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ULTRA WIDE BAND RADAR SYSTEM FOR THROUGH WALL HUMAN VITAL SIGNS DETECTION

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Abstract— The project focuses on the development of a cutting-edge system for monitoring human vital signs through solid barriers. The system utilizes a combination of PIR sensors, IR temperature sensors, and the DHT11 sensor to capture diverse data points related to human presence, body temperature, and environmental factors. A central controller processes this data and interfaces with output devices like displays and buzzers, providing real-time feedback. By harnessing Ultra Wide Band Radar technology, this project endeavors to revolutionize non-invasive human vital sign monitoring, potentially finding applications in security, healthcare, and rescue operations.

Keywords— DHT 11, Embedded System , Alerting System, HIR temoerature

I. INTRODUCTION

The ability to detect and monitor human vital signs through obstructions such as walls has long been a challenging yet highly sought-after capability in various domains. The "Ultra Wide Band Radar System for Through Wall Human Vital Signs Detection" project aims to address this challenge by leveraging a combination of sensors and advanced radar technology. The project involves the integration of PIR sensors, which detect motion, IR temperature sensors for body temperature monitoring, and the DHT11 sensor to capture environmental parameters. These sensors interface with a central controller responsible for data collection, processing, and interpretation. The resulting vital sign information is then conveyed through output devices like displays and buzzers, enabling real-time monitoring and alerts. This project not only aims to demonstrate the feasibility of through-wall vital sign detection but also holds promise for diverse practical applications in security, healthcare, and emergency response scenarios

IOT (Internet of Things) Technology:

IOT devices, sometimes referred to as "smart objects," can be anything from basic "smart home" appliances like smart thermostats to wearable like smart watches and clothing with RFID capabilities to sophisticated industrial and transportation systems. IoT-based "smart cities" as a whole are even being imagined by technologists.

These smart devices may speak with other internet-enabled devices as well as with one another thanks to IoT. establishing an extensive network of linked devices that can communicate with one another and carry out different activities on their own, much like cellphones and gateways. This may consist of:
keeping an eye on the farming environment
utilizing smart automobiles and other smart automotive gadgets to manage traffic patterns
regulating factory equipment and procedures
monitoring shipments and inventories in warehouses

Sensors importance:

Temperature sensors are intended to track variations in body temperature, giving important details about an individual's health, like identifying fever or hypothermia. In contrast, heart rate is continuously measured by pulse rate sensors, which can identify anomalies such as arrhythmias and provide insights into cardiovascular health. SpO2 sensors monitor blood oxygen saturation levels, which aid in the evaluation of respiratory health and the detection of diseases such as hypoxemia. Accelerometers can also identify unusual movement patterns or falls, which can be signs of a cardiac arrest or other medical emergencies and allow for immediate medical attention. When combined, these sensors create a thorough monitoring system that facilitates ongoing evaluations of an individual's vital signs and general health.

Data processing:

To process the real-time data collected from the sensors, complex algorithms are used. These algorithms are very complex, meaning that they are made to carefully examine the data that has been gathered and quickly detect any changes from the normal physiological characteristics. These anomalies may indicate the beginning of a heart attack or other serious health events, allowing for prompt and precise intervention to reduce risks and guarantee immediate medical aid.

Wireless communication protocol:

The system functions by employing sophisticated wireless communication protocols, which enable the smooth transfer of data from the multitude of sensors to the central processing unit (CPU). The system's operation depends on these protocols because they provide dependable and effective data flow for in-the-moment monitoring and analysis. Wi-Fi, Bluetooth, and Zigbee are among the protocols that are frequently used. Wi-Fi is renowned for its high data transfer rates and widespread compatibility, while Bluetooth is best for short-range, low-power connectivity between devices. Zigbee is preferred for its low energy consumption and capacity to support a large number of connected devices within a network. Through the utilization of these state-of-the-art communication protocols, the system guarantees stable connectivity and efficient data transfer, augmenting its efficiency in tracking and reacting to critical health parameters.

