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Paper Title : Contactless Human Vital Sign Monitoring System (CVSMS) using mmWave FMCW Radar for Healthcare Applications

Paper ID: 97

Primary Subject Area : Biomedical Signal Processing

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Faculty of Engineering

Table of Contents

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Motivation

Imagine in case of disease outbreak like covid 19 health caregivers are using CVSMS device that measures human vital signs without any physical contact from distance .

Imagine a firefighter assessing the vital signs of an fire accident victim in a burning building, using CVSMS device that measures these signs without any physical contact.

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Impact of Project/Research on Society

- Enhanced healthcare monitoring for patients, especially the elderly and those with specific medical conditions.
- According to WHO an estimated 17.9 million people died from CVDs in 2019, representing 32% of all global deaths. Of these deaths, 85% were due to heart attack and stroke.
- Improved patient comfort during vital sign monitoring like heart rate and respiratory rate.
- Contribution to disease outbreak management by reducing the risk of virus transmission health service providers.
- Can detect the vital bio-signals in accident scenarios where there is no option for checking the victim by contacting
- Reduction in healthcare costs through affordable remote patient monitoring.
- Ensured the privacy of individuals by preventing video feed surveillance and enhancing their confidentiality during patients monitoring.

Introduction

- **What is Doppler Effect?**
- The change in wave frequency during the relative motion between a wave source and its observer.
- **What is FMCW Radar ?**
- FMCW radar is a specialized radar system capable of measuring the range, velocity, and angle arrival of objects in front of it . the radar transmits a chirp signal, a signal that increases and decreases linearly in frequency over time each chirp signal has a defined duration, bandwidth, and resulting slope.

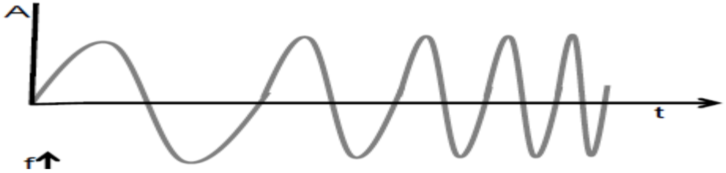
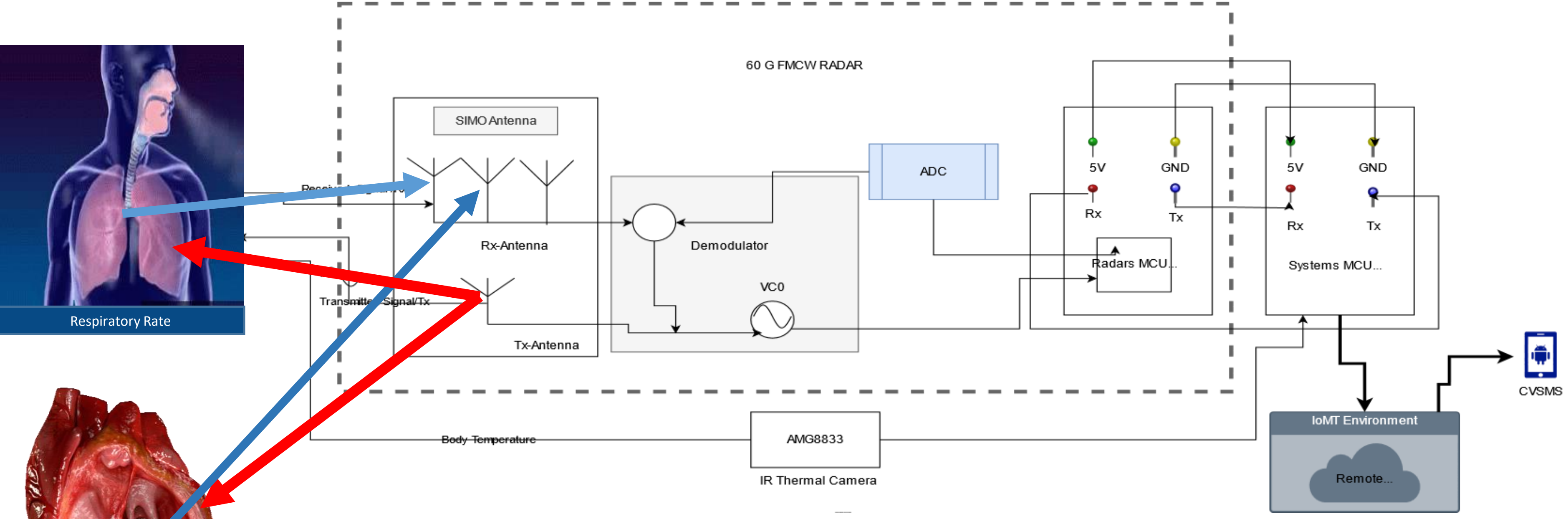
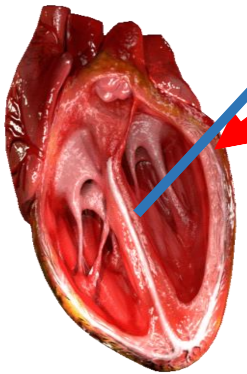


Figure 1: Visual Representation Of Chirp Signal

Working Principle Diagram



Respiratory Rate



Heart Rate

Vital Signs	Amplitude	Frequency
Respiratory Rate(Adults)	1 -12 mm	0.1-0.5Hz
Heart Rate(Adults)	0.1 - 0.5 mm	0.8-2 Hz

