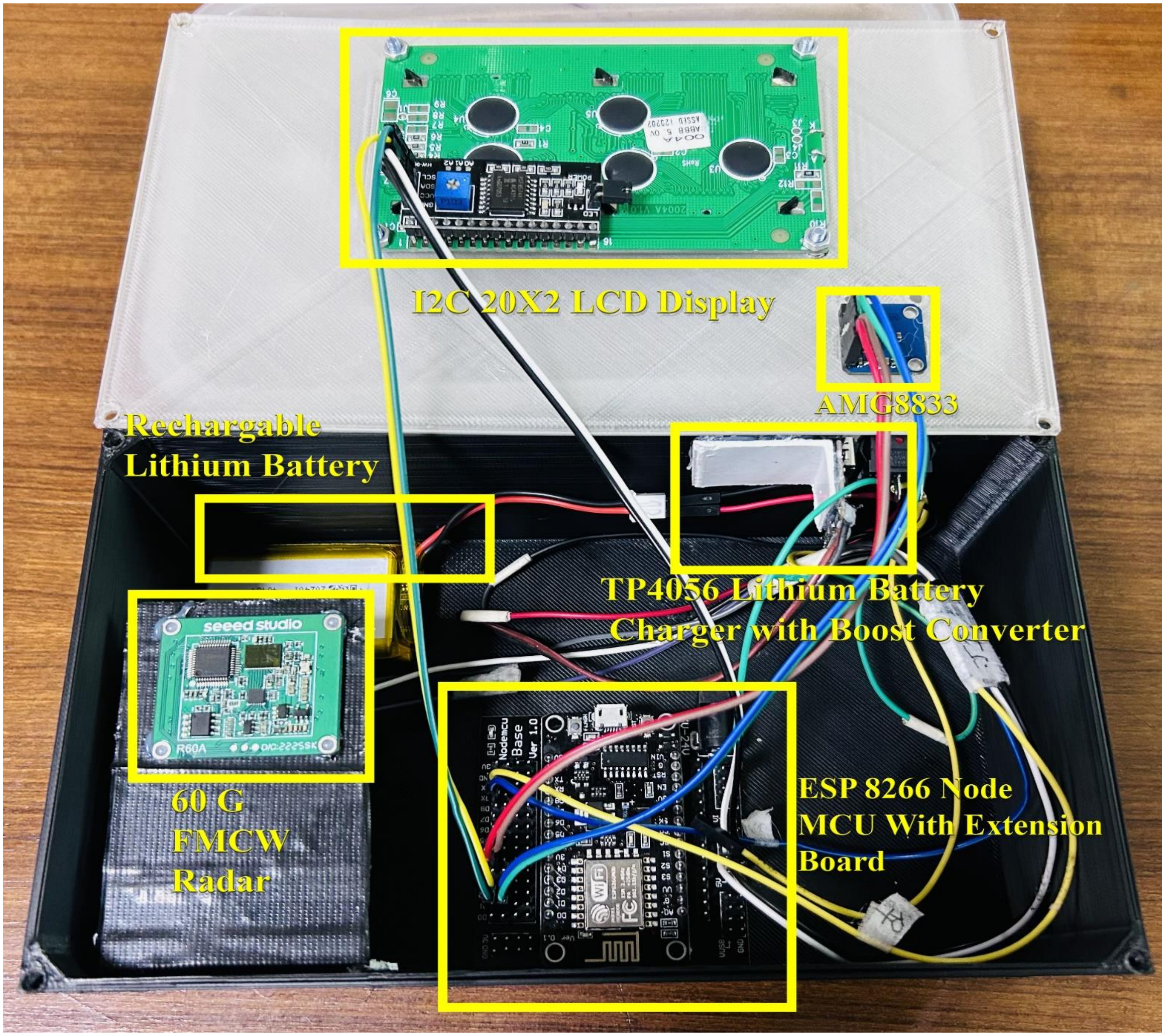


Figure 4.3.2.2: Hardware Model

The 60 GHZ radar and the AMG8833 thermal sensor is connected to ESP 8266 Node MCU. The RX pin of radar sensor is connected to TX pin of Node MCU and Tx of radar is connected with Rx pin of MCU and ESP 8266 is sending data to MATLAB's cloud service ThingSpeak also showing the data on the screen to D1 and D2 screen. From the cloud server the real time data is directly shown to developed android app called (CVSMS) the app was developed using MIT app inventor. The AMG 8266 is also connected with D1 and D2 pin of the node-MCU. The radar, Screen and thermal sensor is powering from ESP 8266 and a

9V adapter. The system should keep aligned with the chest of the patient for more accurate data collection. For lying patients, the system can be set in a PVC pipe structure and aligned with the chest. The radar will collect data of the patient and show it. Also send it to the attendant or nurse through thing speak and firebase. By which the attendant can monitor the patient. To power the entire system, a battery pack with a BMS is used. The battery pack ensures portability of the system. The sensor setup to be deployed in various locations without relying on a constant external power source.
has context menu.

Table 4.3.2 Connection Table of CVSMS

ESP 8266	Equipment
Radar	
Vin	VCC
G	GND
Rx	Tx
Tx	Rx
AMG 8266	
3.3 V	Vin
G	GND
D1	SCL
D2	SDA
I2C LCD Display	
G	GND
Vin	VCC
D2	SDA
D1	SCL

4.4.Engineering Solution in accordance with professional practices

The system is aligned with engineering professional practices by ensuring that it is designed, built, and maintained in a way that is safe for the public. This involves adhering to relevant safety codes and standards, as well as conducting thorough testing and risk assessments to identify and mitigate potential hazards. The team done research about the problem and make a feasibility analysis of the device. The team designed a practical and feasible solution by combining the technical proficiency of biomedical, Signal processing, radar technology and biomedical engineering. The device was tested several times and with different age group people and different phase like general, after exercise, sleeping etc for quality assurance issue. This project thus follows professional practices such that this project is aimed to serve the public interest, and all tests have been conducted with academic honesty.