Cloud computing:

Sensor data is effortlessly sent to distant cloud servers for archiving and comprehensive analysis. One benefit of utilizing cloud computing technology is that it offers scalable storage options that are capable of holding enormous volumes of sensor data. Additionally, cloud platforms have strong processing power that makes it possible to handle and analyze the massive datasets that the sensor network generates in an effective manner. The system's overall effectiveness in monitoring and addressing vital health indicators is improved by this technique, which also guarantees safe data storage and makes real-time insights and actionable information easier to get.

Mobile component:

As user interfaces, mobile applications are essential because they enable people to remotely check in on the health of their loved ones and receive real-time notifications. These apps are painstakingly designed to meet the requirements of medical professionals as well as patients and their families. In order to promote peace of mind and proactive healthcare management, the app provides patients and their families with an easy-to-use interface for tracking vital signs, quick notifications about any irregularities identified by the sensors, and access to full health data. Healthcare providers may use the app to remotely monitor several patients at once, examine past health records, and act quickly in an emergency, all of which will improve patient care efficiency and enable well-informed decision-making. These mobile applications are effective tools for encouraging improved communication between patients, caregivers, and medical professionals, encouraging continuous health monitoring, and eventually improving overall healthy outcomes.

Arduino UNO:

The Arduino Uno is an open-source microcontroller board that was created by Arduino.cc and first made available in 2010. It is based on the Microchip ATmega328P microprocessor (MCU).Various expansion boards (shields) and other circuits can be interfaced to the sets of digital and analog input/output (I/O) pins on the microcontroller board.[1] The board may be programmed using the Arduino IDE (Integrated Development Environment) and a type B USB cable. It includes six analog and fourteen digital I/O pins, six of which can be used for PWM output. It may be powered by a rectangular 9-volt battery or a barrel connection that takes voltages ranging from 7 to 20 volts.

Literature Review:

[1] Printed by ACM December (2023)Using Explainable AI Techniques and Machine Learning to Unveil Key Predictors for Early Heart Attack Detection with LIMEThe growing number of deaths linked to cardiovascular illnesses over time emphasizes the importance of cardiovascular diseases, especially heart attacks, as a major cause of death worldwide.According to the study's eXplainable AI approach, qualities like "kcm" and "troponin" are consistently attributed with importance in all techniques for identifying "Attack" occurrences, suggesting that these features play a crucial role in prediction. The study emphasizes how machine learning

may be used clinically to diagnose heart attacks and recommends using a variety of deep learning strategies to improve prediction accuracy..

[2] **Early Prediction of Heart Attack using Machine Learning Algorithms August(2022)** The goal of this plan is to identify the precise characteristics that lead to a heart attack. If the characteristics are identified, it will be simpler to identify the condition and begin treatment right once, avoiding a heart attack from happening. The dataset used in this proposal came from researchers and is an open data entry dataset from clinical records related to heart failure. Take into consideration that k-means clustering has been used to enhance this. The study made it easier to understand how certain characteristics might lead to a heart attack. We think that by identifying heart dissatisfaction early on and shielding it from more severe harm, our research will benefit the well-being sector.

[3] August 2022 Printed by ACM Smart Water Distribution: Improving Anomaly Detection for Cyber-Attack Identification The alarming rise in cyber attacks targeting industrial and systems-critical assets is making their vulnerability more apparent. This research suggests an improved auto encoder based anomaly detection method for cyber attack detection in water distribution.

[4] Variability in Heart Rate for Non-Intrusive Cyber sickness Identification Cyber sickness refers to all the negative outcomes that can happen during a Virtual Reality (VR) immersion. These outcomes can lower the level of user experience and restrict the functionality, usefulness, and amount of time that VR systems can be used for. Standardized protocols aid in the detection of stimuli that may produce cyber sickness in a number of users, but they are unable to accurately identify which particular users are affected. Heart Rate Variability (HRV) is one of the most commonly employed biometric metrics in prior research to track an individual's cyber sickness.

[5] Dong, Zhang, and Luo (2022) introduce a novel method aimed at enhancing the accuracy of progress indication during the construction of deep learning models. Recognizing the importance of timely progress updates, especially in the context of large datasets, the authors address the challenge of delayed progress estimates due to sparse validation points. Their proposed method strategically inserts additional validation points to provide more frequent updates, resulting in a significant reduction (57.5% on average) in prediction errors associated with estimating model construction time. Implemented in TensorFlow, this approach offers a practical solution to improve progress indicators, enabling faster and more accurate estimates with minimal overhead.