Figure 2: Working Diagram Of Heart Rate And Respiratory Rate Measurement Process

Flowchart

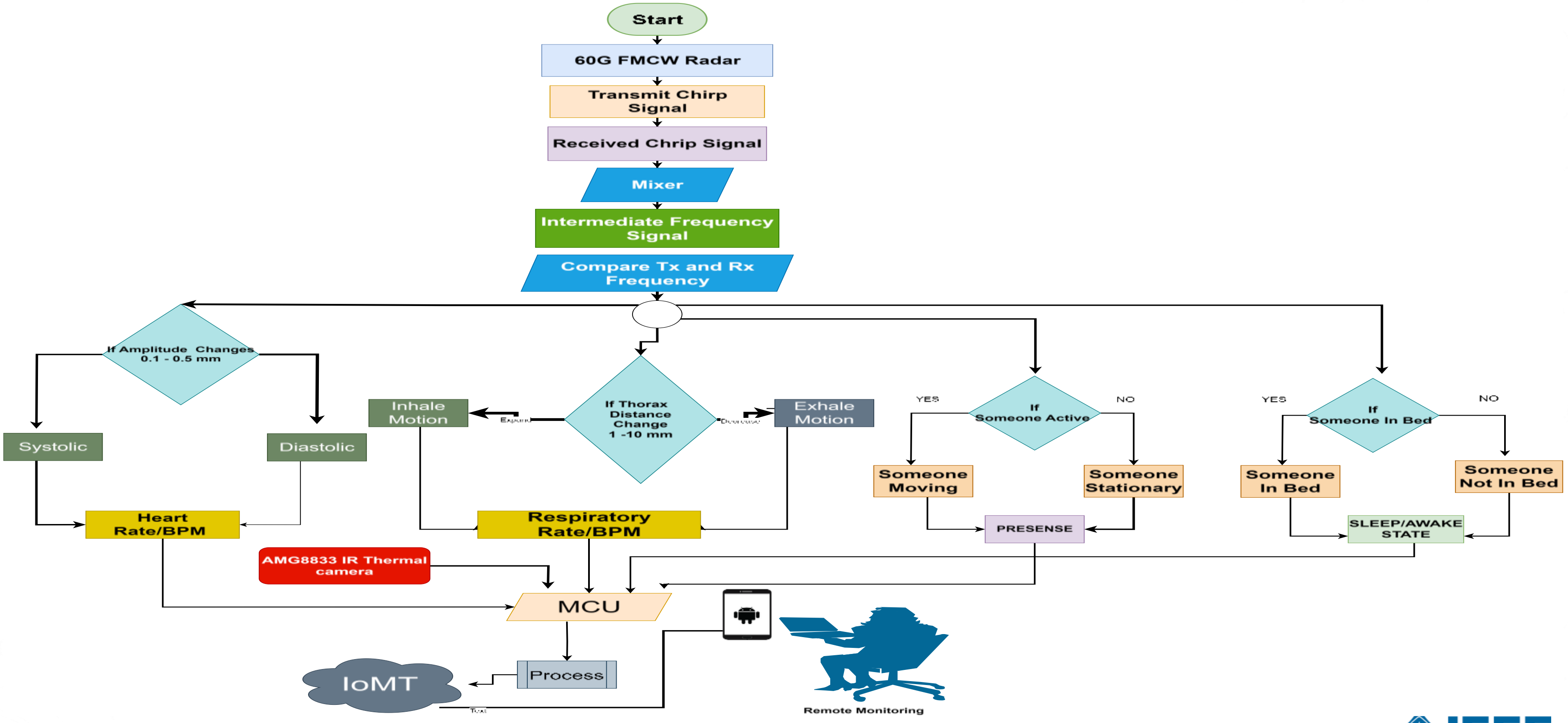


Figure 3: Flowchart of Contactless Vital Sign Monitoring

MATLAB Simulation

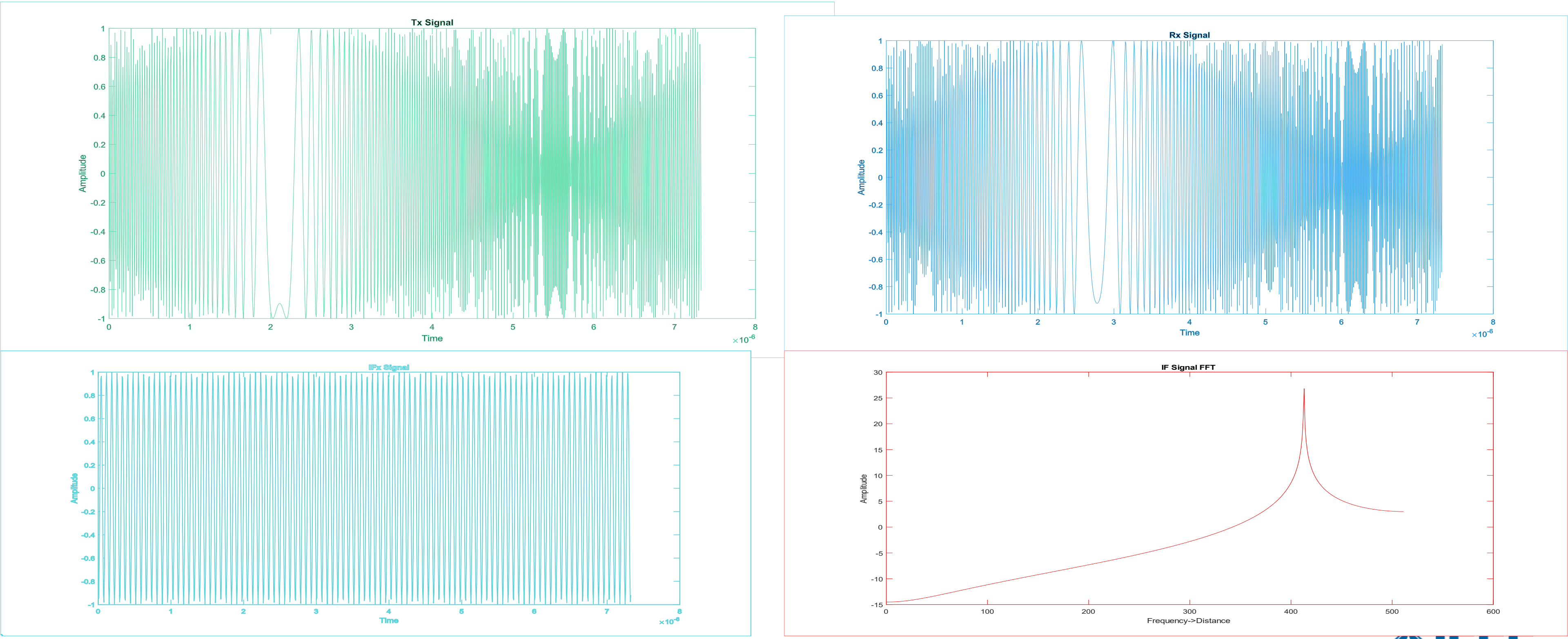


Figure 4. MATLAB Simulation Proof of concept for 60G FMCW Radar Tx, Rx and IF Signal &FFT of IF Signal

