FINAL DEFENSE PRESENTATION

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

Group: 2023.3.2

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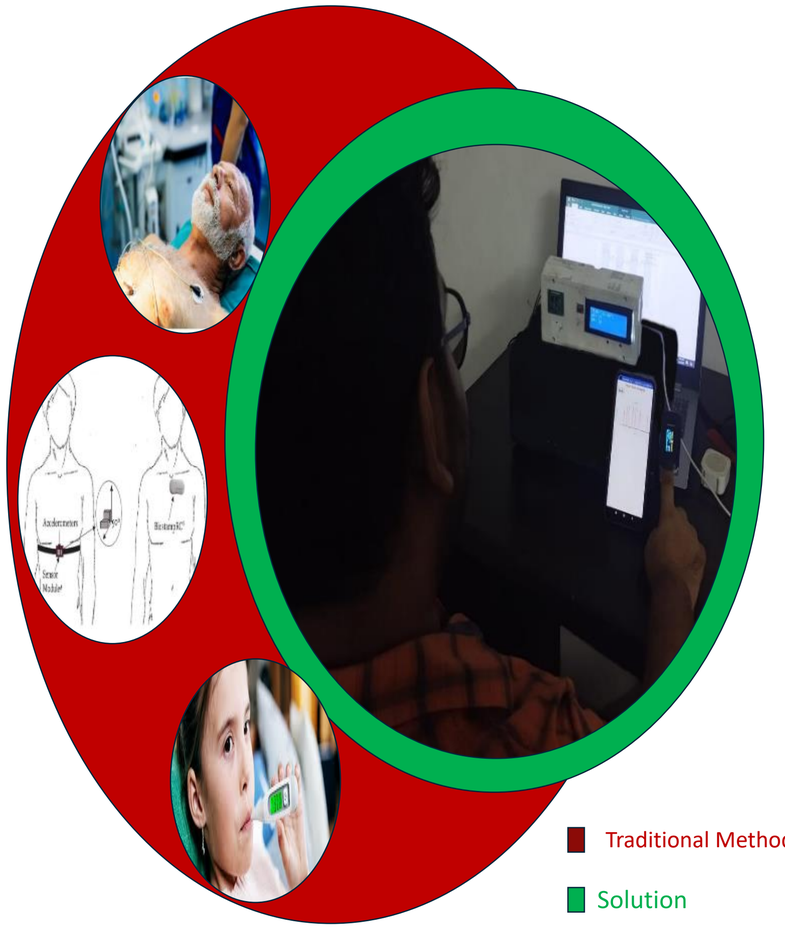
Introduction & Project Goal



- Develop a non-invasive and contactless vital sign monitoring system using mm wave FMCW radar technology.
- Can detect vital signs, including heart rate, respiratory rate and skin temperature without the discomfort associated with traditional probe-based monitoring methods which need body contact.
- Develop an IoMT(Internet of Medical Things) System to eldercare and disease outbreak .
- In short, the project aims to design a contactless IoMT based human vital sign monitoring system using millimeter wave technology, particularly for eldercare and safety monitoring

What is internet of medical things(IoMT)?

- The network of medical devices and applications that connect to healthcare information technology systems through online computer networks.
- It improves patient care by enabling continuous monitoring.
- It integrates health data for advanced analytics, supporting better decision-making and personalized treatment plans.

Motivation

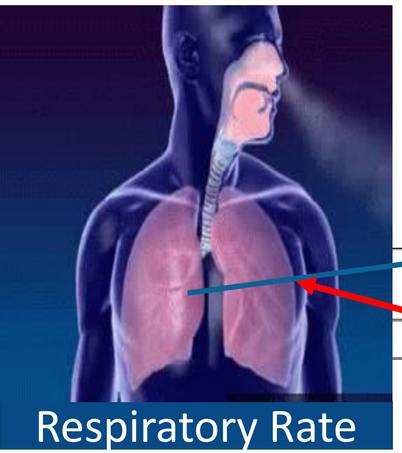
- Imagine in case of disease outbreak like covid 19 health caregivers are using CVSMS device that measures human vital signs without any physical contact from distance .