4.5. **Summary**

This chapter explains the project's simulation and hardware implementation. The engineering solutions implemented in accordance with professional practices while working on the project were also mentioned. Overall, the project was effectively constructed using examples from the simulation model. At first the radar performance is tested through the simulation software and made decision about the appropriate radar. The prototype is built and done the design changes and tested in different situations.

Chapter 5

RESULTS ANALYSIS & CRITICAL DESIGN REVIEW

5.1. Introduction

In this project we have three types of data. The Heart-rate, Respiratory rate and the Temperature. The Radar can measure the heart rate and respiratory rate and the thermal sensor is used to measure the body temperature. The test of the device was done including heart-rate and respiratory-rate testing, validating the tested data with other FDA approved vital sign measuring instrument. Testing the body temperature and validate it with thermometer. App testing communication with the app.

5.2. Results Analysis

5.2.1. MATLAB Simulation Results

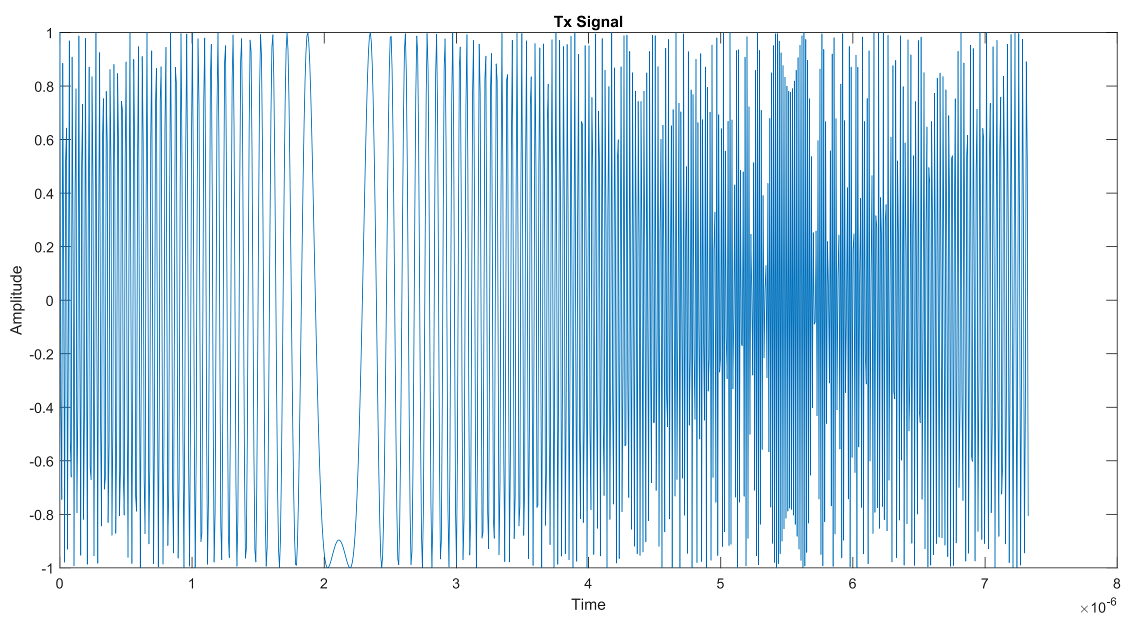


Figure 5.2.1.1: The transmitted signal Tx

Tx waveform angular frequency ($angle_{freq}$):

$$angle_{freq} = f_c \,.\, t + \frac{slope.t^2}{2} \tag{8}$$

Tx waveform (Tx):

$$Tx = \cos(2\pi.\, angle_{freq}) \tag{9}$$

This represents the angular frequency of the transmitted signal, incorporating the carrier frequency and the frequency modulation over time due to the chirp slope. The transmitted signal Tx is a cosine wave with the calculated angular frequency.

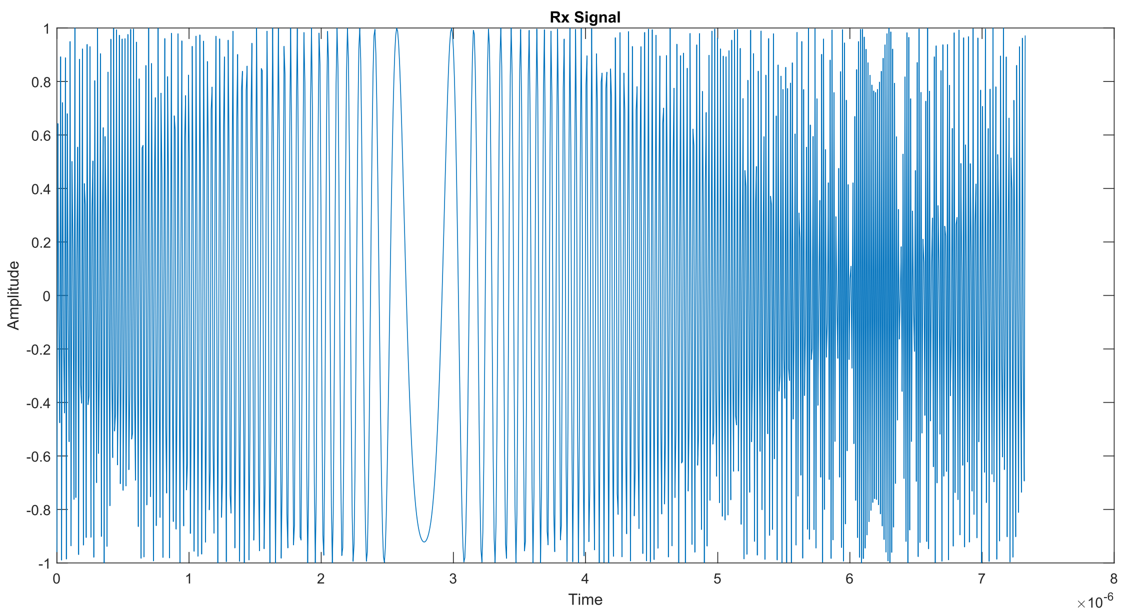


Figure 5.2.1.2: Circuit Diagram of the Designed Project

Rx wave form frequency:

$$freqRx = f_c + slope.\, t \tag{12}$$

Rx Wave form:

$$Rx = \cos(2\pi\left(f_c(t - t_d) + \frac{slope(t-t_d)^2}{2}\right)) \tag{13}$$

Similar to the transmitted signal the frequency of the received signal increase linearly over time due to the slope. The received signal Rx is a cosine wave with the angular frequency considering the time delay td.

