SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU-572103

(An Autonomous Institute under Visvesvaraya Technological University, Belagavi)

Project Report on

"Measurement and Monitoring of Vital Signs using mmWave sensors"

submitted in partial fulfillment of the requirement for the completion of VI semester of

BACHELOR OF ENGINEERING

in

ELECTRONICS & COMMUNICATION ENGINEERING

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

CERTIFICATE

Certified that the mini project work entitled "MEASUREMENT AND MONITORING OF VITAL SIGNS USING mmWAVE SENSOR" is a bonafide work carried out by D K CHANDRAKANTH (1SI20EC020), PREETHAM G M (1SI20EC121), NITHESH KUMAR V (1SI20EC122) and MITHUN J B (1SI20EC124) in partial fulfillment for the completion of VI Semester of Bachelor of Engineering in Electronics & Communication Engineering from Siddaganga Institute of Technology, an autonomous institute under Visvesvaraya Technological University, Belagavi during the academic year 2022-23. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the department library. The Mini project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering degree.

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Course Outcomes

CO 1 : Identify , formulate the problem and define the objectives

CO 2 : Review the literature and provide efficient design solution with appropriate consideration for societal, health and safety issues

CO 3 : Select the engineering tools/components and develop an experimental setup to validate the design

CO 4 : Test, analyse and interpret the results of the experiments in compliance with the defined objectives

CO 5 : Document as per the standard, present effectively the work following professional ethics and interact with target group

CO 6 : Contribute to the team, lead the diverse team, demonstrating engineering and management principles

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO-1	3												3	
CO-2		2				1							2	1
CO-3			2		2							2	2	2
CO-4				2										2
CO-5								2		2		2		2
CO-6									2		1			1
Average	3	2	2	2	2	1		2	2	2	1	2	2	2

Attainment level: - 1: Slight (low) 2: Moderate (medium) 3: Substantial (high)

POs: PO1: Engineering Knowledge, PO2: Problem analysis, PO3: Design/Development of solutions, PO4: Conduct investigations of complex problems, PO5: Modern tool usage, PO6: Engineer and society, PO7: Environment and sustainability, PO8: Ethics, PO9: Individual and team work, PO10: Communication, PO11: Project management and finance, PO12: Lifelong learning

Abstract

The project focuses on the non-invasive vital signs measurement system using a 60 GHz pulsed coherent radar sensor, specifically the XM112 radar. The aim is to enable efficient and contactless monitoring of vital signs, including heart rate and breath rate, without the need for physical contact or wearable devices. The proposed system utilizes the radar sensor to emit a waveform towards the patient and analyzes the reflected signal which consist of chest displacement to calculate the vital signs, by various signal processing techniques, such as downsampling, low-pass filtering, phase unwrapping, power spectrum analysis, and bandpass filtering, are employed to extract accurate vital sign information from the recorded signals.

The developed system offers several advantages, including improved healthcare efficiency and benefits for individuals with skin problems. By reducing the need for skin contact, it offers a more efficient and comfortable vital signs monitoring experience. Additionally, the system provides continuous and real-time monitoring, enabling early detection of potential health issues. To facilitate data analysis and further research, the estimated vital signs are transmitted to the cloud for archival purposes. This allows for comprehensive data collection and analysis, supporting the development of advanced algorithms and insights into vital sign patterns.

Overall, the utilization of a 60 GHz pulsed coherent radar sensor for contactless vital signs measurement holds great promise in revolutionizing healthcare monitoring. The XM112 radar, along with the proposed signal processing techniques, offers a viable solution for accurate and continuous vital signs tracking, improving patient care and enabling personalized healthcare interventions.

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Chapter 1

Introduction

1.1 Motivation

Advancements in healthcare technology have introduced mmWave sensors as a game-changer in vital signs measurements. The motivation to utilize these sensors lies in their non-invasive nature, allowing for comfortable and contactless monitoring. With real-time and continuous data collection, mmWave sensors offer heightened accuracy and precision, ensuring reliable measurements even in dynamic environments. Their versatility enables integration into various healthcare settings, including remote monitoring systems, enhancing accessibility to care. Furthermore, mmWave sensors have the potential to detect early warning signs, facilitating timely interventions and preventive measures. Embracing mmWave sensor technology holds great promise for revolutionizing vital signs monitoring, ultimately leading to improved patient outcomes and proactive healthcare practices.

1.2 Objective of the project

The objectives of utilizing mmWave sensors for vital signs measurements are as follows:

1.Non-Invasive Monitoring: To develop a non-contact approach for vital signs measurements, eliminating the need for physical contact or attachment of devices to the body, thereby ensuring patient comfort and reducing the risk of skin irritation or infection.

2. Accuracy and Reliability: To achieve precise and reliable measurements of vital signs, leveraging the capabilities of mmWave sensors to capture data with minimal errors and variability.

3. Real-time Monitoring: To enable continuous and real-time monitoring of vital signs using mmWave sensors, allowing for prompt detection of any deviations or abnormalities and facilitating timely intervention.

4. Versatile Integration: To explore the integration of mmWave sensors into various healthcare settings, including hospitals, clinics, and remote monitoring systems, to enhance accessibility to vital signs monitoring and improve patient care.

5. Early Detection and Prevention: To utilize mmWave sensors' capabilities for early detection of potential health issues by capturing subtle changes in vital signs, enabling timely interventions and preventive measures to improve patient outcomes..

1.3 Organisation of the report

The organization of the report on vital signs measurements using mmWave sensors is structured as follows:

1. Introduction: Provides a brief overview of the importance of vital signs monitoring and introduces the concept of mmWave sensors as a non-invasive solution.
2. Background: Discusses the existing methods of vital signs measurements and their limitations, highlighting the need for an innovative approach using mmWave sensors.
3. Methodology: Describes the technical aspects of mmWave sensors, including their operating principles, data collection process, and signal processing techniques used for vital signs extraction.
4. Results and Analysis: Presents the findings obtained from the utilization of mmWave sensors for vital signs measurements, including accuracy, precision, and comparison with traditional methods.
5. Discussion: Analyzes the implications of using mmWave sensors for vital signs monitoring, considering their advantages, limitations, and potential challenges in real-world healthcare settings.
6. Applications and Future Directions: Explores the potential applications of mmWave sensors in healthcare, such as remote monitoring and early detection, while discussing future research directions and advancements in the field.
7. Conclusion: Summarizes the key findings, highlights the significance of mmWave sensors for vital signs measurements, and emphasizes their potential to revolutionize healthcare practices.
8. References: Provides a comprehensive list of cited sources used in the report to support the claims and findings presented.

Chapter 2

Literature Survey

A systematic and thorough search of all types of published literature as well as other sources including dissertation, theses in order to identify as many items as possible that are relevant to this project.