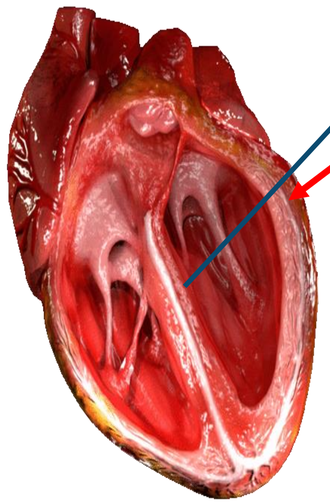
- Imagine a firefighter assessing the vital signs of an fire accident victim in a burning building, using CVSMS device that measures these signs without any physical contact.

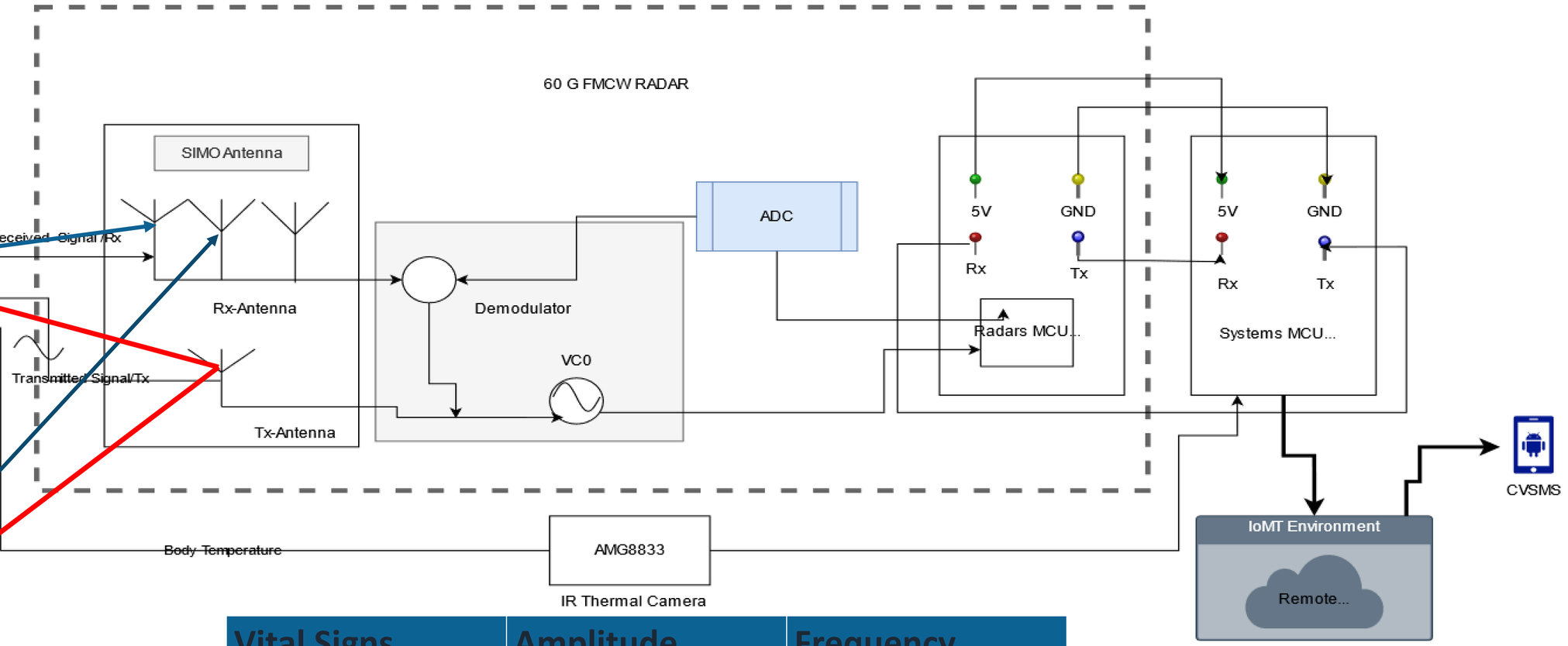
Impact of Project on Society

- 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.