[6] In the realm of workload prediction for edge computing, researchers have made significant strides employing diverse machine learning and deep learning techniques to refine prediction accuracy. Notably, Miao et al. (2021) delves into the exploration of graph neural networks (GNNs) as a solution to capture the spatial dependencies and correlations inherent in the interconnected topology of edge servers. Their study integrates GNNs with recurrent neural network (RNN) architectures, particularly long short-term memory (LSTM), to effectively model temporal dynamics and improve prediction performance. This research highlights the ongoing efforts to tackle the challenges posed by the dynamic nature of end-user behaviors, ultimately aiming to optimize resource utilization in edge computing environments.

[7] In the domain of query execution optimization, Wang, Fang, Yan, Yiu, Li, Mao, and Tang (2023) present a novel approach to speeding up end-to-end query execution through Learning-based Progressive Cardinality Estimation (LPCE). Their work addresses the challenge of balancing model complexity and estimation accuracy in existing cardinality estimators, proposing LPCE as a solution that integrates an initial model (LPCE-I) and a refinement model (LPCE-R). LPCE-I provides cardinality estimations before query execution, while LPCE-R progressively refines these estimations using actual cardinalities from executed operators. This methodology allows for query re-optimization during execution, leading to more efficient execution plans for remaining operators. Both LPCE-I and LPCE-R are lightweight query-driven estimators that jointly achieve high efficiency and accuracy. Furthermore, the authors integrate LPCE into PostgreSQL, a widely used database engine, demonstrating its effectiveness in yielding shorter end-to-end query execution times compared to state-of-the-art learning-based estimators.

[8] Georgoulakis, Misegiannis, Kantere, and d'Orazio (2022) present a significant advancement in Apache Spark's query optimization within cloud environments by introducing a multi-objective cost model. The primary objective is to minimize both query execution time and monetary cost concurrently, offering a novel methodology for selecting Pareto-optimal query plans. Through experimental validation,

II. CHALLENGE OVERVIEW

2.1. CURRENT FRAMEWORK:

The existing systems predominantly relied on basic motion sensors with limited resolution and accuracy. These systems struggled to differentiate between multiple individuals or accurately capture specific vital sign data through obstacles like walls. Additionally, their scope was often confined to specific applications due to their limited sensor capabilities and processing power. The lack of comprehensive integration among sensors environmental sensors hindered the holistic monitoring of vital signs through barriers. Overall, the systems lacked the sophistication required for robust, real-time through-wall human vital sign detection and analysis, impeding advancements in fields like security, healthcare, and emergency response.

2.2. DISADVANTAGES:

1. Limited Sensing Capabilities
2. Poor Resolution and Accuracy
3. Scope Limitations
4. Limited Integration
5. Technological Constraints

III. METHODOLOGY

In this proposed system, the integration of multiple sensors and the incorporation of a panic button feature within the wearable device mark a significant advancement in cardiac monitoring technology. By leveraging IoT connectivity and sophisticated algorithms, the system enables real-time tracking of vital signs and immediate alerting mechanisms, empowering both patients and healthcare providers to respond swiftly to potential cardiac emergencies, ultimately enhancing patient outcomes and saving lives.

By combining the use of many sensors and a panic button built into a wearable, the suggested system offers a revolution in cardiac monitoring technology. The drawbacks of conventional cardiac monitoring techniques are addressed by this combination, which represents a noteworthy breakthrough. This device uses complex algorithms and Internet of Things (IoT) connection to detect vital signs in real-time and deliver fast alerts. This allows healthcare personnel and patients to respond quickly to cardiac crises. The ultimate goals of this novel strategy are to improve patient outcomes and preserve lives.

This system's capacity to smoothly integrate several sensors is fundamental to its efficacy. The wearable gadget has these sensors positioned in key locations to continually monitor a variety of vital indications, including blood pressure, heart rate, oxygen saturation levels, and even ECG readings. In contrast to conventional monitoring equipment that are restricted to assessing individual vital signs, this all-encompassing method offers a full picture of the patient's heart condition in real time.