IF signal

According to the processing, assuming the IF signal can be represented by

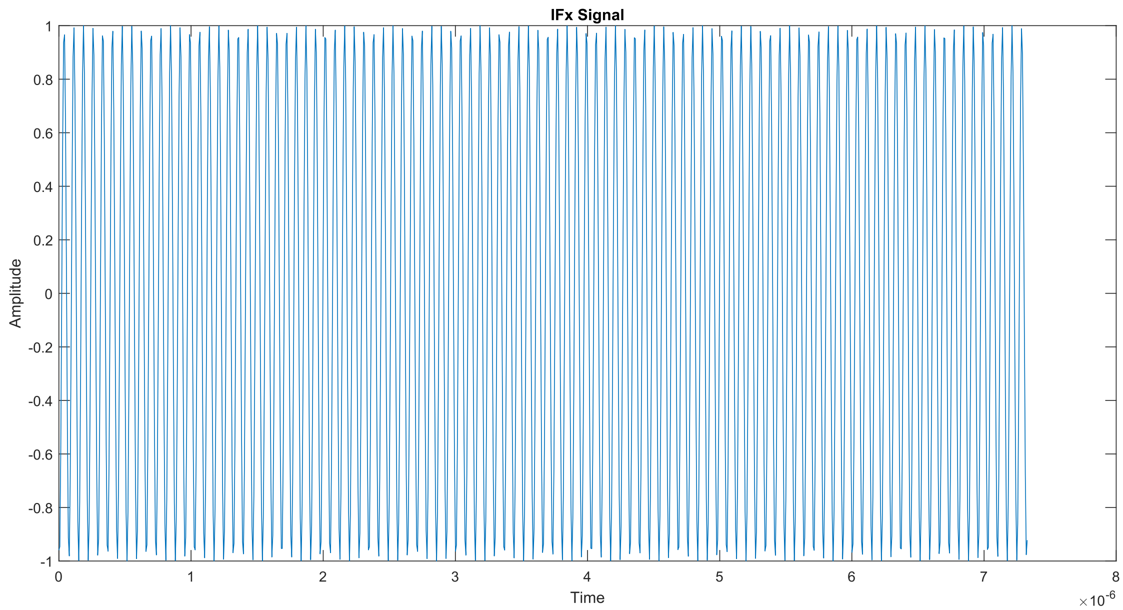


Figure 5.2.1.3: Intermediate Frequency (IF) signal

Intermediate Frequency (IF) signal angular frequency

$$IFangle_{freq} = f_c \,.\, t + \frac{slope \,.t^2}{2} - (f_c.\,(t - t_d) + \frac{slope \,.(t-t_d)^2}{2} \tag{14}$$

The equations are representing the angular frequency difference between the transmitted the received signal which corresponds to the beat frequency.

IF wave form

$$IFx = \cos(-2\pi(f_c(t - t_d) + \frac{slope(t - t_d)^2}{2} 2\pi.\, angle_{freq}) \tag{15}$$

The IF signal IFx is difference between the transmitted and received signals resulting in a beat frequency

IF signal frequency

$$freqIF = slope.\, t_d \tag{16}$$

The frequency of the intermediate frequency (IF) signal is determined by the product of the chirp slope and time delay td

FFT of IF signal

In this step, we calculate,

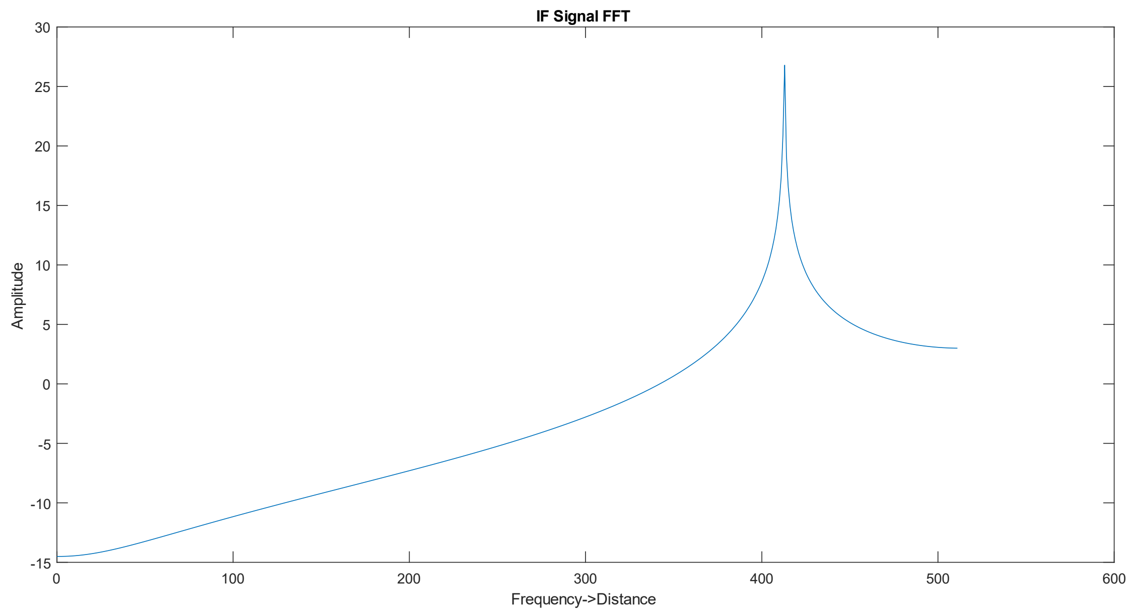


Figure 5.2.1.4: the frequency of IF signal by the FFT of IF signal

$$frequency = fftshift(\left(\frac{-N_r}{2} : \frac{N_r}{2} - 1\right).\left(\frac{F_s}{N_r}\right)) \quad (18)$$

The equations generate the frequency axis for the FFT result shifted to center around zero

Range

$$range = frequency\,.\frac{c}{2.\,slope} \quad (19)$$

The range is calculated form the frequency axis of the FFT result, using the speed of light and the chirp slope which translates the frequency components into distance measurements.