MATLAB Simulation

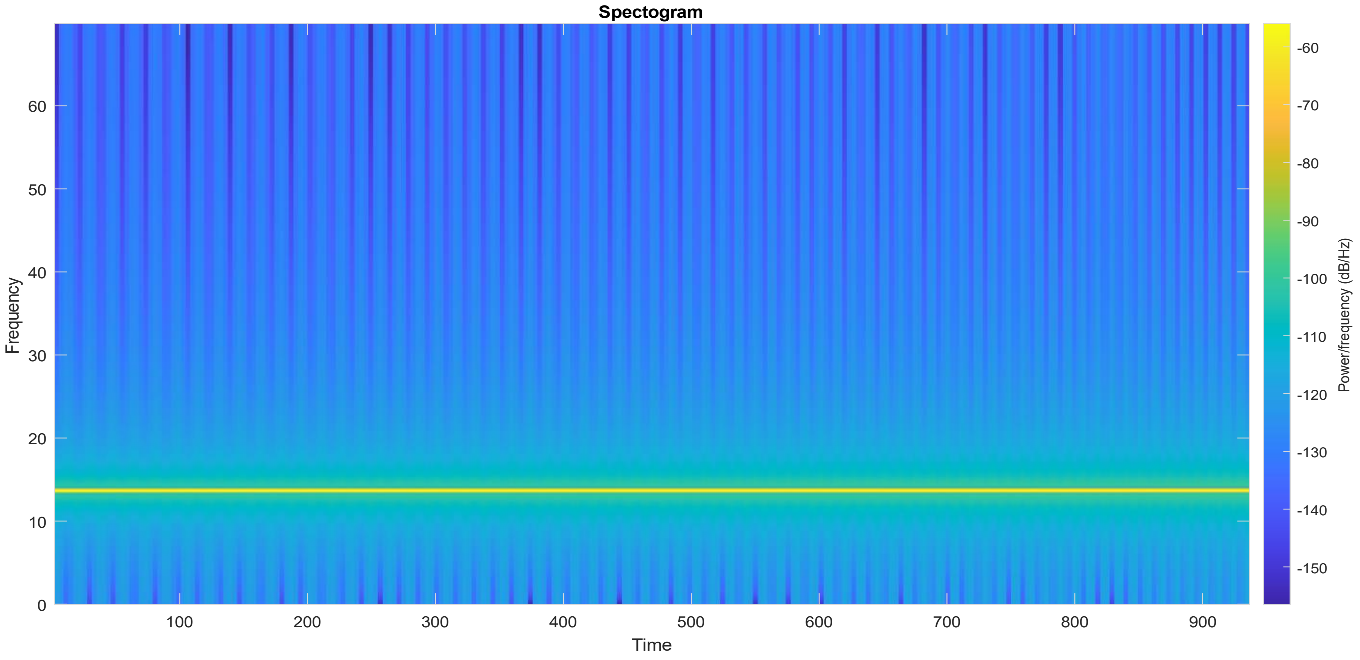


Figure 5. Spectrogram of the 60Ghz FMCW radar antenna

Figure 6.Experimental Setup of 60G FMCW Radar

Circuit Diagram

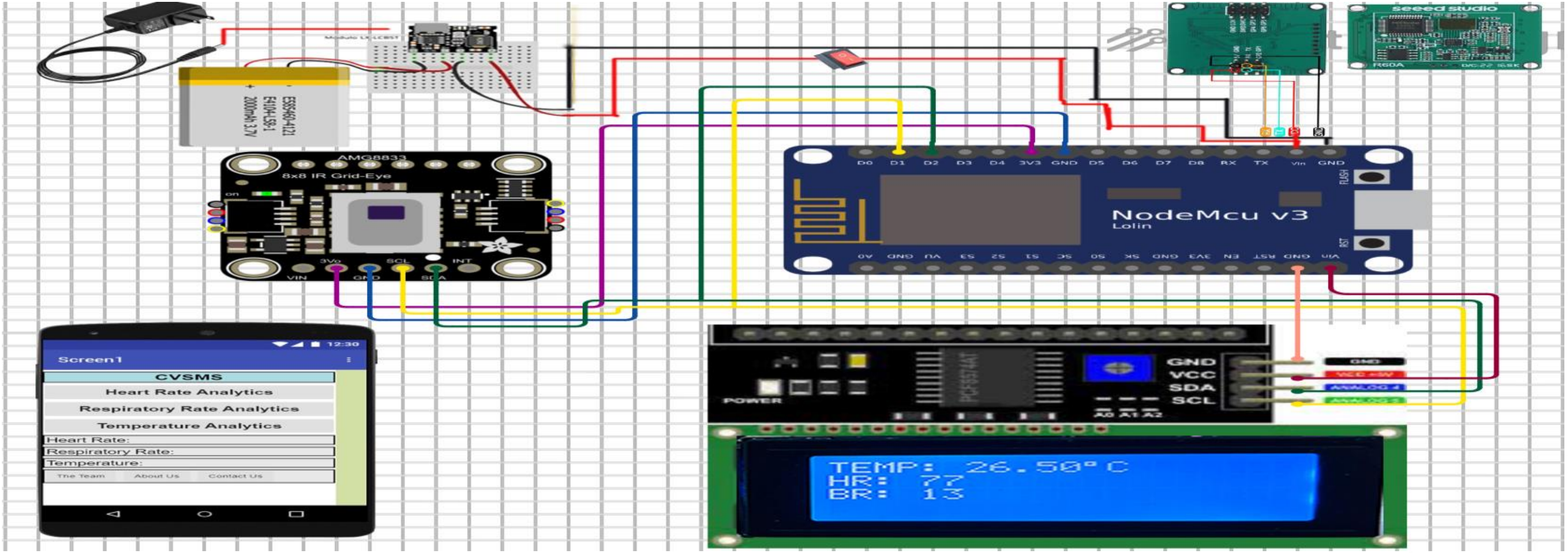


Figure 7: Circuit Diagram of Contactless Vital Sign Monitoring System

Hardware Implementation

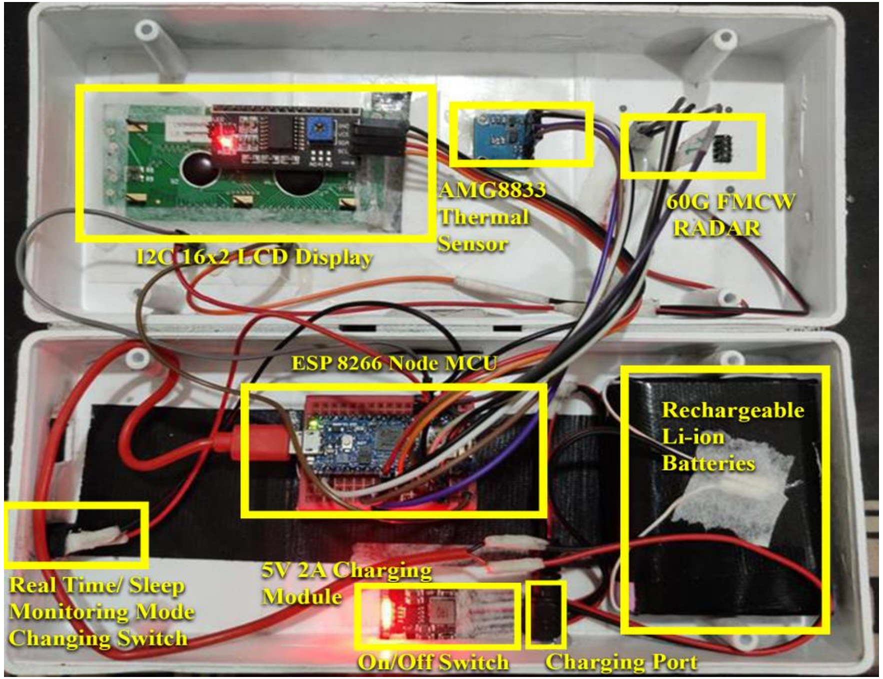


Figure 8.Inside View of the Device

Figure 9. Outer View of the Device

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Results Analysis

TABLE I. DATA FOR 60G RADAR MEASUREMENTS VS TRADITIONAL METHODS : AGE(22 TO 25)

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

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

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

Graphical Comparison of Traditional Measurements vs. 60G Radar Measurements: Age(22 to 25)