2.1 Papers refered

• Gromert. L and Alnasser. M, Heart Rate Measurement using a 60 GHz Pulsed Coherent Radar Sensor, 2022. The paper focuses on contactless heart rate monitoring using a 60 GHz pulsed coherent radar sensor, specifically the Acconeer A111 radar module. The radar captures IQ radar sweeps from the subject's chest, enabling the measurement of chest surface motion caused by lung inflation and deflation, as well as the motion generated by the heart. The breathing motion ranges from 4 to 12 mm with a frequency range of 0.1 to 0.7 Hz, while the heart-induced motion ranges from 0.2 to 0.5 mm with a frequency range of 0.75 to 3 Hz. To estimate heart rate, the paper incorporates ECG measurements as a reference, leveraging the accuracy and reliability of ECG data. By combining radar-based vital sign monitoring with ECG, the algorithm enhances the accuracy of heart rate estimation and provides a comprehensive approach to monitoring cardiovascular activity and evaluating cardiac health [1].

• Lazaro. A, Lazaro. M, Villarino. R and Girbau. D, Seat-occupancy detection system and breathing rate monitoring based on a low-cost mm-Wave radar at 60 GHz. IEEE Access,9, pp.115403-115414, 2021. This project presents a seat-occupancy detection system based on a Pulsed Coherent Radar (PCR) operating at the unlicensed 60 GHz ISM band. The radar measures distances with a sub-millimeter resolution, allowing it to detect seat occupancy by capturing small body movements caused by breathing. The system not only detects seat occupancy but also estimates breathing rates by filtering the radar's amplitude measurements to remove noise and analyzing the resulting peaks. The radar-based approach offers the advantage of non-contact detection without the need for additional equipment or physical contact with the passengers. However, a drawback lies in the difficulty of accurately monitoring vital signs in a non-stationary environment, as the radar signal also contains information about car-induced vibrations and voluntary passenger movements. This poses a challenge in distinguishing between vital signs and unwanted movements [2].

• Nguyen. T. P. V, The investigation of non-contact vital signs detection microwave theoretical models and smart sensing systems: a thesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Mechanical and Electrical Engineering, SFAT at Massey University, Palmerston North, New Zealand (Doctoral dissertation, Massey University), 2020. This study focuses on microwave radar sensing systems for detecting human life and monitoring vital signs in various applications. Conventional detection devices have limitations, such as the need for an expert operation or a quiet environment. Microwave sensors offer non-invasive and accurate vital signs information, making them valuable for locating people and predicting health conditions. The research explores theoretical models, antenna systems, and the integration of artificial intelligence to enhance the accuracy and capabilities of the radar sensing system. The experimental study validates the performance of the antenna system across different frequencies, while mathematical models help evaluate system accuracy in advance. Inspired by the Micro Bat animal, a nature-inspired radar sensing system is proposed, improving detection probability and reducing null points. The combination of radar sensing and artificial intelligence enables classification functions with high accuracy. These microwave radar sensing systems show promise in search and rescue, healthcare and smart home applications, allowing for contactless detection and health monitoring [3].

• Thorstrom. M and Anderson. G, Presence Detectors and Remote Heartbeat Sensing using Radar Technology, 2020. This paper discusses the application of pulsed radar technology in measuring heart rate variability (HRV). Pulsed radar works by transmitting and receiving pulses to determine distance and velocity. In the context of HRV, the time intervals between successive heartbeats are measured using pulsed radar. This allows for the analysis of variations in heart rate over time. The paper highlights the advantages of pulsed radar, such as its accuracy in distance measurement and its potential for low-power and mobile applications. By utilizing pulsed radar for HRV analysis, researchers can gain valuable information about an individual's cardiac health and autonomic function [4].

2.2 Summary

• Vital signs such as heart rate rate and breath rate of patients are currently monitored using contact-based, short-range techniques but mmWave sensor can measure by non contact to patients.

• The Radar Technology which can measure the chest displacement at the millimeter level is gaining its attraction due to its advantages such as low cost, contactless, remote and precise monitoring of vital signs.

• Contactless Monitoring enables early identification of deteriorating situations in asthmatic patients.

• mmWave radar sensor has the ability to detect short movements at a fraction of millimetre level, the reflected wave from the chest are phase shifted due to motion of chest during breathing and heartbeat.

• The Acconeer XM112 radar provides improved accuracy, power efficiency, coherence compared to FMCW radars making it a suitable choice for a wide range of applications that require precise distance measurements and reliable radar sensing capabilities. The next chapter provides a overview that outlines the design and implementation of an asthma detection system utilizing mmWave sensors and machine learning models.