Working Principle Diagram







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 1: Working Diagram Of Heart Rate And Respiratory Rate Measurement Process

Heart Rate

Flowchart

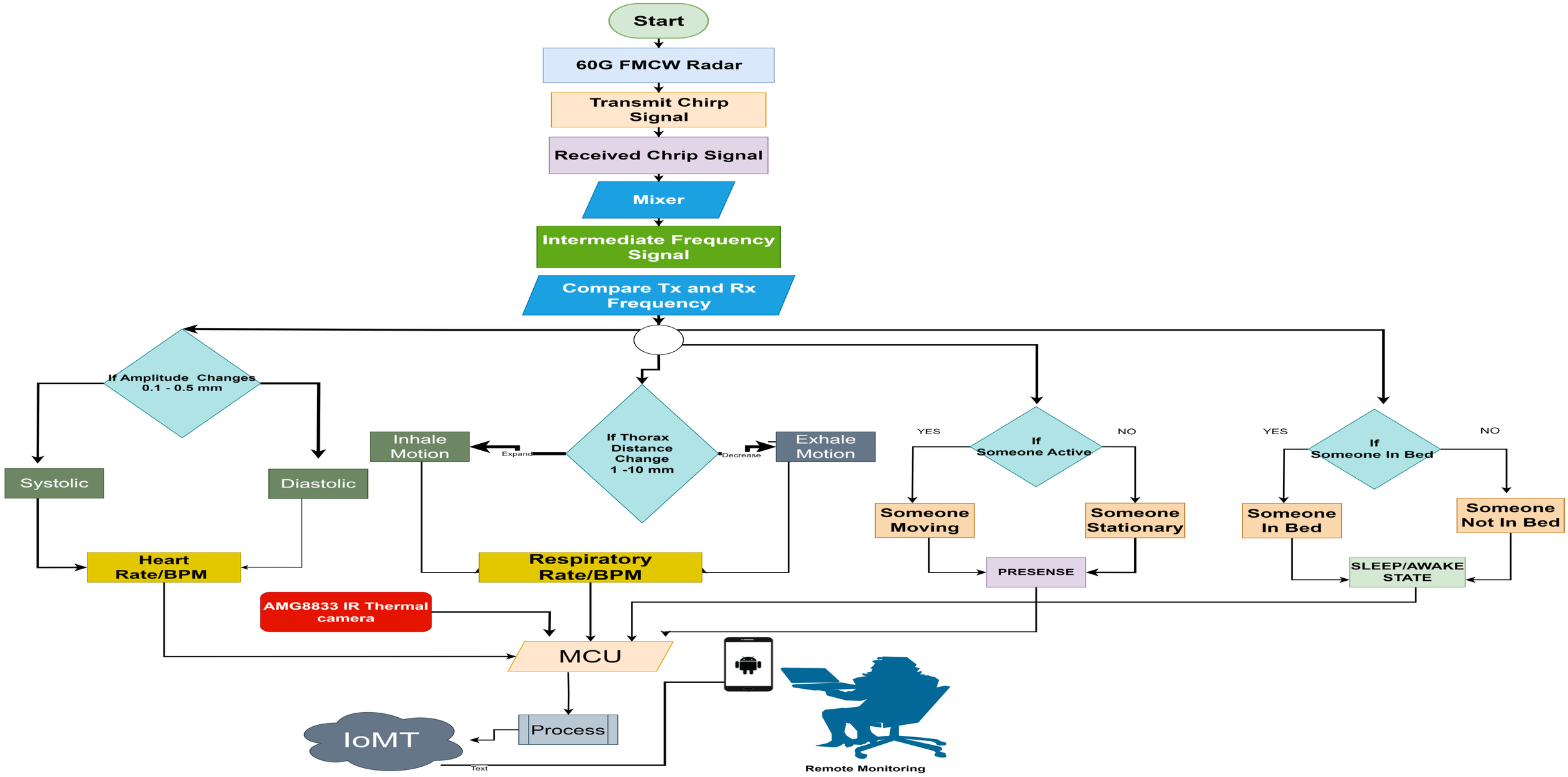
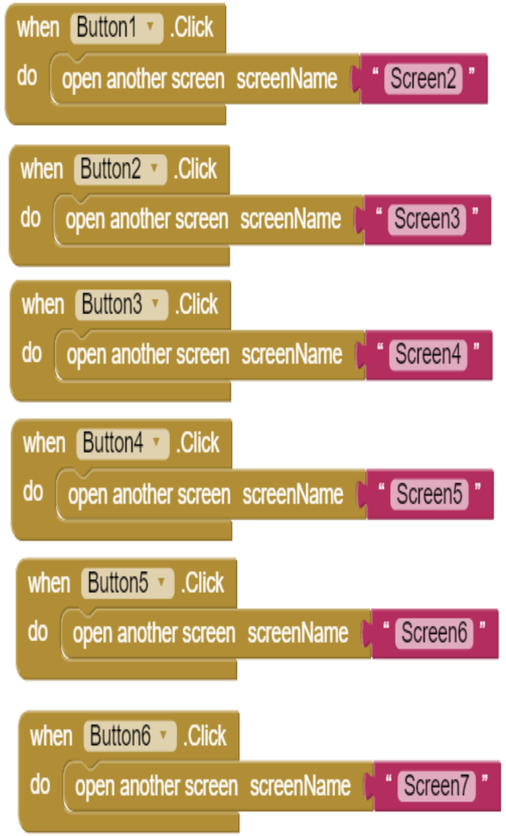