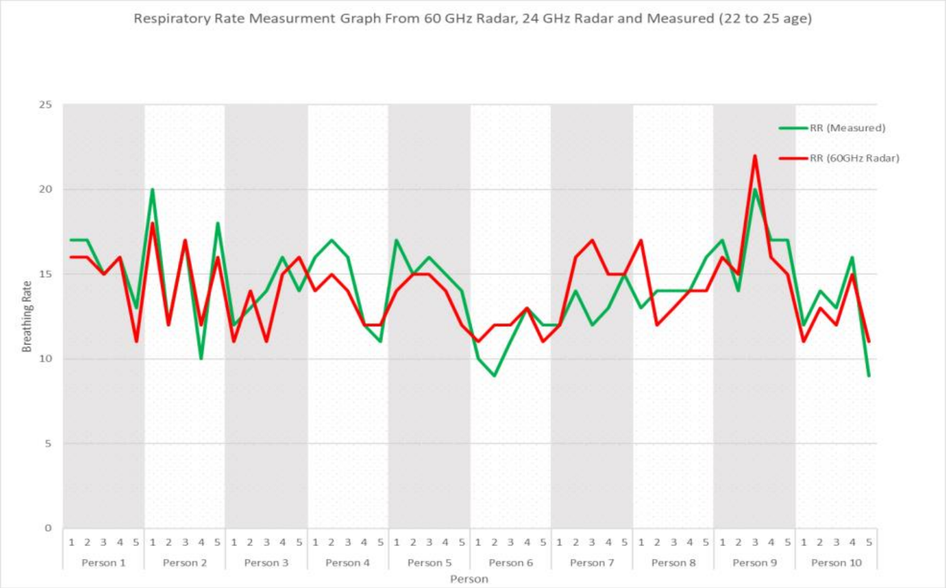


Figure 10.Respiratory Rate Age: 22-25

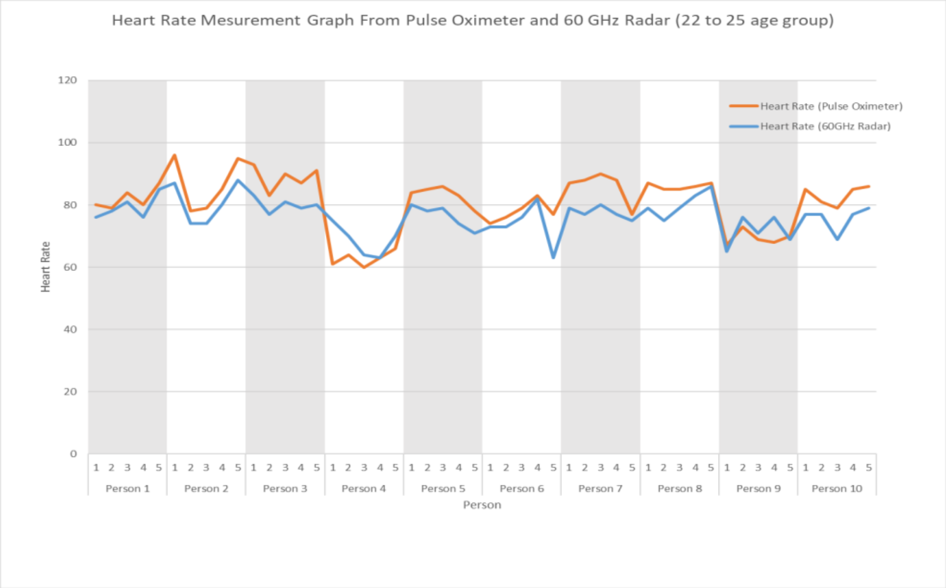


Figure 11.Heart Rate Age: 22-25

TABLE II. DATA FOR 60G RADAR MEASUREMENTS VS TRADITIONAL METHODS : AGE(40 TO 79)

Subject	Gender	Age	BMI	Heart Rate (Pulse Oximeter)	Heart Rate (60GHz Radar)	MAPE% (Individual)	MAPE% (Overall)	RR (Measured Value)	RR (60GHz Radar)	MAPE% (Individual)	MAPE % (Overall)
11	F	50	27.68	88, 88, 84, 87, 84	90, 90, 85, 86, 85	1.61	3.95	20, 22, 18, 17, 18	18, 21, 17, 16, 16	7.41	6.27
12	F	62	23.36	71, 73, 80, 77, 76	73, 73, 79, 77, 76	0.81		16, 12, 13, 12, 15	15, 13, 12, 12, 14	5.78	
13	M	79	25.03	69, 64, 72, 68, 69	64, 62, 62, 63, 63	8.06		12, 13, 12, 16, 14	11, 12, 12, 15, 15	5.88	
14	F	51	21.28	76, 74, 73, 73, 77	77, 77, 74, 77, 71	4.01		12, 13, 15, 16, 16	11, 12, 16, 16, 17	5.78	
15	M	56	26.28	79, 82, 78, 83, 83	75, 90, 79, 81, 81	4.18		20, 21, 21, 21, 19	17, 21, 19, 18, 18	8.81	
16	M	45	32.17	82, 82, 78, 75, 75	78, 79, 82, 78, 77	4.07		10, 09, 11, 13, 12	10, 09, 12, 13, 11	3.48	
17	M	56	26.28	91, 93, 90, 90, 89	85, 85, 82, 83, 84	7.49		20, 21, 20, 21, 19	19, 20, 16, 19, 18	8.90	
18	M	40	27.04	82, 80, 85, 85, 85	81, 79, 83, 84, 83	1.61		15, 16, 13, 12, 11	14, 15, 12, 12, 11	4.12	