Chapter 3

System Overview

3.1 Block Diagram

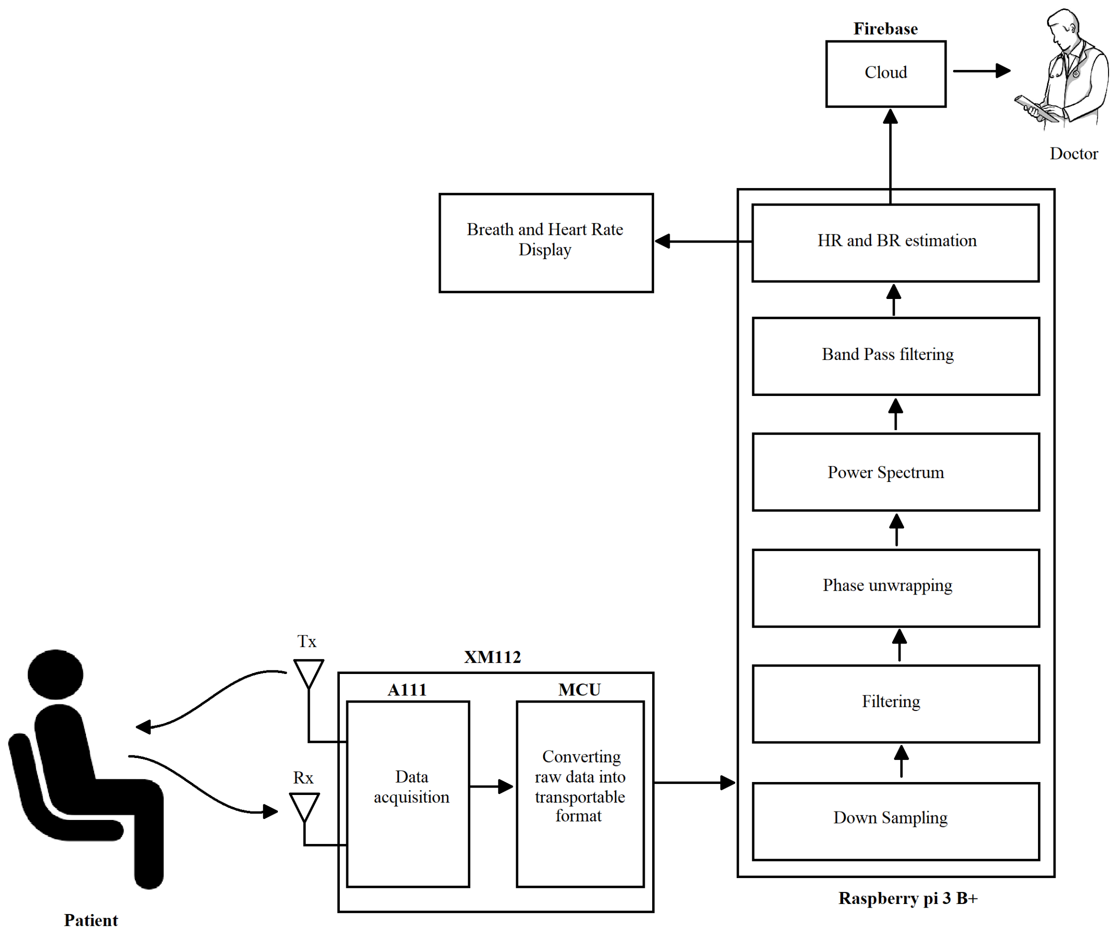

Figure 3.1: Block diagram

The block diagram illustrates a non-invasive and non-contact method for measuring vital signs using a mm-wave coherent radar sensor. The process begins with a waveform being transmitted from the sensor towards the person sitting on the left-hand side. The transmitted signal interacts with the person, and the corresponding waveform is received by the sensor's receiver.

Both the received and transmitted signals undergo further processing through the mmwave radar system's built-in components. These signals are fed into a low-pass filter and other components to remove unwanted noise and interference. The objective is to extract information related to chest displacement, which is indicative of heart rate and breath rate.

The transmitted and received signals are multiplied together and then subjected to down-sampling. The resulting signal is passed through a low-pass filter to obtain an intermediate-frequency signal. This signal is then processed through filtering, phase unwrapping, power spectrum analysis, and bandpass filtering stages.

By analyzing the processed signals, the heart rate and breath rate can be estimated. These measurements are then sent to the cloud via a Raspberry Pi, allowing for remote storage and analysis of the vital sign data.

Overall, this block diagram outlines the steps involved in using a mm-wave coherent radar sensor to non-invasively measure heart rate and breath rate by analyzing chest displacement. The obtained measurements are transmitted to the cloud for further analysis and monitoring.

3.2 Flowchart

Figure 3.2 gives the flow diagram of the procedure involved in the vital signs detection system,

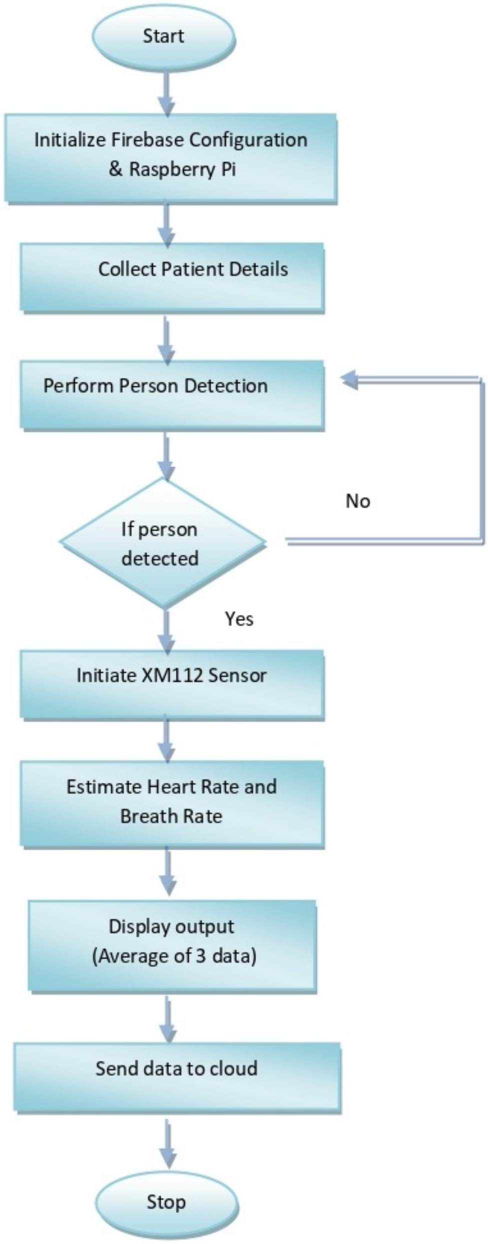

Figure 3.2: Flowchart

Chapter 4

Methodology

This chapter illustrates, the algorithm used in our project

4.1 Algorithm for breath rate

4.1.1 Sleep breath

An example of a “sleep breathing” detection algorithm assuming that the person is still (as when in sleep) where only the motion from breathing is to be detected.

The algorithm can be divided into three parts;
(i) extracting the motion of the breathing person,
(ii) performing a Fourier transform of the position over time to search for oscillations, and finally
(iii) detecting the respiration rate in the spectra.

Abbreviation	Description
f_s	Sweep frequency [Hz]
s	Sweep index
d	Range index
$x[s,d]$	Data from the IQ Service
τ_{iq}	Fast filter length [s]
f_{low}	Lowest frequency of interest [Hz], typically 0.1
f_{high}	Highest frequency of interest [Hz], typically 1
D	Range downsampling factor
M	Sweep (or time) downsampling factor
$\phi[s]$	The phase of sweep s [rad]
T	Fourier transform time window [s]
λ_p	Peak to noise detection threshold
$\lambda_{1/2}$	Peak to signal at half frequency threshold

4.1.2 Obtaining motion signal

The radar is configured to collect IQ radar sweeps with a range covering the chest of a breathing person. For example, the radar sensor could be mounted in a device on the night stand next to the bed where a person is sleeping. The radar should be aimed at the chest of the person and scanning the range of approx. 30 cm to 90 cm. The data samples from the IQ API are represented by

$$x[s, d]$$

where,d , is the range index, s , is the sweep index. Typically, the spacing between samples in range is approx. 0.5 mm and the sweep rate,f_s , is in the 100 Hz range, depending on configuration.

Since neighbouring samples in range are strongly correlated, the IQ samples can be downsampled in range to $x_D[s, d]$, where

$$x_D[s, d] = x[s, dD + D/2]$$

and D is a range downsampling factor, typically close to 100. The purpose of the downsampling is simply to reduce the amount of data for further processing.

The next step is a simple noise reducing low-pass filter in the time (or sweep) dimension,

$$\bar{x}[s, d] = \alpha_{iq}\bar{x}[s-1, d] + (1 - \alpha_{iq})\, x_D[s, d]$$

where $\alpha_{iq} = exp[-2/T_{iq}f_s]$

The last step in this part of the algorithm is the unwrapping of the phase of the IQ samples. Here, it is performed via

$$\phi[s] = \alpha_\phi \phi[s-1] + \angle\left\{\sum_{d=0}^{N_d-1} \bar{x}_D[s, d]\bar{x}^*_D[s-1, d]\right\}$$

where $\alpha_{phi} = exp[-2f_{low}/f_s]$ is a high-pass filter factor to remove the any build-up of phase over time,$angleZ$ denotes the complex phase of , Z and $Z*$is the complex conjugate of Z . N_d is the number of samples in each sweep after range downsampling. With the approach described above, a single phase, representing the whole sweep, is obtained for each sweep.