Moreover, the inclusion of a panic button function gives patients an additional sense of security and empowerment. The patient can quickly inform authorized caretakers or medical experts by pressing the panic button in the case of discomfort or suspicion of a heart problem. In times when every second counts, having this rapid and clear line of communication can be crucial to enabling timely intervention and perhaps stopping the progression of a cardiac emergency.

An other important feature that distinguishes this system is its use of IoT connection. Real-time data transmission of the wearable device's sensors to a centralized monitoring system is possible by connecting it to a secure cloud-based platform. No matter where they are, medical professionals may get the most recent information regarding a patient's heart condition because to this connectivity. The ability to monitor patients remotely is particularly helpful for those who need constant supervision but are unable to visit a clinical facility in person.

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3.1 Requirement Analysis:

Requirements serve as vital descriptors of a system's capabilities, outlining what the system aims to achieve.

3.1.1 Arduino ide:

Programming Arduino microcontroller boards is done via the software platform known as the Arduino Integrated Development Environment (IDE). It makes code creation, compilation, and uploading to Arduino boards easy for both novice and seasoned developers with its user-friendly interface.

3.1.2 Embedded c:

A version of the C programming language created especially for creating embedded devices is known as embedded C. Computer systems called embedded systems are made specifically to carry out certain tasks inside bigger systems or gadgets. These systems sometimes lack an operating system and have low memory and processing capability. Designed to function effectively within these limitations, Embedded C finds extensive application in sectors such as automotive, consumer electronics, medical devices, and industrial automation.

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3.2 RESOURCE REQUIREMENTS:

SOFTWARE REQUIREMENTS:

Operating System	Windows 7or later
Simulation Tool	Arduino uno
Language	Embedded c

HARDWARE REQUIREMENTS:

- Microcontroller
- PIR Sensor
- IR Temperature
- DHT 11
- Buzzer
- I2C LCD

3.3 PROPOSED SYSTEM

The proposed system integrates advanced Ultra Wide Band Radar technology with an array of sensors, including PIR, IR temperature, and DHT11, connected to a central controller. This system aims to achieve comprehensive and real-time monitoring of human vital signs through barriers like walls. The combination of sensors facilitates the capture of diverse data points related to motion, body temperature, and environmental conditions. A sophisticated central controller processes this data, enabling accurate analysis and interpretation. Output devices such as displays and buzzers provide immediate feedback, enhancing the system's usability in security, healthcare, and emergency response scenarios. This innovative system strives to overcome the limitations of prior technologies by offering enhanced accuracy, broader data integration, and the potential for versatile applications in diverse settings.

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3.3.1 ADVANTAGES

1. **Enhanced Accuracy:** Integrating various sensors like PIR, IR temperature, and DHT11 with Ultra Wide Band Radar technology improves accuracy in detecting and monitoring human vital signs through barriers, ensuring more reliable data collection.
2. **Comprehensive Data Capture:** The combination of sensors allows for a holistic approach to vital sign monitoring, capturing diverse parameters such as motion, body temperature, and environmental conditions, providing a more comprehensive picture.
3. **Real-time Monitoring:** The central controller processes data swiftly, enabling real-time analysis and interpretation of vital sign information. This feature is crucial in time-sensitive scenarios, like security breaches or emergency responses.
4. **Versatile Applications:** The system's capability to accurately monitor vital signs through walls opens doors for versatile applications in security systems, healthcare monitoring, and emergency response situations, enhancing their effectiveness and efficiency.
5. **Improved Usability:** Output devices like displays and buzzers offer immediate feedback, making the system user-friendly and facilitating quick responses to detected vital sign changes or anomalies.

3.4 SYSTEM ARCHITECTURE

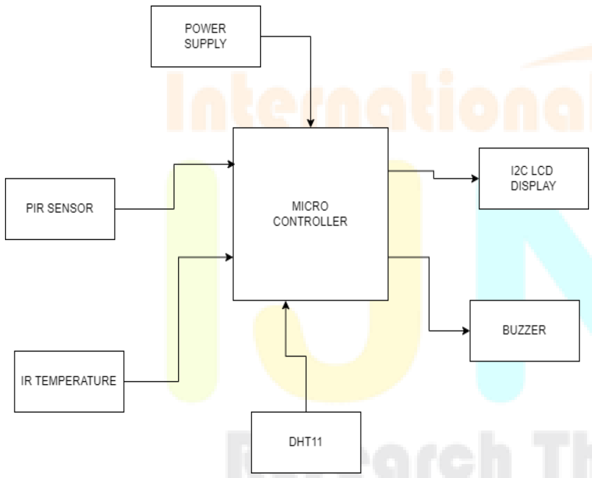

Figure 1. Architecture of the proposed system.