Graphical Comparison of Traditional Measurements vs. 60G Radar Measurements: Age(40 to 79)

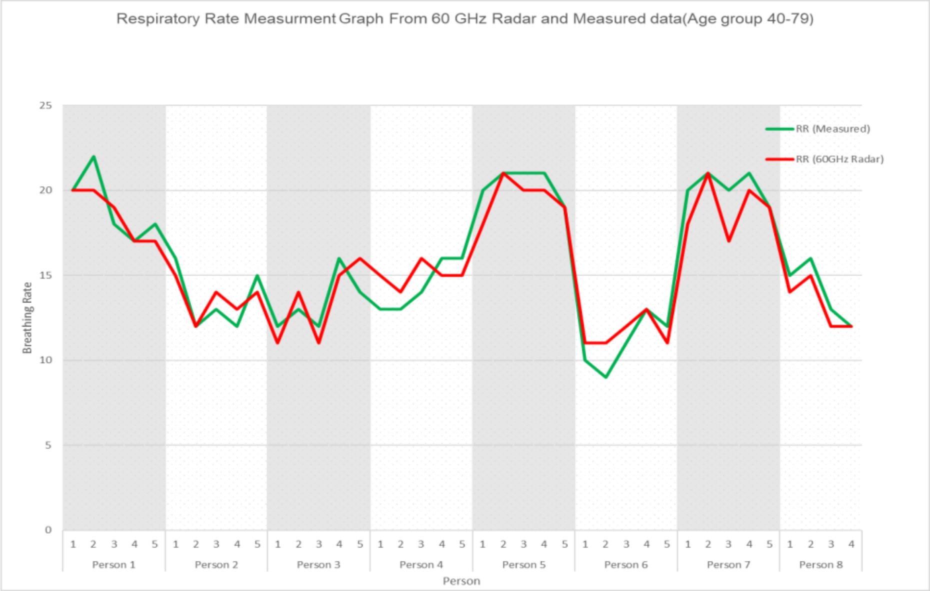


Figure 12.Respiratory Rate Age: 40-79

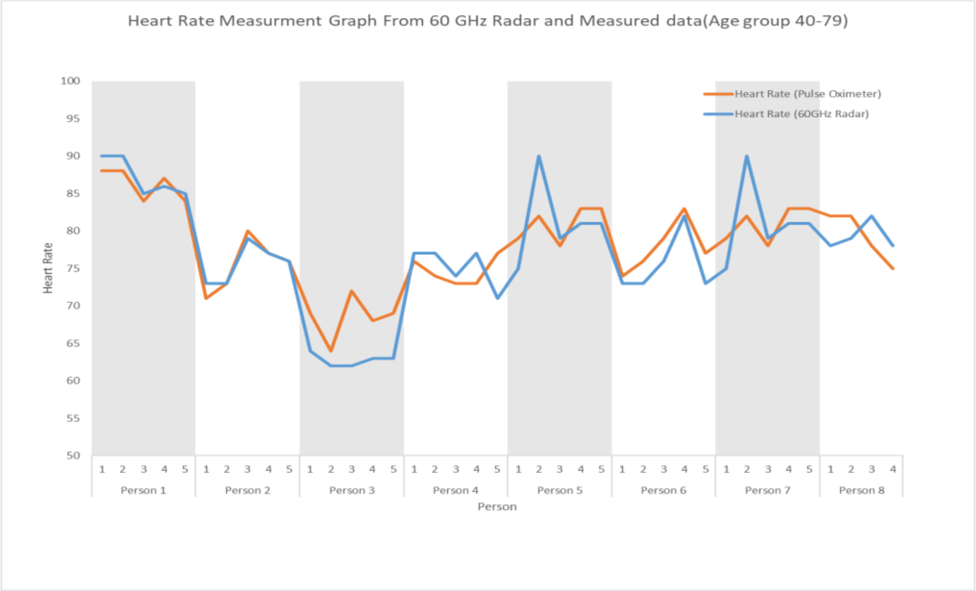
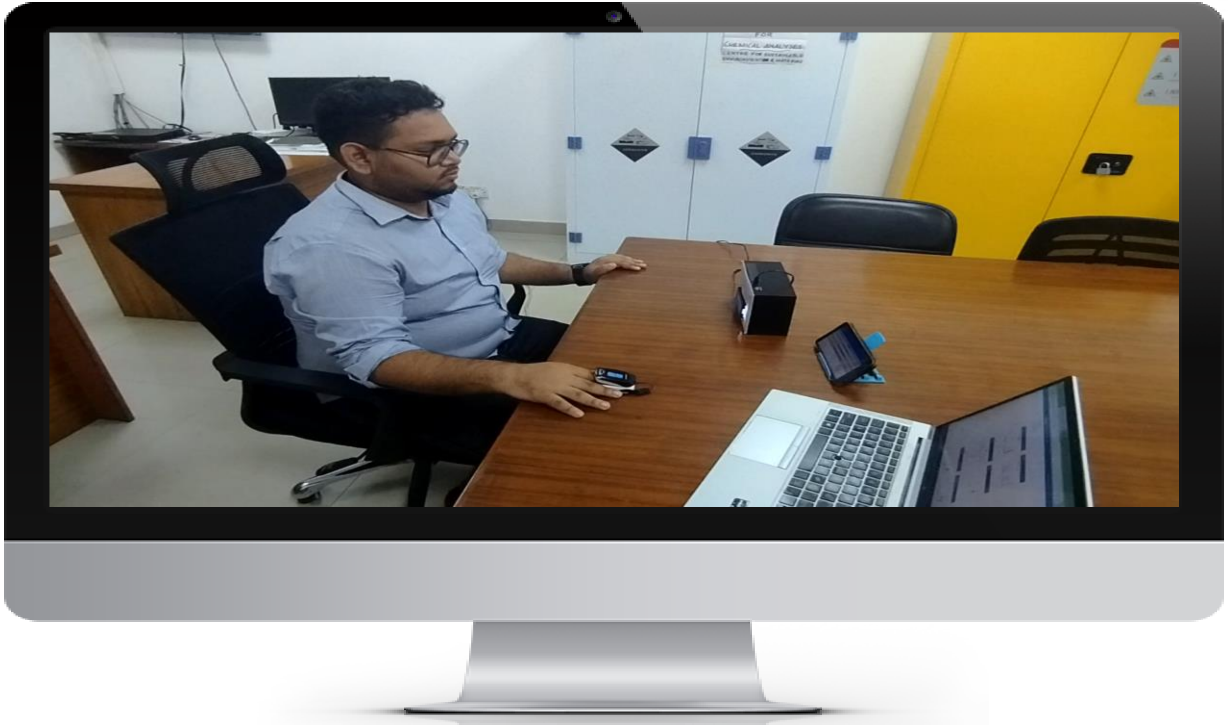