4.1.3 Searching for oscillations

The motion of the chest of the sleeping person can be seen in as oscillations in the phase signal, $phi[n]$, from the previous section. A variety of approaches can be employed to find the respiration rate of the person, such as searching for zero-crossings or inspecting peaks in the autocorrelation function. Here, we instead search for peaks in the Fourier transform.

Since human breathing most often occur in the 0.1-1 Hz frequency range, the typical radar sweep frequency,f_s, of approx 100 Hz is unnecessary high for spectral estimation in the frequency range of interest. The sweep frequency should however be lowered with care, since it also limits the maximum radial speed allowed for correct phase unwrapping.

Before downsampling in time the phase needs to be low-pass filtered. We apply amsecond order Butterworth low-pass filter with cut-off-frequency of f_{high} . The low-pass filtered phase $\bar{\phi[S]}$ can then be downsampled in time according to

$$\bar{\phi}_M[S] = \bar{\phi}[M - s]$$

where is chosen so that the sampling rate of the downsampled phase,$\phi - M[S]$, is approximately 10 Hz. This corresponds to a Nyquist frequency of 5 Hz, well above the highest frequency of interest,f_{high} , of approx 1 Hz.

A Discrete Fourier Transform (DFT) is performed on the last seconds of low-pass filtered downsampled phase. The magnitude square of each frequency component $P[i]$ corresponding to the spectral power in the frequency bin $f[i]$.

The spacing of frequency bins are set by the length in time of the data set, so to increase the frequency resolution the frequency of the peak is interpolated assuming a Gaussian peak shape,

$$f_p = f\left[i_p\right] + \frac{\Delta f}{2} \frac{\log P\left[i_p + 1\right] - \log P\left[i_p - 1\right]}{2 \log P\left[i_p\right] - \log P\left[i_p + 1\right] - \log P\left[i_p - 1\right]}$$

where i_p is the index of the spectral bin with the highest power, $i_p = \operatorname{argmax}_i P[i]$, and Δf is the frequency spacings of the bins.

4.1.4 Breathing detection

The final step in the algorithm is to see if the peak in the spectra is high compared to the spectral noise. The noise level is estimated as the average power level in the half of the frequency bins with the lowest power. If the peak is higher than the threshold, λ_p, times the noise level, breathing is detected.

Since chest motion during breathing is highly non-sinusodial, many harmonics of the breathing frequency are often seen in the spectra. To avoid detecting the first harmonic, instead of the fundamental, a final check is carried out to inspect the spectral power at half the frequency of the highest peak in the spectra. This spectral power is compared to a second threshold, $\lambda_{1/2}$, so that half the frequency is chosen if,

$$P\left[i_p/2\right]/P\left[i_p\right] > \lambda_{1/2}$$

and $i_p/2$ corresponds to a valid frequency. These two thresholds has been set after analyzing detector performance on data sets collected on a few adults and children. However, depending on the mechanical integration of the sensor and the trade-off between missed detections and false detection, these thresholds might need tuning to achieve the optimal performance for each design.

4.2 Algorithm for Heart rate

The algorithm used for estimating heart rate is identical to that for estimating breath rate; the only differences are the number of DFT points, the duration for frequency estimation, and the higher and lower cutoff frequencies, which are provided in Table 3.1.

4.3 Standard Values

This section illustrates, the default values used for the measurement of vital Signs,

Table 4.1: Standard values

Standards	**N dft**	**t(fe)**	**D**	**f(low)**	**f(high)**	**lambda(P)**	**lambda(0.5)**
Heart rate	5	0.2	62	0.6	2	40	1
Breath rate	15	0.2	124	0.2	0.5	40	1

The algorithm is set up with these standard configurations for measuring vital indicators like heart rate and breathing rate.

Chapter 5

System Hardware

The technical section is the most work-specific, and hence is the least described here.

Terminology: Define each term/symbol before you use it, or right after its first use. Stick to a common terminology throughout the report.

5.1 XB112 Breakout Board

The XB112 is a breakout-board designed for the XM112 Radar Module. It makes the interfaces from the XM112 radar module accessible for evaluation and debug. It also enables flashing of the XM112 via USB-UART or SWD. The XM112 is connected to the XB112 via a board-to-board connector on the top side of the PCB. Below you will find pictures of both front and back side of the breakout board.

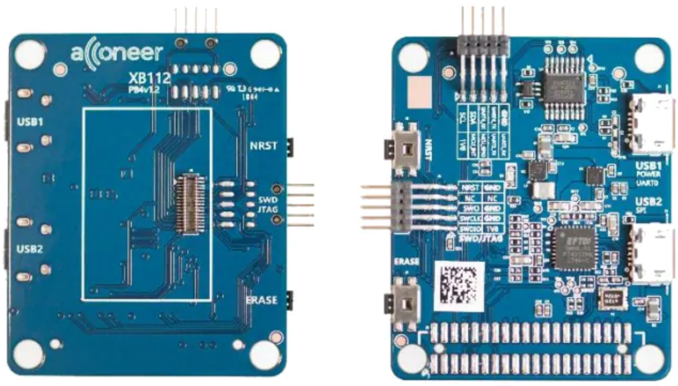

Figure 5.1: XB112 Breakout board

5.2 XM112 Module

The pulsed coherent radar module XM112 from Acconeer is a 24 mm x 16 mm module that integrates the A111 pulsed coherent radar and a 32- bit ARM Cortex-M7 ATSAME70Q20A microprocessor on the same printed circuit board (PCB). The ATSAME70020A is equipped with 384 Kbytes SRAM and 1 MB Flash and has a maximum core processor frequency of 300 MHz.

The XM112 is a reference module that can be integrated into a product via the slim 30-pin board-to-board connector to decrease users cost and time for bringing a product to market. The XM112 can also be used as an evaluation kit together with the breakout board XB112.

Figure 5.2: XM112 Module

5.3 A111 Radar

The A111 is a radar system based on Pulsed coherent radar (PCR) technology and is setting a new benchmark for power consumption and distance accuracy – fully integrated in a small package of 29 mm2.

The A111 60 GHz radar system is optimized for high precision and ultra-low power, delivered as a one package solution with integrated Baseband, RF front-end and Antenna in Package (AiP). This will enable easy integration into any portable battery driven device.

The A111 60 GHz radar remains uncompromised by any natural source of interference, such as noise, dust, color and direct or indirect light.