Figure 2: Flowchart of Contactless Vital Sign Monitoring

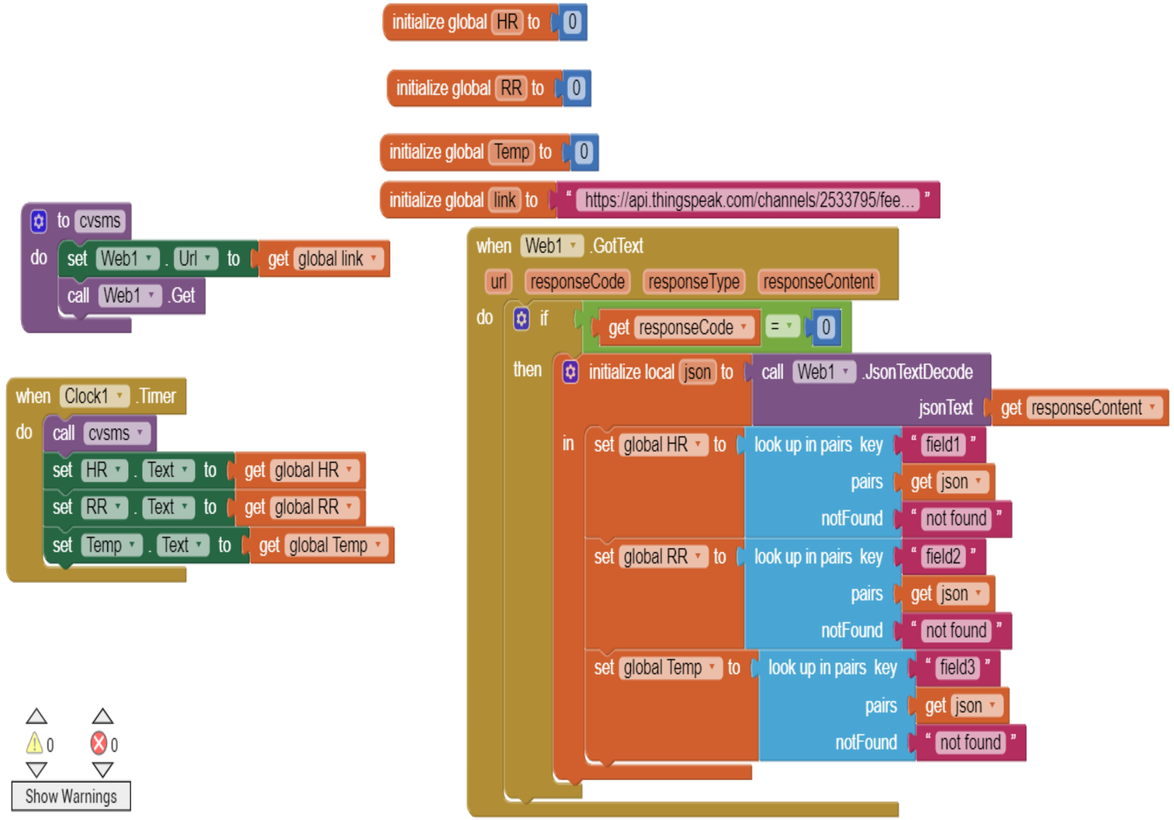
3D MODEL OF THE PROTOTYPE

Figure 3: 3D model of device case using FUSION 360° of Contactless Vital Sign Monitoring Device