Figure 13.Heart Rate Age: 40-79

Project Demonstration Video



Novelty

Contactless Vital Sign Monitoring

Traditional system available in market is contact based like attaching probes to the body we have develop a system which can measure human vital signs totally contact less

Remote Monitoring

Our developed device called CVSMS sends vital signs data to our IoMT based server from the server the data's can be accessed for decision making by the doctors or health care givers as per need.

Personalized Android App

We have also developed an Android app called CVSMS the apps pulls real time heart rate, respiratory rate and temperature rata data from our IoMT based servers to show real time graphical data

FMCW mm Wave Technology

Our develop device uses FMCW radar technology to accurately detect heart rate and respiratory rate which differs it from others traditional approaches

Sustainability & SDG Goals

SDG 3

GOOD HEALTH AND WELL-BEING

SDG 11

SUSTAINABLE CITIES AND COMMUNITIES

SDG 9

INDUSTRY, INNOVATION AND INFRASTRUCTURE

Limitations

Minimum Separation between Users:

It can not detect multi person heart rate and respiratory tracking.

Monitoring Range:

The maximum distance at which users can be detected is 1.5 meters.

Quasi-static Requirement:

The device measures vital signs only for quasi-static users e.g., those who are sitting Infront of the device.

Non-human Motion

CVSMS can distinguish reflections from various moving objects, including humans, fans, and pets, using FMCW.

Conclusion

Developed a contactless vital sign detection technology with a 60 GHz FMCW radar. The system is running perfectly. To analyze the vital signs data accuracy around 90 samples data was taken. The data accuracy is Promising. In future update we are going to update the device with better preforming radar models and plan to take bigger sample data for analyzing. Plan to develope an android App called **CVSMS** which emphasizes for future innovation like non-invasive real-time remote patient tracking through IoMT(**Internet of Medical Things**) Environment.

References

[1] C. Li *et al.*, “A Review on Recent Progress of Portable Short-Range Noncontact Microwave Radar Systems,” *IEEE Trans. Microw. Theory Tech.*, vol. 65, no. 5, pp. 1692–1706, May 2017, doi: 10.1109/TMTT.2017.2650911.

[2] C. Haahr-Raunkjaer *et al.*, “Continuous monitoring of vital sign abnormalities; association to clinical complications in 500 postoperative patients,” *Acta Anaesthesiol. Scand.*, vol. 66, no. 5, pp. 552–562, 2022, doi: 10.1111/aas.14048.

[3] “mmWave Radar Sensor Guide | Seeed Studio Wiki.” Accessed: Nov. 12, 2024. [Online]. Available: https://wiki.seeedstudio.com/mmwave_radar_Intro/

[4]“Fundamentals of Physics, Extended, 11th Edition | Wiley.” Accessed: Feb. 05, 2024. [Online]. Available: https://www.wiley.com/en-us/Fundamentals+of+Physics%2C+Extended%2C+11th+Edition-p-9781119306856

[5] F. Adib, H. Mao, Z. Kabelac, D. Katabi, and R. C. Miller, “Smart Homes that Monitor Breathing and Heart Rate,” in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, Seoul Republic of Korea: ACM, Apr. 2015, pp. 837–846. doi: 10.1145/2702123.2702200.

[6] M. Alizadeh, G. Shaker, J. C. M. D. Almeida, P. P. Morita, and S. Safavi-Naeini, “Remote Monitoring of Human Vital Signs Using mm-Wave FMCW Radar,” *IEEE Access*, vol. 7, pp. 54958–54968, 2019, doi: 10.1109/ACCESS.2019.2912956.