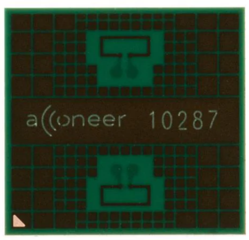

Figure 5.3: A111 Radar

5.4 Raspberry pi

The Raspberry Pi 3 is a credit card-sized single-board computer that offers impressive capabilities in a compact form factor. Powered by a 1.2GHz quad-core ARM Cortex-A53 processor and 1GB of RAM, it provides ample processing power for various projects. The device features built-in Wi-Fi and Bluetooth connectivity, making it convenient for IoT applications. It also has a full-size HDMI port, USB ports, an Ethernet port, and a microSD card slot for expandable storage. With its GPIO pins, the Raspberry Pi 3 can interface with sensors, motors, and other electronics. This versatile and affordable computer has become popular for hobbyists, educators, and tinkerers alike.

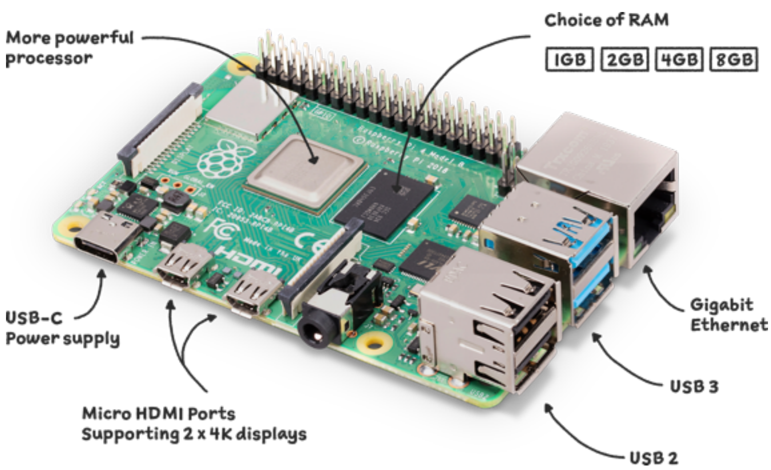

Figure 5.4: Raspberry Pi 3

5.5 LCD display

A 16x2 LCD (Liquid Crystal Display) is a commonly used alphanumeric display module consisting of two lines, with each line capable of displaying up to 16 characters. It utilizes liquid crystals to control the light transmission, making it easy to read characters on a backlit screen. These displays are commonly found in various electronic devices, such as digital watches, calculators, and embedded systems. They offer a simple interface for displaying text-based information and can be controlled using microcontrollers or dedicated display drivers. With their compact size and versatility, 16x2 LCD displays are widely used in many applications requiring basic text output.

Figure 5.5: 16x2 LCD Display

5.6 Ultrasonic Sennsor

An ultrasonic sensor is a device that uses high-frequency sound waves to measure distance and detect objects in its surrounding environment. It emits ultrasonic waves and measures the time it takes for the waves to bounce back after hitting an object. This information is then used to calculate the distance to the object. Ultrasonic sensors are commonly used in various applications such as robotics, parking systems, security systems, and industrial automation. They provide accurate and reliable distance measurements, making them essential in many fields. With their non-contact operation and wide range of applications, ultrasonic sensors have become an indispensable tool in modern technology.

Figure 5.6: Ultrasonic Sensor

Chapter 6

System Software

6.1 BOSSA 1.9.1

BOSSA 1.9.1 is a versatile software tool widely used in the field of embedded systems for programming and configuring microcontrollers. With its latest version, BOSSA offers enhanced features and improved performance for seamless device management. It supports a wide range of microcontroller architectures and provides a user-friendly interface for easy interaction. BOSSA 1.9.1 offers robust firmware programming capabilities, allowing users to flash firmware onto microcontrollers efficiently. It also provides extensive support for bootloader and firmware updates, making it an indispensable tool for developers and engineers working on embedded systems. Overall, BOSSA 1.9.1 empowers professionals with a reliable and efficient solution for microcontroller programming and configuration.

6.2 Acconeer Exploration tool

Acconeer Exploration Tool consists of a set of tools and examples to help us get started with our Evaluation Kits (EVK). With a graphical interface for your PC and python-based development, it allows you to quickly start exploring the world of Acconeer's radar sensor technology.

6.3 Python IDE

Python 3.11.4 is a powerful programming language version, offering numerous enhancements and improvements. It provides an extensive standard library, supports multiple platforms, and offers enhanced performance. With its rich ecosystem, Python 3.11.4 is an excellent choice for developing a wide range of projects, from web applications to data analysis and machine learning.

6.4 VNC Server

VNC (Virtual Network Computing) is a remote desktop sharing system that allows you to view and control a computer desktop from another device over a network connection. VNC operates on a client-server model, where the VNC server runs on the computer whose desktop you want to access, and the VNC client runs on the device from which you want to control that desktop.

6.5 Firebase cloud

Firebase is a mobile and web development platform provided by Google. It offers a suite of cloud-based services and tools to help developers build, improve, and scale their applications more easily and efficiently. Firebase provides various features and functionalities that simplify common development tasks, such as backend infrastructure management, real-time data synchronization, authentication, hosting, and more.

Chapter 7

Results

Figure 7.1: System overview of Vital signs measurement system

The system hardware overview: It has acconeer XM112 for data acquisition (Breathe rate and Heart rate) and Ultrasonic sensor (presence detection). Raspberry Pi is used as micro-controller and the output is given to the LCD Display.