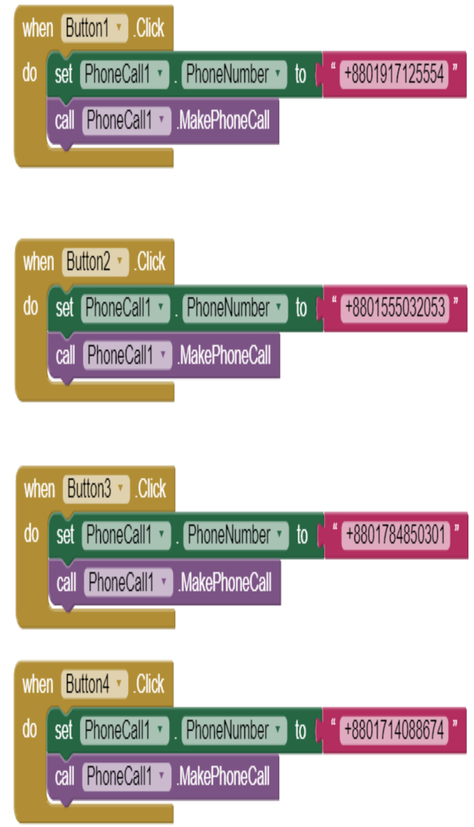
Android App Development



Logic For Screen Changing



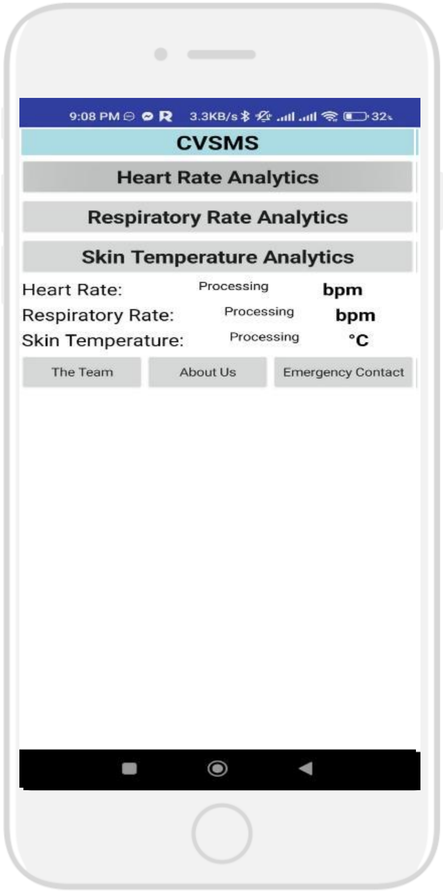
Logic For Pulling Date From ThingSpeak To CVSMS App