5.2.2. **Hardware Results**

When a human present in front of radar the Yellow LED turned on. The Heart-rate and Respiratory rate and the temperature showed in the screen and the app. The radar simultaneously measures the parameters and show the result in the screen. 5 data for every person was taken to validate the data and further medical analysis.

The table represents 5 males and 5 female 22-to-25-year person data. The Age, height, weight is collected first from the volunteers of the project. Then the BMI was calculated,

$$\text{BMI}= \frac{Weight\ (KG)}{Height^2(m)} \tag{20}$$

Five male and five female volunteers took part in the system's development to collect data. Five sets of data were taken from each participant. Total fifty data samples were collected for analysis. Heart beat and respiratory rates were measured. The heart rate was compared with FDA approved Pulse Oximeter (Jumper -JPD 500D). Three techniques were used to measure the respiratory rate. Volunteers initially counted their respiration rate. To obtain additional respiratory rate data, a 24GHz mm Wave radar sensor and an ADS1292R ECG/respiration Module were used simultaneously. Following that, a comprehensive analysis was conducted on the gathered datasets. From table we calculated Mean Absolute Percentage Error

$$\text{MAPE}= \frac{1}{n}\sum_{l=1}^{n}\left|\frac{A_t-F_t}{A_t}\right| \tag{21}$$

Table5.2.1 Data table for 22 to 25 age

Subject	Gender	Age	BMI	Heart Rate (PO)	Heart Rate (Radar R60A)	MAPE(Individual)	MAPE(OVERALL)	RR (Calculated)	RR (Radar R60A)	MAPE(Indivual)	MAPE (Overall)
Person 1	M	25	33.15	80	76	3.43	7.89	17	16	5.43	10.12
				79	78			17	16		
				84	81			15	15		
				80	76			16	16		
				87	85			13	11		
Person 2	F	24	19.57	96	87	6.82		20	18	8.22	
				78	74			12	12		
				79	74			17	17		
				85	80			10	12		
				95	88			18	16		
Person 3	M	24	24.81	93	83	11.42		12	11	11.60	
				83	77			13	14		
				90	81			14	11		
				94	78			16	15		
				91	80			14	16		
Person 4	F	22	26.21	61	75	9.01		16	14	9.17	
				64	70			17	15		
				60	64			16	14		
				63	63			12	12		
				66	70			11	12		
Person 5	M	24	29.50	84	80	11.01		17	14	8.97	
				85	78			15	15		
				90	70			16	15		
				83	74			15	14		
				78	71			14	12		
Person 6	F	24	32.17	74	73	5.70		10	11	12.15	
				76	73			9	12		
				79	76			11	12		
				83	82			13	13		
				77	63			12	11		
Person 7	M	24	25.55	91	74	11.48		12	12	14.27	
				88	77			14	16		
				90	80			12	17		
				88	77			13	15		
				77	75			15	15		
Person 8	F	23	24.16	87	79	6.53		13	17	12.94	
				85	75			14	12		
				85	79			14	13		
				86	83			14	14		
				87	86			16	14		
Person 9	M	22	21.19	67	65	4.64		17	16	8.13	
				73	76			14	15		
				69	71			20	22		
				68	76			17	16		
				70	69			17	15		
Person 10	F	22	19.68	85	77	8.91		12	11	10.33	
				81	77			14	13		
				79	69			13	12		
				85	77			16	15		
				86	79			9	11		

Table 1 consists of 10 volunteers heart rate and respiratory rate taken from radar and their reference values by conventional elements. The MAPE percentage of each individual participant and for all the percipients are also presented on the table. The MAPE of heart rate is 6.67 % and the respiratory rate is 10.12% and 12.19% respectively. This error is comparatively higher. The respiration rate accuracy is 89.88% and 87.

81%. Respiratory rate accuracy is lower as the fractional values of respiration were not counted properly with fractional values.