BLOCK DIAGRAM EXPLANATION

The Ultrawide Band Radar System for Through Wall Human Vital Signs Detection incorporates various components interconnected to a microcontroller for efficient operation. The microcontroller serves as the central processing unit, coordinating data acquisition, processing, and output control. The PIR sensor detects motion, triggering the system to initiate vital sign monitoring. The IR temperature sensor measures body temperature, while the DHT11 sensor records environmental temperature and humidity. Upon detection of vital signs, the system activates the buzzer for alerts and displays the information on the I2C LCD screen for real-time monitoring. This integrated setup ensures accurate and timely detection of human vital signs through solid barriers, facilitating applications in security, healthcare, and rescue operations

3.5 MODULES

NODEMCU(ESP8266):

In fact, the ESP8266 has established itself as a key component in the field of IoT development. It is a great option for both engineers and enthusiasts due to its robust features and reasonable price. A strong basis for seamless connectivity is provided by the ESP8266's TCP/IP stack and Wi-Fi capabilities, which are useful when designing a weather station, smart home gadget, or remote-controlled robot. Its widespread community support and plenty of tools, which facilitate troubleshooting and innovation for developers, are other factors contributing to its popularity.

Figure.1. Node MCU

I2C Interface::

ESP8266EX has one I2C used to connect with micro-controller and other peripheral equipments such as sensors. The pin definition of I2C is as below. Both I2C Master and I2C Slave are supported. I2C interface functionality can be realized via software programming, the clock frequency reaches 100 kHz at a maximum. It should be noted that I2C clock frequency should be higher than the slowest clock frequency of the slave device.

Figure.2.Accleration sensor

Pulse-Width Modulation (PWM)

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ESP8266EX has four PWM output interfaces. They can be extended by users themselves. The pin definitions of the PWM interfaces are defined as below. The functionality of PWM interfaces can be implemented via software programming. For example, in the LED smart light demo, the function of PWM is realized by interruption of the timer, the minimum resolution reaches as much as 44 ns. PWM frequency range is adjustable from 1000 μs to 10000 μs, i.e., between 100Hz and 1 kHz. When the PWM frequency is 1 kHz, the duty ratio will be 1/22727, and over 14 bit resolution will be achieved at 1 kHz refresh rate.

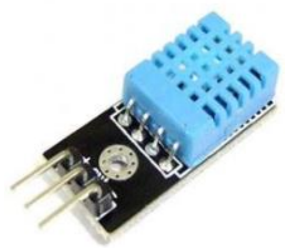

Figure.3.DH11 sensor

pulse sensor:

The term PIR is the short form of the Passive Infra-Red. The term "passive" indicates that the sensor does not actively take part in the process, which means, it does not emit the referred IR signals itself, rather passively detects the infrared radiations coming from the human body in the surrounding area. IR radiation is the section of the electromagnetic spectrum that has wavelengths smaller than microwaves and longer than the visible light wavelengths. The infrared region is from 0.75um to 1000umand, the IR waves are too small to be seen with the human eyes. If the wavelength region is from 0.75um to 3um – it is called as near infrared; the region from 3um to 6um is called as mid infrared; and, if the region is higher than 6um, then it is called as far infrared.

Figure.4. Passive infrared sensor

PIR Working :

The SpO2 sensor measures blood oxygen saturation levels by analyzing light absorption through a person's fingertip. It utilizes red and infrared light to determine the ratio of oxygenated to deoxygenated hemoglobin, providing vital information about respiratory and circulatory health. Commonly integrated into pulse oximeters and medical monitoring devices, it aids in the diagnosis and management of conditions like hypoxemia and sleep apnea

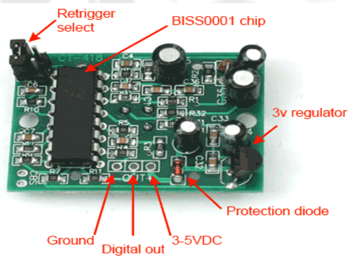

Figure.5. SPO2 sensor

IR sensor:

IR sensor is a simple electronic device which emits and detects IR radiation in order to find out certain objects/obstacles in its range. Some of its features are heat and motion sensing.