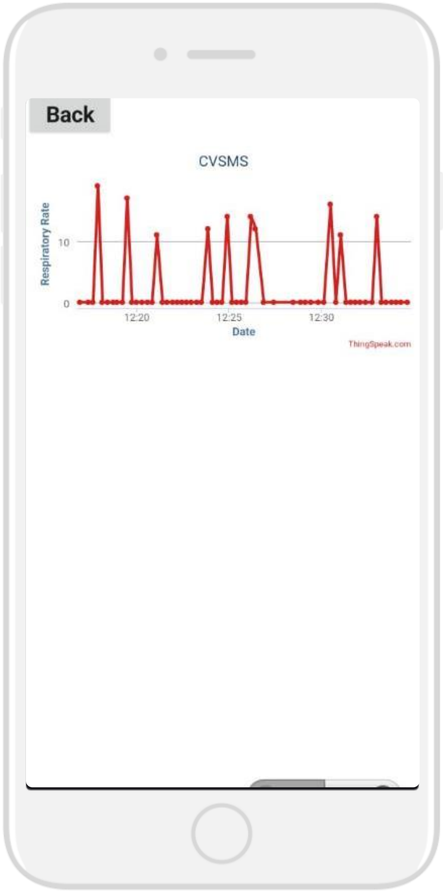


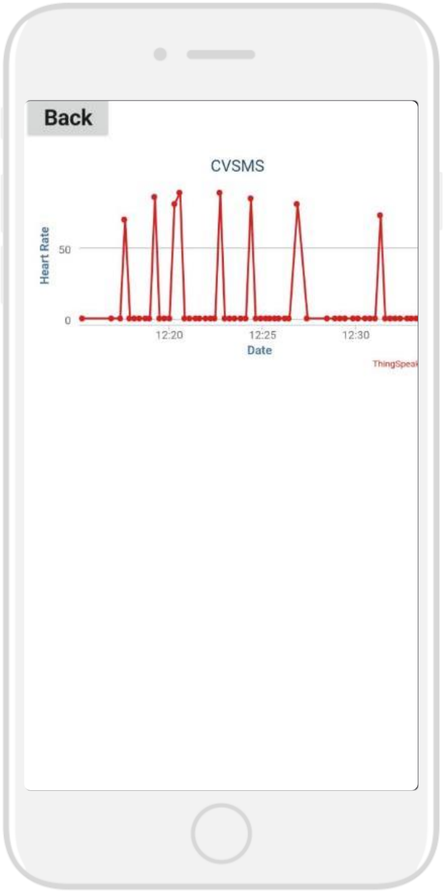
Logic for Emergency Contact

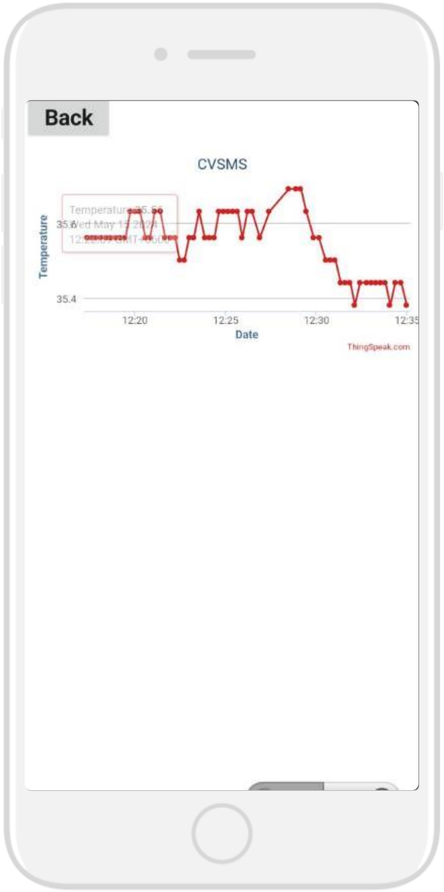
Figure 4: Logic Blocks Contactless Vital Sign Monitoring System App