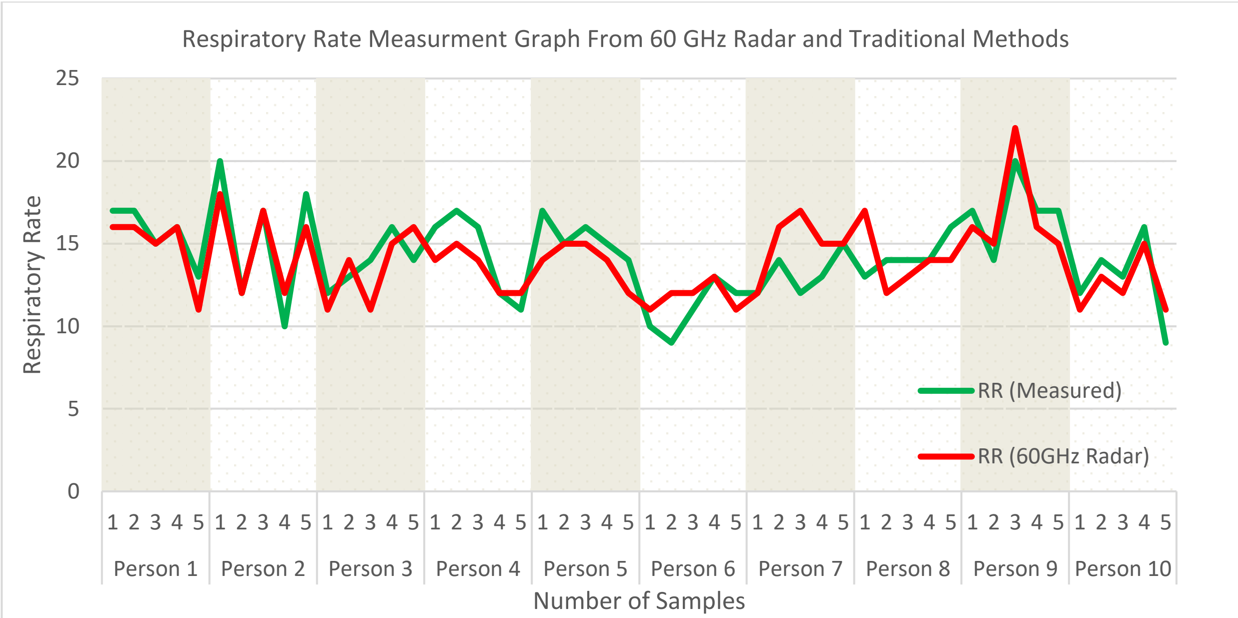


Figure 5.2.1 Respiratory rate data for measured and radar data

The respiratory rate graph analysis of reference material measurement data, 60 GHz radar data. As 60 GHz radar has the shorter wave signal and 24 GHz radar has the longer wave signal. The heart rate data graph analyzes the data between pulse oximeter and 60 GHz radar data. The radar data is nearly accurate with an accuracy of 93.34%. Heart rate values vary every time, but the radar can give data with very good accuracy. The average difference between reference values and radar data is 5.90 for heart rate and for respiratory rate it is 1.60.

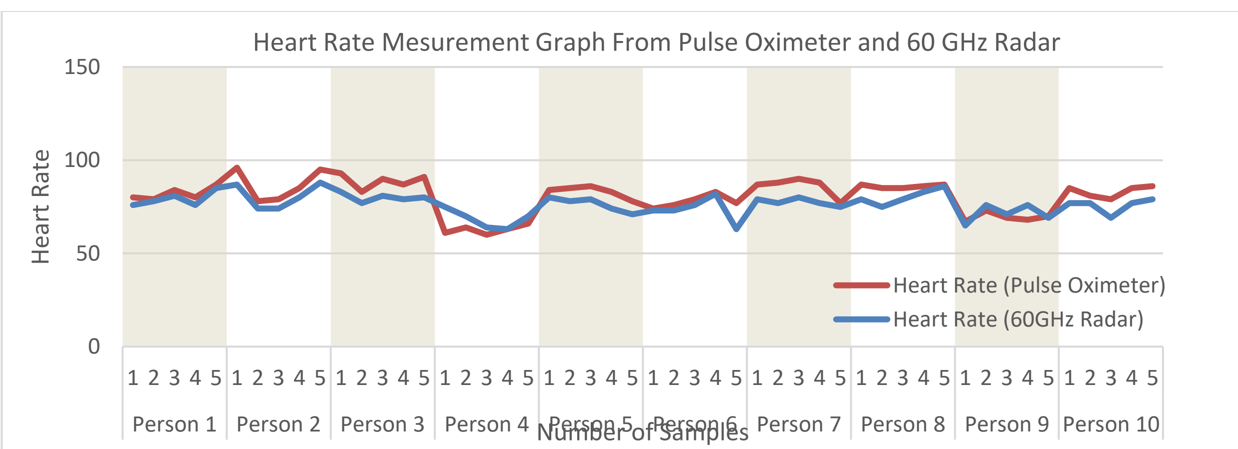


Figure 5.2.2: Heart rate data for measured and radar data

For aged people a new data table is created for comparing the data’s:

Table 5.2.2 Data table for 45 to 79 ages

Subject	SEX	Age	BMI	Heart Rate (PO)	Heart Rate (Radar R60A)	MAPE(Individual)	MAPE(OVERALL)	RR (Calculated)	RR (Radar R60A)	MAPE(Individual)	MAPE (Overall)
Person 1	F	50	27.68	88	90	1.61	4.29	20	20	7.44	6.86
				88	90			22	20		
				84	85			18	19		
				87	86			17	17		
				84	85			18	17		
Person 2	F	62	23.36	71	73	0.81		16	15	5.78	
				73	73			12	12		
				80	79			13	14		
				77	77			12	13		
				76	76			15	14		
Person 3	M	79	25.03	69	64	8.06		12	11	5.52	
				64	62			13	14		
				72	62			12	11		
				68	63			16	15		
				69	63			14	16		
Person 4	F	51	21.28	76	77	4.01		13	15	14.47	
				74	77			13	14		
				73	74			14	16		
				73	77			16	15		
				77	71			16	15		
Person 5	M	56	26.28	79	75	4.18		20	18	9.15	
				82	90			21	21		
				78	79			21	20		
				83	81			21	20		
				83	81			19	19		
Person 6	M	45	32.17	82	78	4.07		10	11	8.12	
				82	79			9	11		
				78	82			11	12		
				75	78			13	13		
				75	77			12	11		
Person 7	M	56	26.28	91	85	8.12		20	18	8.60	
				93	85			21	21		
				90	82			20	17		
				90	83			21	20		
				89	84			19	19		
Person 8	M	45	27.04	82	78	1.61		15	14	7.44	
				82	79			16	15		
				78	82			13	12		
				75	78			12	12		
				75	77			11	11		

Table 2 consists of 8-person data age range 40 to 79. From the data table The MAPE for individual measurements usually looks low, with most values below 10%. This shows that the Radar R60A measurements are roughly the same as the PO readings. The overall MAPE for each individual is similarly relatively low, ranging from 4.29% to 20%. Each person's heart rate results vary slightly depending on the measurement. This could be related to a number of variables, including exercise level, stress, or time of day. From 2 data table analysis it can be said that the device is more effective for aged people. As the heart rate is comparatively low for the aged people so comparing with young people so the device can detect the measurement easily. The breathing rate MAPE is also low comparing with young people. So the device is more compatible for elderly people.