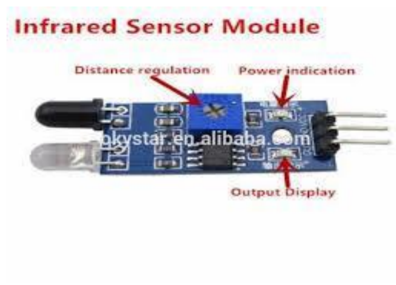

Figure.6. IR SENSOR

I2C LCD pinout:

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16×2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

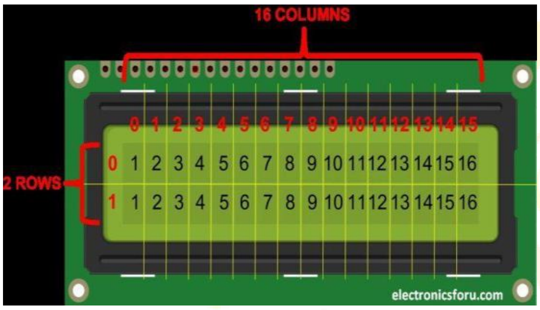

Figure.6. I2C LCD

IV FUTURE WORK

- Enhance system accuracy and range
- Develop real-time vital sign imaging
- Explore applications in different fields

V.RESULT AND DISCUSSION

In order to verify the progressiveness of the proposed method, 20 sets of repeated experiments for the proposed algorithm and some existing methods in the above four scenarios with different setting parameters were carried out, some important indicators were calculated during each detection task in four scenarios, the results have been shown in Table 6. Where, the indicator “Accuracy” indicates the vital signs identifica- tion accuracy of specific algorithm, the indicator “RMSE” indicates root mean square error of the estimation trajectory relative to the real motion trajectory, the indicator "RF" indicates respiratory frequency, the indicator “R-SNR” indicates signal-to-noise ratio of extracted respiratory signal, the indicator "HF" indicates heartbeat frequency, the indicator “H-SNR” indicates signal-to-noise ratio of extracted heartbeat frequency, the indicator “Time” indicates algorithm running time in specific device configuration for each detection task, and the indicator “Success rate” indicates the task success rate of 20 groups of repeated experiments after changing the settings of different personnel, distance, movement speed, obstacles and so on. In addition, most of the exiting methods have only achieved dynamic target trajectory detection, and not extracted vital signs information, therefor the “CLEAN-KF” method [29], “SVM” method [37] and OS-CFAR [35] are chosen as the control group for indicators “Accuracy”, “RMSE”, “Time” and “Success rate” to illuminate the improvement of proposed method, other indicators are advanced functions that have not been implemented before.

The measurement results of key indicators in Table 6 show that the proposed algorithm has high accuracy, real-time performance, robustness and stability. In multiple static targets detection task, most of the algorithms can ensure the successful detection, however the CNN model recognition accuracy and position detection accuracy of the algorithm in this paper are the highest. In the dynamic target detection tasks, theSVM method is difficult to achieve successful detection, the CLEAN-KF method and OS-CFAR method have good performance, and proposed method has a higher identification accuracy, a smaller motion trajectory estimation error and only a little bit longer running time relative to CLEAN-KF method and OS-CFAR method. At the same time, when the experimental settings are changed, the CLEAN-KF method and OS-CFAR method fail in some highly complex scenarios such as multi-target interference and long-range detection, however the proposed method still has a high detection success rate, which illustrates the high sensitivity and stability of it. Furthermore, a more complete scheme which can extract the vital signs information of respiratory and heartbeat signals is proposed. For most detection tasks, the extracted respiratory signal is relatively pure and accurate, but the signal- to-noise ratio of heartbeat signal is relatively low, this is because the human heartbeat signal is inherently unstable and vulnerable to interference during motion.