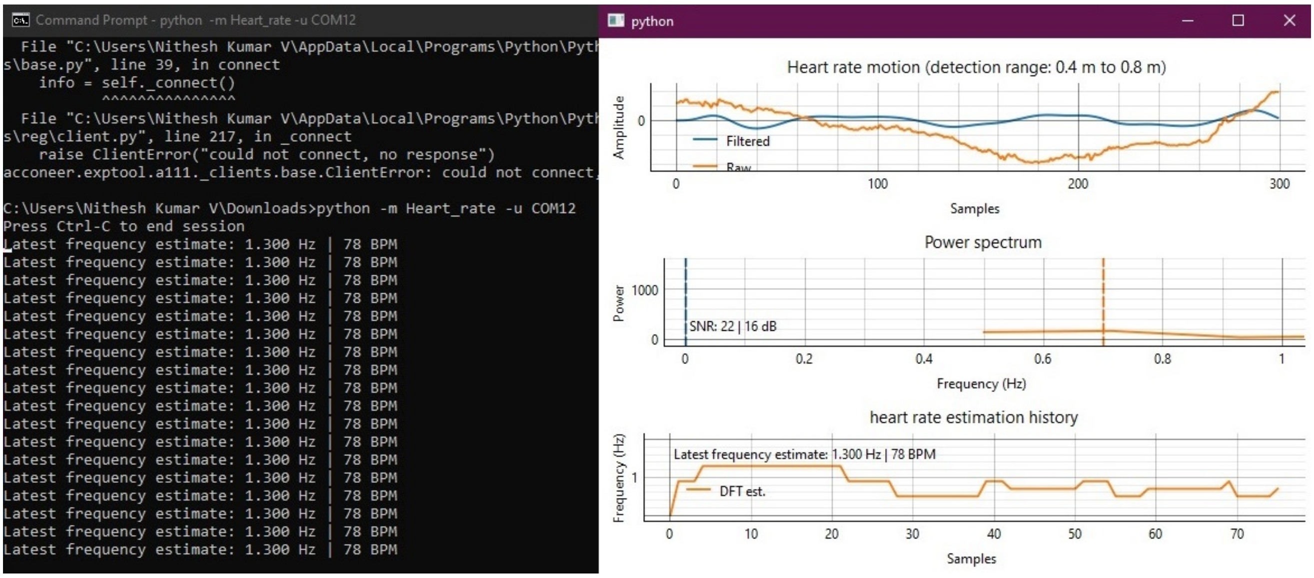

Figure 7.2: Heart rate values from the Acconeer XM112 sensor

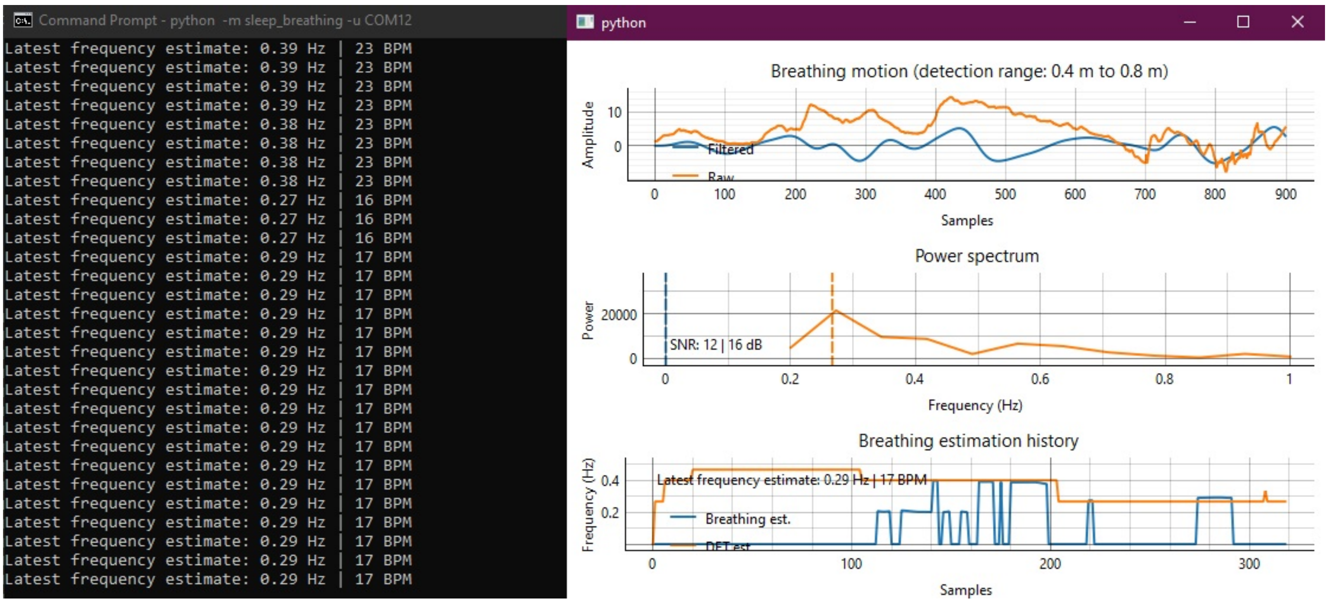

Figure 7.3: Breath rate values from the Acconeer XM112 sensor

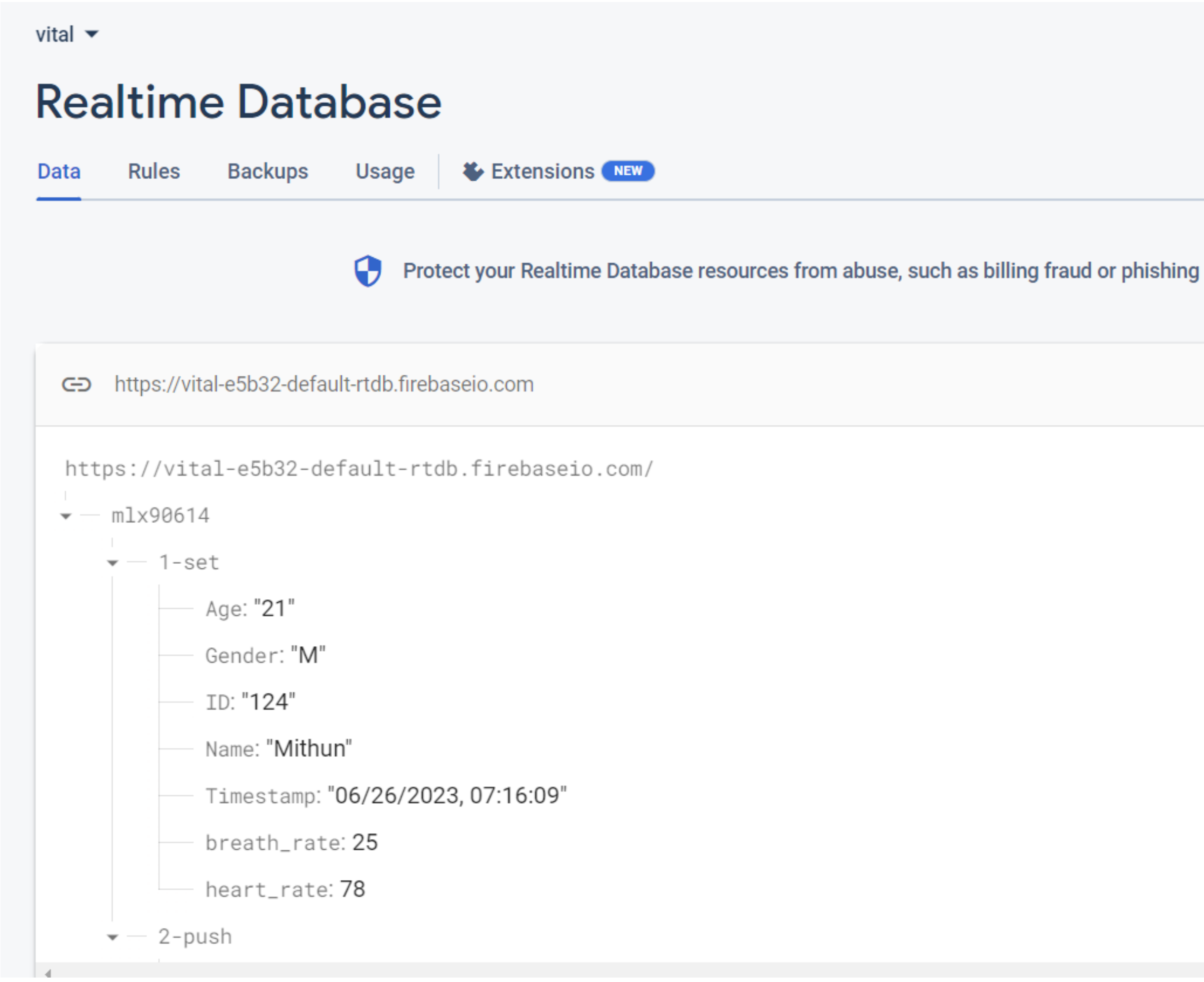

Figure 7.4: The real-time data from the Acconeer XM112 is displayed on the website through Firebase (Cloud)