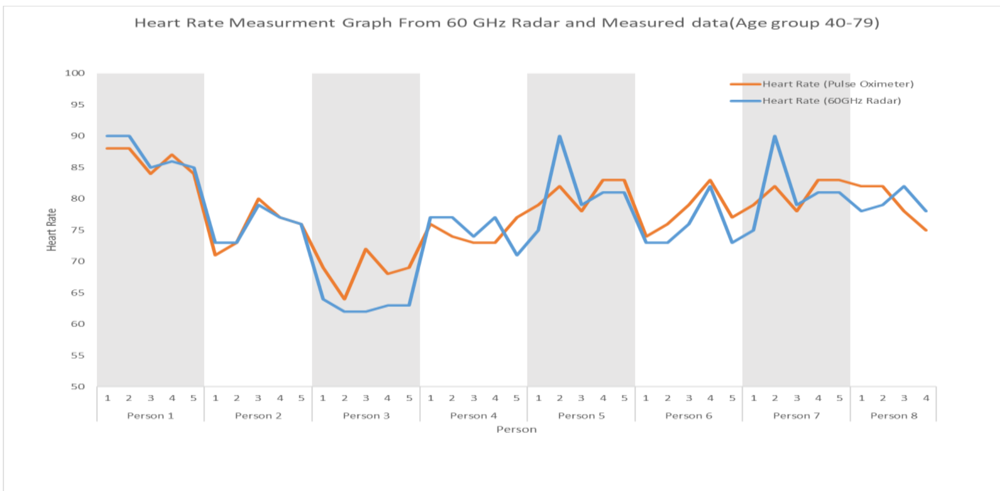


Figure 5.2.3: Heart rate data for measured and radar data for aged people

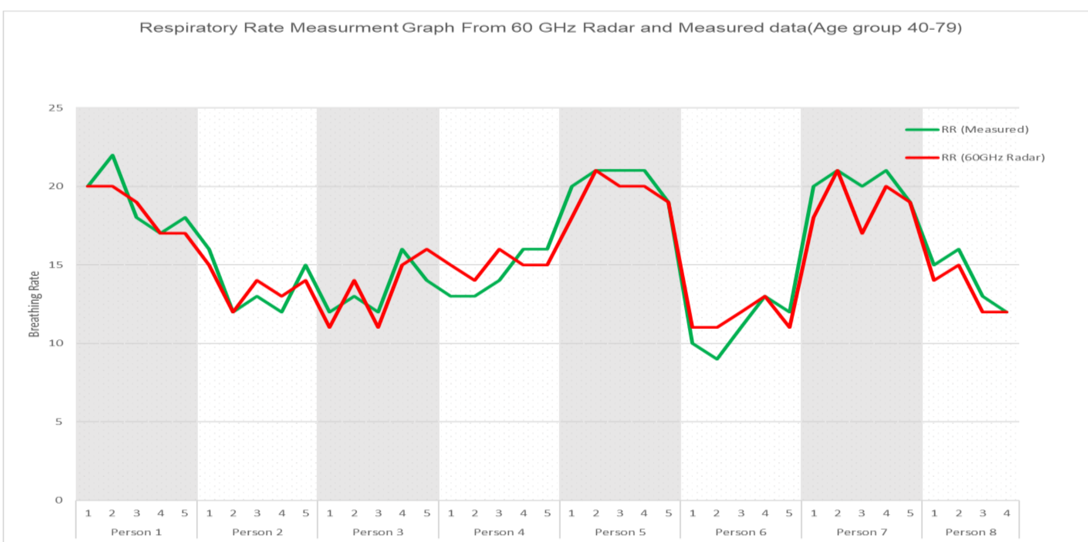


Figure 5.2.3: Respiratory rate data for measured and radar data for aged people

5.3. Comparison of Results

Table 5.3.1 Comparison with other system

Author	Radar Frequency	Accuracy Rate		Radar & Baseboard Price
		Respiratory rate	Heart Rate	
Project Device	60 GHz	89.88%	92.11%	5000
Fadel Adib et al.[3]	5.46 GHz to 7.25 GHz	99%	99%	Own developed
Alizdeh et al.[5]	77GHz AWR1443	94%	80%	73500
Wang et al.[7]	77 GHz AWR 1642	93%	93%	73000
G. Sacco, et al[24]	5.8 GHz ISM band	93.34%	96%	
Fuchuan Du et al.[25]	Infineon BGT60TR13C shield 60 GHz	91.25%		23000
Turppa et al[12]	24 GHz	91%	96%	
Xiang et al[13]	77 GHz AWR1642 from Texas Instruments	98.67%	98.04%	73000
Xue et al[26]	77 GHz Texas Instruments (TI) IWR1443	94.2%	95.1%	72000
Wang et al[27]	77 GHz AWR1642 from Texas Instruments	87%	85%	73000

The result comparison shows that implemented device is the cheapest solution for contactless monitoring of the vital sign. The system gives the solution about 22.61% cost effective then other device. According to comparative analysis the features that an expensive radar can give we can provide the same service at very low cost. The accuracy rate is also comparable with the other device. The accuracy of the system is also good according to the cost of the project.

5.4. **Summary**

This chapter presents a detailed analysis and comparison of the results obtained from our contactless vital sign monitoring device. Upon analyzing the data, we found that the device achieves an accuracy of approximately 92.11% for heart rate and 89.88% for respiratory rate. When comparing these results with those of other existing systems, our project not only demonstrates competitive accuracy but also stands out as the most cost-effective solution. This combination of high accuracy and affordability highlights the effectiveness and value of our device in the market for contactless vital sign monitoring.

Chapter 6

CONCLUSION

6.1. Summary of Findings

This result of contactless vital sign detection system proved that the device is working correctly. This device makes it easier to detecting the vital signs like heart rate, respiratory rate, temperature, respiratory rate that satisfies the needs of its intended users, save their time and money, and gives people more flexibility. We have used 60GHz FMCW radar which have a variety of functions and advantages. Because higher frequency means higher accuracy. The device can measure the Heart-Rate and Respiratory-Rate of one person at a time. This contactless vital sign detection system is user friendly and a user can carry it with them everywhere. And also by the own developed android app patient and the attended also can monitor the patient. The doctor and healthcare employee also can monitor data and the graphs to see patient HR & BR rate fluctuations. This 60GHz FMCW radar can detect within a limited distance otherwise it can't show accurate value to vital signs. To continually enhance the designs, it should be encouraged that the healthcare industry, technologists, designers, and elderly aged groups collaborate.