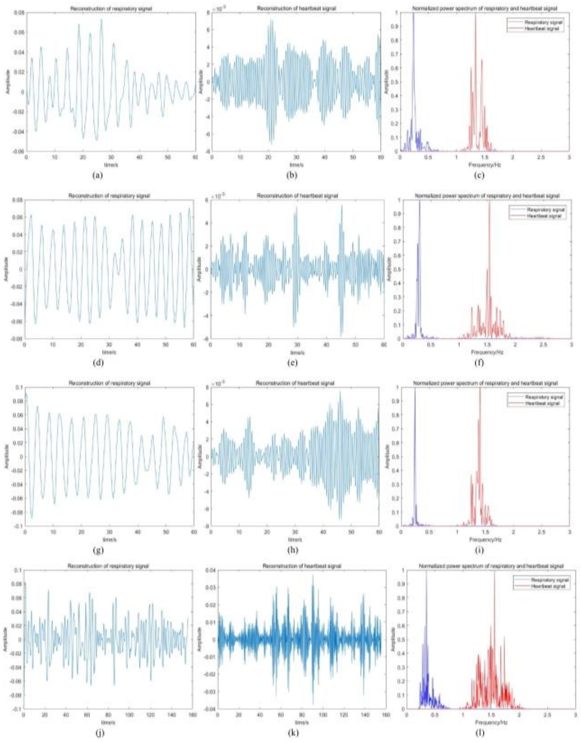

FIGURE 17. The waveforms and power spectrums of respiratory and heartbeat signals for all detected person in scenarios 1, 2, 3, and 4: (a) Waveform of respiratory signal of personnel 1 in scenario 1, (b) Waveform of heartbeat signal of personnel 1 in scenario 1, (c) Normalized spectrum of respiratory and heartbeat signals of personnel 1 in scenario 1, (d) Waveform of respiratory signal of personnel 2 in scenario 1, (e) Waveform of heartbeat signal of personnel 2 in scenario 1, (f) Normalized spectrum of respiratory and heartbeat signals of personnel 2 in scenario 1, (g) Waveform of respiratory signal of personnel 3 in scenario 1, (h) Waveform of heartbeat signal of personnel 3 in scenario 1, (i) Normalized spectrum of respiratory and heartbeat signals of personnel 3 in scenario 1, (j) Waveform of respiratory signal of personnel in scenario 2, (k) Waveform of heartbeat signal of personnel in scenario 2, (l) Normalized spectrum of respiratory and heartbeat signals of personnel in scenario 2, (m) Waveform of respiratory signal of personnel 1 in scenario 3, (n) Wave-form of heartbeat signal of personnel 1 in scenario 3, (o) Normalized spectrum of respiratory and heartbeat signals of personnel 1 in scenario 3, (p) Waveform of respiratory signal of personnel 2 in scenario 3, (q) Waveform of heartbeat signal of personnel 2 in scenario 3, (r) Normalized spectrum of respiratory and heartbeat signals of personnel 2 in scenario 3, (s) Waveform of respiratory signal of personnel 3 in scenario 3, (t) Waveform of heartbeat signal of personnel 3 in scenario 3, (u) Normalized spectrum of respiratory and heartbeat signals of personnel 3 in scenario 3, (v) Waveform of respiratory signal of personnel in scenario 4, (w) Waveform of heartbeat signal of personnel in scenario 4, (x) Normalized spectrum of respiratory and heartbeat signals of personnel in scenario 4.

VI. CONCLUSION

The development of the Ultra Wide Band Radar System for Through Wall Human Vital Signs Detection marks a significant stride towards non-invasive, accurate monitoring through barriers. This project showcases the potential for integrating various sensors and Ultra Wide Band Radar technology, enabling comprehensive vital sign detection including motion, body temperature, and environmental parameters. The system's real-time monitoring capabilities, coupled with immediate feedback mechanisms, demonstrate its viability for applications in security, healthcare, and emergency response. While the project presents a robust foundation, further refinements and advancements in sensor technologies could amplify its accuracy and broaden its scope. Ultimately, this innovative system stands poised to revolutionize vital sign monitoring, offering a promising solution for real-world scenarios requiring precise, non-intrusive human vital sign detection through obstructions.

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