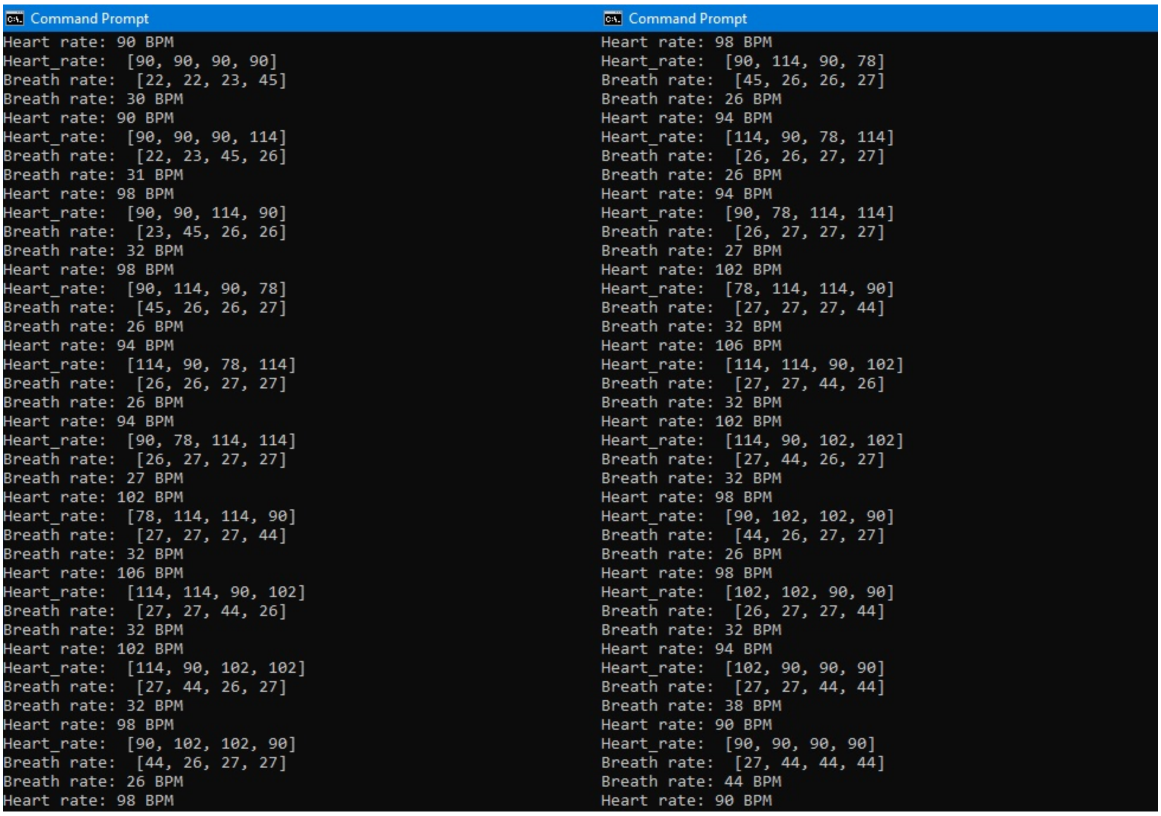

Figure 7.5: Averaged values of Heard and Breath rate

Figure 7.6: Testing the project in hospital

Figure 7.7: The measurement setup to detect vital signs using i) Acconeer XM112 radar sensor ii) Pulse oximeter (heart rate) iii) Manual counting by doctor for breath rate calculation

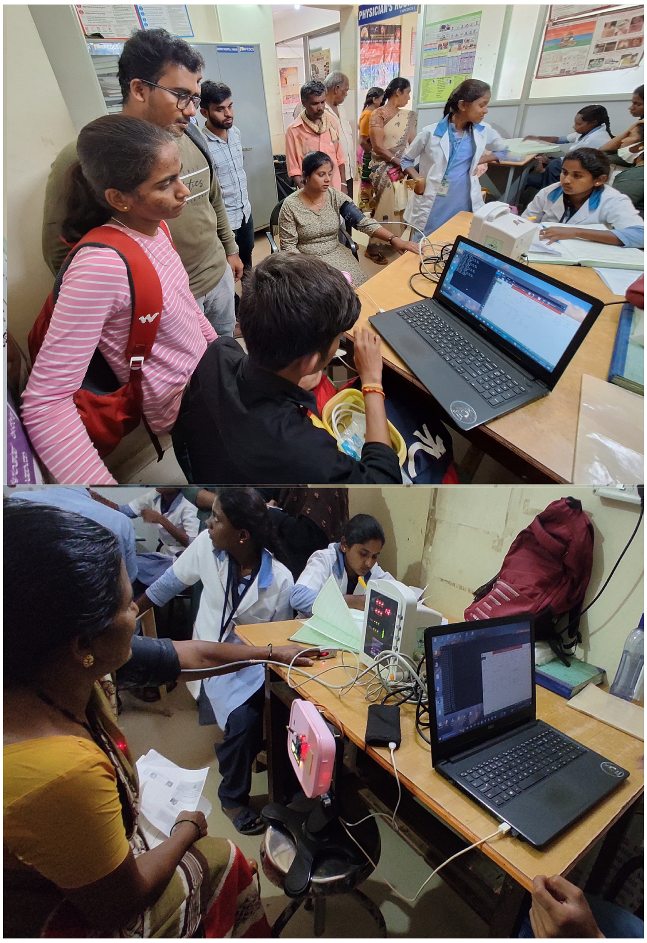

Figure 7.8: Testing the project in hospital

Name	**Heart rate**	**Breath rate**	**Breath rate (Manual counting by doctor)**	**Heart rate (Pulse oximeter)**
D K Chandrakanth	78	17	17	76
Preetham G M	73	15	15	75
Nithesh Kumar V	80	14	15	80
Mithun J B	65	15	15	63
Sachin	70	18	18	72
Usama Ahamed	74	11	12	74
Neha	68	13	13	69
Ramya	71	14	14	70
Rithin	72	12	13	72
Meghana	62	16	16	63

Chapter 8

Conclusion

The Project "Measurement and Monitoring of Vital Signs using mmWave sensors" has shown promising results for accurately tracking heart rate and breathing rate. Throughout the project, extensive testing was conducted on nearly 300 individuals, and the obtained measurements closely aligned with normal heart rate and breathing rate values.