6.2. Novelty of the work

Contactless Vital Sign Monitoring: The device can contactless monitor the vital signs of the human body. The vital sign can be measured from distance. Also healthcare employees can see the vital signs.

Remote Monitoring: The CVSMS device, a wearable sensor that delivers vital sign data, communicates with a secure cloud-based IoMT server. This server records and visualizes data so that doctors may remotely monitor patients, enabling for faster diagnosis, better care decisions, and early intervention in potential health issues, which benefits both patients and healthcare providers.

Personalized Android App: a designed an Android app to complement your CVSMS device and IoMT server. This software provides a real-time view into a patient's health. It securely gets heart rate, respiration rate, and temperature data from the IoMT server and converts it into understandable graphs. This enables healthcare personnel to monitor these vital signs remotely and in real time, offering critical insights for timely treatment decisions and better patient outcomes.

FMCW mm Wave Technology: Unlike traditional methods that require physical contact like fingertip clips or chest straps, your CVSMS device utilizes FMCW radar technology. This innovative approach uses radio waves to detect minute chest and abdominal movements caused by breathing and heartbeats, enabling contactless monitoring for improved patient comfort and potentially reduced infection risk.

6.3. Cultural and Societal Factors and Impacts

6.3.1. Cultural Factors

1. **Privacy:** Some cultures might be more sensitive about personal health data and having their vital signs monitored without direct contact. There might be concerns about who has access to this data and how it's being used.
2. **Touch vs. Non-Touch:** In some cultures, there might be a preference for human contact during medical checkups. A contactless system might seem impersonal or less caring.

6.3.2. Societal Impacts:

1. **Accessibility:** This system could be a big benefit for people who have difficulty going to clinics or hospitals regularly. It could also be useful in places with limited medical staff.
2. **Hygiene:** This system could reduce the spread of germs in hospitals and clinics, especially beneficial during outbreaks.
3. **Cost-Effectiveness**: If widely used, this system could potentially lower healthcare costs allowing for remote monitoring and early detection of health issues.

Overall, a contactless vital sign monitoring system has the potential to improve healthcare access and efficiency, but it's important to consider cultural sensitivities and privacy concerns when developing and implementing such a system.

6.4. Limitations of the Work

A radar that uses radio waves to track breathing and heartbeat without touching. That's the idea behind 60G FMCW radar for vital sign monitoring. It's something new, but it has some limitations:

1. **Single person measurement:** The radar can only measure one-person data at a time. So if there is two or more persons it cannot be measured simultaneously. In situations where there are several possible targets the data can be not accurate.

2. **Quasi-Static Requirement:** The device measures vital signs only for quasi-static users (e.g., those who are sitting In front of the device) because full body movements can overwhelm the small variations caused by vital signs, hindering accurate capture of these minute movements.

3. **Signal Interruption:** Wi-Fi and mobile is common device in every house. But the signal extract from Wi-Fi router can interrupt with the radar signal which may differ the accuracy of the radar by adding noise.

6.5. Future Scopes

We can imagine a world where doctors can check heartbeat and breathing from a far, without even touching. That's the future of 60GHz FMCW radar for contactless vital sign monitoring. Here is what the future might hold:

1. **Improved Accuracy:** With better technology and algorithms, the radar will become more precise at picking up tiny movements from our bodies.

2. **Multi-Person Tracking:** The system will be able to track vital signs of multiple people at once, making it useful in crowded places like hospitals or nursing homes.

3. **Remote Patient Monitoring:** Doctors could keep tabs on patients remotely, allowing for quicker diagnoses and better care, especially in remote areas.

4. **Combined with Other Sensors:** The radar might be combined with other sensors to gather more health data, like temperature or blood pressure.

Overall, 60GHz FMCW radar has the potential to revolutionize healthcare by making monitoring easier, faster, and more convenient. It's like having a tiny health scanner that works without touching.

6.6. Social, Economic, Cultural and Environmental Aspects

6.6.1. Sustainability

We design the system to use minimal power. Strong, recycled materials mean less waste and a longer lifespan for the monitor. Using materials and expertise from Bangladesh reduces our environmental footprint.

1. **Economic Impact Cost-Effectiveness:** This system be affordable for hospitals and individuals in Bangladesh
2. **Job Creation:** This project creates new jobs in Bangladesh's Biomedical sector

6.6.2. Economic and Cultural Factors

1. **Privacy:** This system respect Bangladeshi privacy concerns about health data.
2. **Doctor-Patient Relationship:** This system maintains the trust and connection between doctors and patients in Bangladesh

6.6.3. Environmental Impact

1. **Sustainable Materials:** We use eco-friendly materials to build this system.

By following the code of ethics ,60 GHz is not harmful for human body. We can say, in this device there is no radiation. While making this device we followed the code of ethics.

6.7. Conclusion

In the end, building a great contactless vital sign monitor isn't just about the tech. We need to think about how it affects people's lives, is affordable, respects Bangladeshi culture, and protects the environment (sustainability). By keeping all these things in mind, we can create a monitor that's good for everyone and everything in Bangladesh.