CVSMS Android App

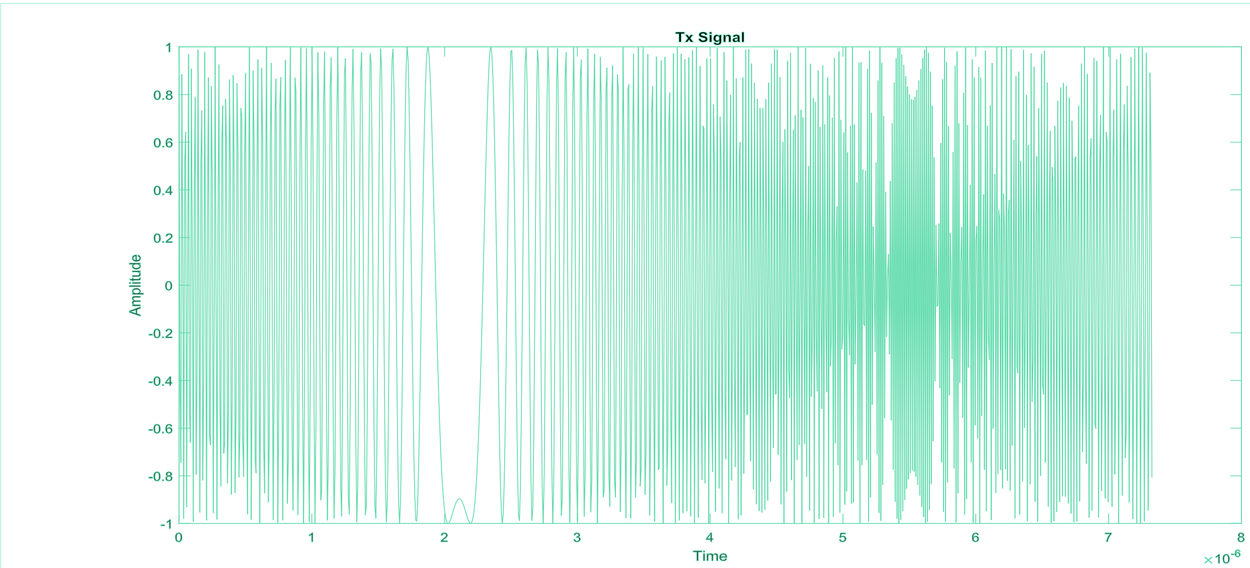


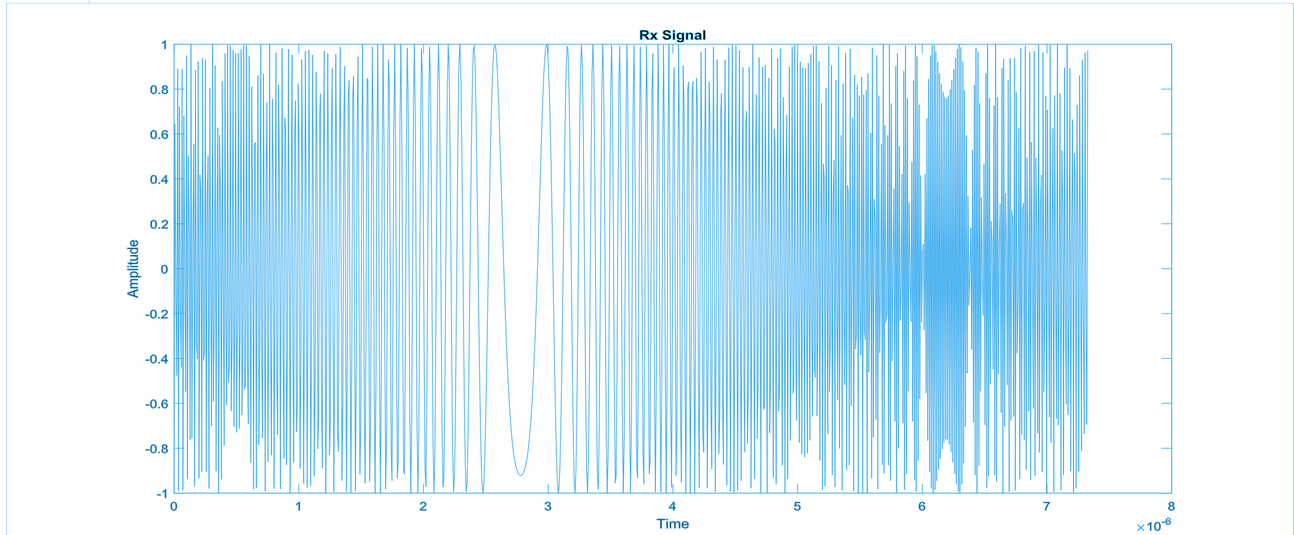


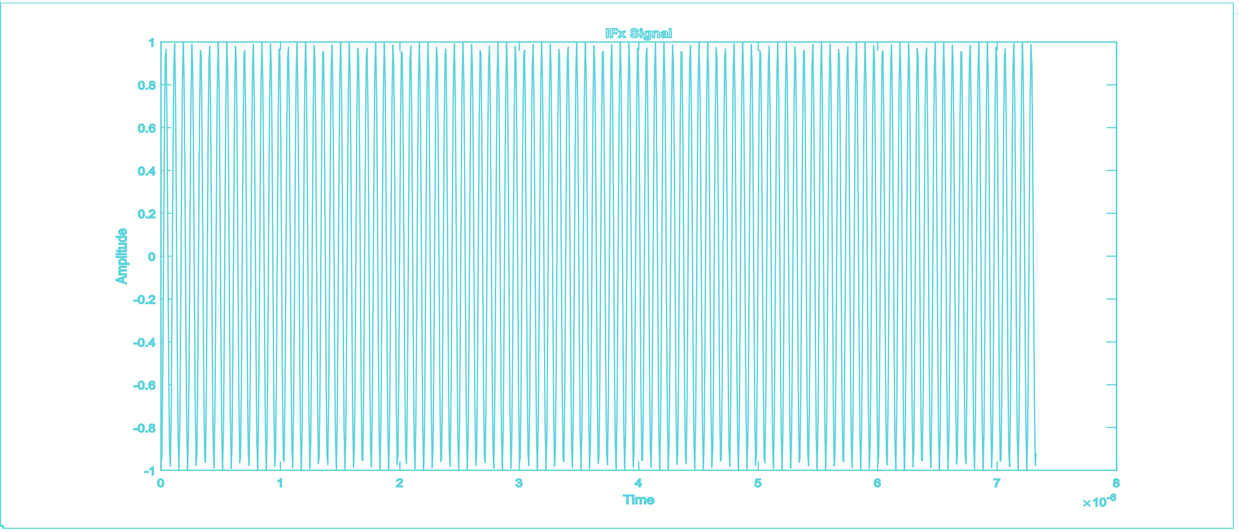




Simulation Results