The breath rate measurement component of the system demonstrated exceptional accuracy, achieving a 100 percent success rate. This is particularly noteworthy considering the lack of available devices for directly measuring breath rate. By leveraging the radar sensor and analyzing the chest displacement resulting from the interaction of signals, the system accurately determined the breathing rate of individuals, providing a valuable tool for healthcare professionals in assessing respiratory health.

Regarding heart rate measurements, the system achieved reliable results with a minor bias of plus or minus 2 beats per minute. While there was a slight margin of error, this bias falls within an acceptable range for most clinical applications. The heart rate measurements were obtained by analyzing the reflected signals and applying appropriate signal processing techniques to extract the necessary information. The system's ability to consistently track heart rate without physical contact or wearable devices offers a convenient and comfortable solution for patients, particularly those with skin problems or sensitivity.

To ensure data management and accessibility, the patient details and vital sign measurements were securely stored in the Firebase cloud. This allows for convenient archival and further research purposes, enabling comprehensive data analysis and the development of advanced algorithms in the future.

8.1 Scope for future work

Future Scope of the Project is

1. Widening the Range of Frequencies: Explore the incorporation of higher frequencies beyond 60 GHz to enable the detection of higher heart rates. This would allow for accurate

measurements in individuals with elevated heart rates, such as athletes or patients with certain medical conditions.

2. Calibrating the Sensor to Overcome Bias: Further refine the calibration process of the sensor to minimize or eliminate the bias observed in heart rate measurements. This would enhance the accuracy and reliability of the system across different individuals and physiological conditions.

3. Increasing Penetrating Depth: Investigate methods to increase the penetrating depth of the radar waves to enable measurements through materials, such as clothing or bedding. This would provide more flexibility and convenience in real-world scenarios, allowing vital signs to be monitored without the need for direct skin contact.

4. Increasing the Measuring Range: Extend the measuring range of the radar sensor from the current range to 5 to 10 meters. This would enable remote vital signs monitoring in larger spaces, such as hospital rooms or public areas, providing a broader scope for applications and monitoring multiple individuals simultaneously.

5. Automatic Height Adjustment: Develop an automatic height adjustment feature for the focusing view of the sensor. This would enable the system to account for variations in individuals' heights, ensuring accurate vital signs measurements for individuals of different stature. This would be particularly beneficial in scenarios where patients may be lying down or in situations requiring measurements from individuals of varying heights.

By addressing these areas of future exploration, the project can pave the way for more advanced and versatile non-invasive vital signs monitoring systems, improving healthcare outcomes and patient experiences.

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Chapter 9

Appendix

9.1 Data Sheet

[1]. A111 Pulsed Coherent Radar (PCR) Datasheet:
https://www.acconeer.com/products

[2]. XM112 Module Evaluation Kit, User guide:
https://www.acconeer.com/products

[3]. XM112 Module Server, User guide:
https://www.acconeer.com/products

[4]. XB112 Radar Module Breakout Board, Product brief:
https://www.acconeer.com/products

[5]. Acconeer Module SW Image for XM112:
https://developer.acconeer.com/

[6]. Acconeer Exploration tool:
https://github.com/acconeer/acconeer-python-exploration

[7]. Bossa: Available from https:
https://github.com/shumatech/BOSSA/releases

[8]. Our Project complete details:
Project drive link

Chapter 10

Self- Assessment of the Project

Title of the project: "Measurement and Monitoring of Vital Signs using mmWave sensors" byTeam members:D K Chandrakanth(1SI20EC020),Preetham G M(1SI20EC121),Nithesh Kumar V(1SI20EC122),Mithun J B(1SI20EC124).

Level				
Poor 1	Average 2	Good 3	V.Good 4	Excellent 5

	PO PSO	Contribution from the project	Level
1	Engineering Knowledge: Knowledge of mathematics, engineering fundamentals engineering specialization to form of complex engineering problems	Contributes to the advancement of engineering knowledge by applying mathematical principles and engineering fundamentals to solve complex problems in the field of healthcare monitoring and technology development.	5
2	System Analysis: Identify, formulate, research literarture and analyse engineering problems to derive substaintiate conclusions by first principles of mathematics, natural and engineering science	XM112 sensor contributes by analyzing engineering problems through research and mathematical principles, leading to substantiated conclusions for advancing healthcare monitoring and technology.	5
3	Design/development of solutions: Design solutions of complex engineering problems, design system components or process that meet the specified process with appropriate consideration for the public health, safety and the cultural and environmental considerations.	Developed solutions for complex engineering problems in healthcare monitoring, considering public health, safety, cultural, and environmental factors to create system components and processes that meet specified requirements.	4
4	Conduct investigations of complex problems: Use research based knowledge and research methods including design experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.	conducting investigations of complex problems in healthcare monitoring, employing research-based knowledge, research methods, and data analysis techniques to provide valid conclusions through experimental design, data interpretation, and information synthesis.	5
5	Modern tool usage: Create, insert and apply appropriate techniques, resources and modern engineering and tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	modern engineering tools, techniques, and resources, including prediction and modeling, to effectively address complex engineering activities in healthcare monitoring while acknowledging their limitations.	5
6	The Engineer and Society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice.	contributes by applying contextual knowledge to evaluate societal, health, safety, legal, and cultural considerations, thereby fulfilling the responsibilities associated with professional engineering practice in the healthcare monitoring domain.	4

7	Environment and Sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	contributes by assessing the societal and environmental impact of the engineering solutions involved, and showcasing the understanding and implementation of sustainable development principles in healthcare monitoring practices..	4
8	Ethics: Apply ethical principles and commit to professional ethics and norms of the engineering practice.	The project contributes to the development of ethical principles and norms for the use of 60GHz mmWave sensors in the measurement and monitoring of vital signs.	5
9	Individual and Team Work: Function effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings.	The project requires participants to work effectively in diverse teams and in multidisciplinary settings, which helps them to develop their individual and team work skills.	4
10	Communication: communicate effectively on complex engineering activities with the engineering community and with the society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	Effective documentation is done using Latex (Overleaf). Plagiarism check is done for the report.	5
11	Project Management and Finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	Cost efficient, flexible and customizable.	5
12	Life-long Learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in broadcast context of technological change.	preparing individuals to engage independently and adaptively in continuous learning to keep pace with advancements in healthcare monitoring technology.	5
13	PSO1: Apply the concepts of electronic circuits and systems to analyses and design systems related to Microelectronics, Communication, Signal processing and Embedded systems for solving real world problems	Applied electronic circuit and system concepts to analyze and design a system that integrates microelectronics, communication, signal processing, and embedded systems, effectively solving real-world problems in healthcare monitoring.	5
14	PSO2: To identify problems in the area of communication and embedded systems and provide efficient solutions using modern tools/algorithms working in a team	The project on Measurement and Monitoring of Vital Signs using the 60GHz mmWave sensor XM112 contributes by identifying and addressing problems related to communication and embedded systems, specifically in the context of healthcare monitoring, thereby contributing to the advancement and improvement of these areas.	5