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Appendix A

Datasheet of the ICs used

Appendix B

iThenticate Plagiarism Report

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Appendix Z

MATLAB SIMULATION CODE: For Proof of Concept Of FMCW Radar

```
% Radar parameters setting
maxR = 200; % Maximum range
rangeRes = 1; % Range resolution
maxV = 70; % Maximum speed
fc = 60e9; % Carrier frequency
c = 3e8; % Speed of light

r0 = 100; % Target distance
v0 = 70; % Target speed
% Calculate bandwidth, chirp time, and other parameters
B = c/(2*rangeRes); % Bandwidth
Tchirp = 5.5*2*maxR/c; % Chirp time
endle_time = 6.3e-6; % Endle time
slope = B/Tchirp; % Chirp slope
f_IFmax = (slope*2*maxR)/c; % Maximum IF frequency
f_IF = (slope*2*r0)/c; % Current IF frequency
Nd = 128; % Number of chirps
Nr = 1024; % Number of ADC sampling points
vres = (c/fc)/(2*Nd*(Tchirp+endle_time)); % Speed resolution
Fs = Nr/Tchirp; % Sampling rate

% Tx waveform parameters
t = linspace(0, Nd*Tchirp, Nr*Nd); % Sampling time for Tx and Rx signals
angle_freq = fc*t + (slope*t.^2)/2; % Angular frequency
freq = fc + slope*t; % Frequency
Tx = cos(2*pi*angle_freq); % Tx waveform

% Update target distance for Rx waveform
r0 = r0 + v0*t;
```

```
% Rx waveform parameters
td = 2*r0/c; % Time delay
freqRx = fc + slope*t; % Frequency for Rx
Rx = cos(2*pi*(fc*(t-td) + (slope*(t-td).*(t-td))/2)); % Rx waveform

% Intermediate Frequency (IF) signal parameters
IF_angle_freq = fc*t + (slope*t.^2)/2 - ((fc*(t-td) + (slope*(t-td).*(t-td))/2)); % Angle frequency for IF
freqIF = slope*td; % Frequency for IF
IFx = cos(-(2*pi*(fc*(t-td) + (slope*(t-td).*(t-td))/2)) + (2*pi*angle_freq)); % IF waveform

% Range FFT
doppler = 10*log10(abs(fft(IFx(1:1024)))); % Doppler signal
frequency = fftshift((-Nr/2:Nr/2-1)*(Fs/Nr)); % Frequency
range = frequency*c/(2*slope); % Range

% Plot all graphs in separate figure windows
figure;
plot(t(1:1024), Tx(1:1024))
xlabel('Time')
ylabel('Amplitude')
title('Tx Signal')

figure;
plot(t(1:1024), Rx(1:1024))
xlabel('Time')
ylabel('Amplitude')
title('Rx Signal')

figure;
plot(t(1:1024), freq(1:1024))
xlabel('Time')
```

```
ylabel('Frequency')
title('Tx F-T')

figure;
plot(t(1:1024)+td(1:1024), freqRx(1:1024))
xlabel('Time')
ylabel('Frequency')
title('Chirp F-T')

figure;
plot(t(1:1024), IFx(1:1024))
xlabel('Time')
ylabel('Amplitude')
title('IFx Signal')

figure;
plot(range(1:512), doppler(Nr/2:Nr/2+511))
xlabel('Frequency->Distance')
ylabel('Amplitude')
title('IF Signal FFT')

% 2D plot (Spectrogram)
figure;
spectrogram(IFx,1024,[],[],Fs,'yaxis');
xlabel('Time')
ylabel('Frequency')
title('Spectrogram')
```

CVSMS Device Program

```
#include "Arduino.h"
#include <Wire.h>
#include <60ghzbreathheart.h>
#include <Adafruit_AMG88xx.h>
#include <LiquidCrystal_I2C.h>
#include <ESP8266WiFi.h>

BreathHeart_60GHz radar = BreathHeart_60GHz(&Serial);
Adafruit_AMG88xx amg;
LiquidCrystal_I2C lcd(0x3F, 20, 4);

//const char *ssid = "CVSMS"; // replace with your WiFi SSID
//const char *pass = "cvsms2023";
const char *ssid = "House of Dragon";
const char *pass = "janinaami";
const char *server = "api.thingspeak.com";
String apiKey = "QBFW9HLP8BKKVLFH";

WiFiClient client;

void setup() {
  Serial.begin(115200);

  // Connect to WiFi
  WiFi.begin(ssid, pass);
  Serial.print("Connecting to WiFi");
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");

  // Initialize LCD
  lcd.init();
  lcd.backlight();
  lcd.print("Ready");

  // Initialize AMG88xx sensor
  if (!amg.begin()) {
    Serial.println("Could not find a valid AMG88xx sensor, check wiring!");
    while (1);
  }
  Serial.println("-- Thermistor Test --");
```

```
  Serial.println("Ready");
  delay(500);
  lcd.clear();
}

void loop() {
  // Read temperature from AMG88xx sensor
  float thermistorTemp = amg.readThermistor();
  Serial.print("Thermistor Temperature = ");
  Serial.print(thermistorTemp);
  Serial.println(" *C");

  // Display temperature on LCD
  lcd.setCursor(0, 0);
  lcd.print("TEMP: ");
  lcd.print(thermistorTemp);
  lcd.print((char)223);
  lcd.print("C");

  // Perform radar sensor measurement
  radar.Breath_Heart();

  // Display heart rate or breath rate based on sensor report
  if (radar.sensor_report != 0x00) {
    switch (radar.sensor_report) {
      case HEARTRATEVAL:
        Serial.print("Heart Rate: ");
        Serial.println(radar.heart_rate);
        lcd.setCursor(0, 1);
        lcd.print("HR: ");
        lcd.print(radar.heart_rate);
        break;
      case BREATHVAL:
        Serial.print("Breath Rate: ");
        Serial.println(radar.breath_rate);
        lcd.setCursor(0, 2);
        lcd.print("BR: ");
        lcd.print(radar.breath_rate);
        break;
    }
  }

  // Check WiFi connection and send data to ThingSpeak
  if (WiFi.status() == WL_CONNECTED && client.connect(server, 80)) {
    String postStr = apiKey;
    postStr += "&field1=";
```

```
    postStr += String(radar.heart_rate);
    postStr += "&field2=";
    postStr += String(radar.breath_rate);
    postStr += "&field3=";
    postStr += String(thermistorTemp);
    postStr += "\r\n\r\n";

    client.print("POST /update HTTP/1.1\n");
    client.print("Host: api.thingspeak.com\n");
    client.print("Connection: close\n");
    client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
    client.print("Content-Type: application/x-www-form-urlencoded\n");
    client.print("Content-Length: ");
    client.print(String(postStr.length()));
    client.print("\n\n");
    client.print(postStr);

    Serial.println("Data sent to ThingSpeak.");
    client.stop(); // Close connection after sending data
  } else {
    Serial.println("Failed to connect to ThingSpeak or WiFi not connected.");
  }

  // Wait before next iteration
  delay(200);
}
```