[7] Y. Wang, W. Wang, M. Zhou, A. Ren, and Z. Tian, “Remote Monitoring of Human Vital Signs Based on 77-GHz mm-Wave FMCW Radar,” *Sensors*, vol. 20, no. 10, Art. no. 10, Jan. 2020, doi: 10.3390/s20102999.

[8] G. Sacco, E. Piuzzi, E. Pittella, and S. Pisa, “An FMCW Radar for Localization and Vital Signs Measurement for Different Chest Orientations,” *Sensors*, vol. 20, no. 12, Art. no. 12, Jan. 2020, doi: 10.3390/s20123489.

[9] S. K. Leem, F. Khan, and S. H. Cho, “Vital sign monitoring and mobile phone usage detection using IR-UWB radar for intended use in car crash prevention,” *Sensors*, vol. 17, no. 6, p. 1240, 2017.

[10] F. Du, H. Wang, H. Zhu, and Q. Cao, “Vital Sign Signal Extraction Based on mmWave Radar,” *J. Comput. Commun.*, vol. 10, no. 3, Art. no. 3, Mar. 2022, doi: 10.4236/jcc.2022.103009.

[11] Y. Hu and T. Toda, “Remote Vital Signs Measurement of Indoor Walking Persons Using mm-Wave FMCW Radar,” *IEEE Access*, vol. 10, pp. 78219–78230, 2022, doi: 10.1109/ACCESS.2022.3193789.

[12] E. Turppa, J. M. Kortelainen, O. Antropov, and T. Kiuru, “Vital Sign Monitoring Using FMCW Radar in Various Sleeping Scenarios,” *Sensors*, vol. 20, no. 22, Art. no. 22, Jan. 2020, doi: 10.3390/s20226505.

[13] M. Xiang, W. Ren, W. Li, Z. Xue, and X. Jiang, “High-Precision Vital Signs Monitoring Method Using a FMCW Millimeter-Wave Sensor,” *Sensors*, vol. 22, no. 19, Art. no. 19, Jan. 2022, doi: 10.3390/s22197543.

[14] “Improved Heartbeat Detection by Exploiting Temporal Phase Coherency in FMCW Radar | IEEE Journals & Magazine | IEEE Xplore.” Accessed: Nov. 11, 2024. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/9635781

[15] Md. S. R. Akash, Md. N. Shahria, Md. A. Morshed, S. S. Rodsee, N. Hannan, and M. H. Imam, “Elderly Patient Monitoring and Fall Detection Using mmWave FMCW Radar System,” in *2023 26th International Conference on Computer and Information Technology (ICCIT)*, Dec. 2023, pp. 1–6. doi: 10.1109/ICCIT60459.2023.10441619.

[16] Md. S. R. Akash, R. M. Fahim, A. Islam, A. H. Real, Y. A. Anik, and M. H. Imam, “Design of a Robotic Arm for Human Contactless Patient Monitoring Through Measuring Different Bio-signals,” in *2023 26th International Conference on Computer and Information Technology (ICCIT)*, Dec. 2023, pp. 1–6. doi: 10.1109/ICCIT60459.2023.10441458.

[17] M. Arsalan, A. Santra, and C. Will, “Improved Contactless Heartbeat Estimation in FMCW Radar via Kalman Filter Tracking,” *IEEE Sens. Lett.*, vol. 4, no. 5, pp. 1–4, May 2020, doi: 10.1109/LSENS.2020.2983706.

[18]“FMCW radar working principle simulation based on python — Chapter 1：Distance simulation.” Accessed: Nov. 12, 2024. [Online]. Available: https://community.infineon.com/t5/Knowledge-Base-Articles/FMCW-radar-working-principle-simulation-based-on-python-Chapter-1-Distance/ta-p/366803

Appendix

Survey Questions: "Contactless Vital Sign Monitoring System using FMCW Radar for Healthcare Applications."

1) Are you familiar with vital sign (e.g., heart rate, temperature, respiratory rate) monitoring techniques [i.e. putting sensor on limbs, wireless/contactless monitoring]?

a) Yes. b) No. c) Somewhat. d) Not sure.

2) How do you generally monitor vital signs like heart rate and breathing?

a) Sensors on the body b) Manual counting c) Wirelessly d) Not sure

3) Are you aware of that vital signs can be measured without any physical contact?

a) Yes. b) No. c) Somewhat. d) Not sure.

4) Would you feel comfortable about the traditional vital sign monitoring methods that require physical contact with patients?

a) Very Concerned. b) Somewhat Concerned. c) Neutral. d) Not Very Concerned.

5) Are you aware of the concept of contactless vital sign monitoring technology?

a) Very Aware. b) Somewhat Aware. c) Not Aware. d) No Opinion.

6) How likely would you be to use a contactless vital sign monitoring system in your home or healthcare facility?

a) Very Likely. b) Somewhat Likely. c) Neutral. d) Not Very Likely.

7) Which of the following applications of contactless vital sign monitoring do you find most valuable?

a) Monitoring heart rate. b) Monitoring respiratory rate. c) Monitoring body temperature. d) Detecting abnormal changes.

8) What do you think are the important features for a good system that checks vital signs without touching a person? a) A real-time alert system for detecting irregular situations. b) A monitoring system based on a mobile app. c) Affordability.

QUESTION

ANSWER

SESSION

THANK YOU!