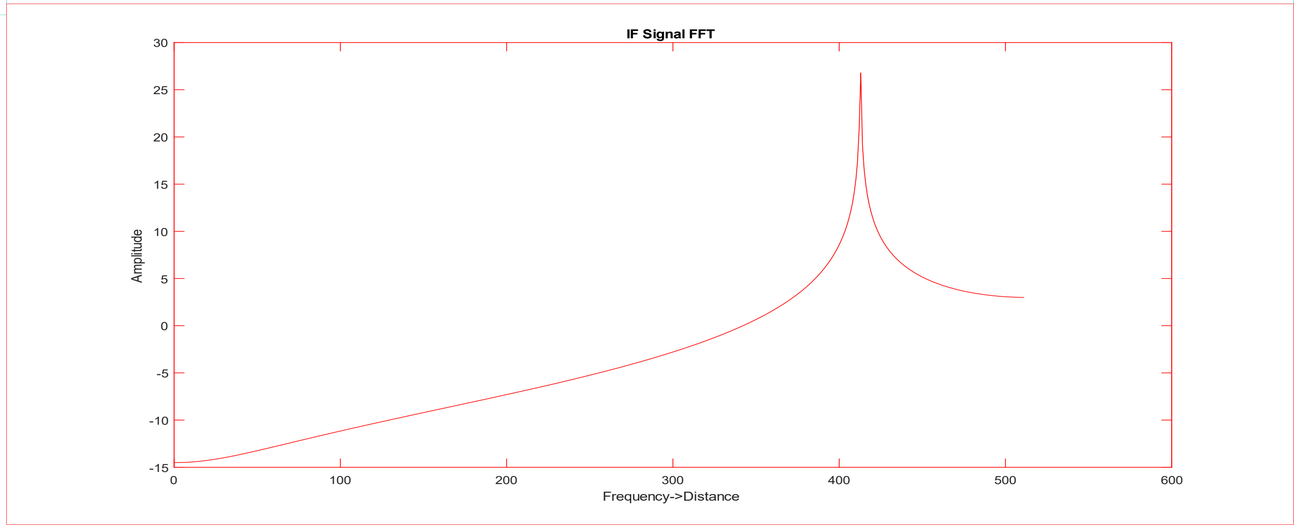


Figure 5. MATLAB Simulation Proof of concept for 60G FMCW Radar Tx, Rx and IF Signal &FFT of IF Signal

Simulation Results

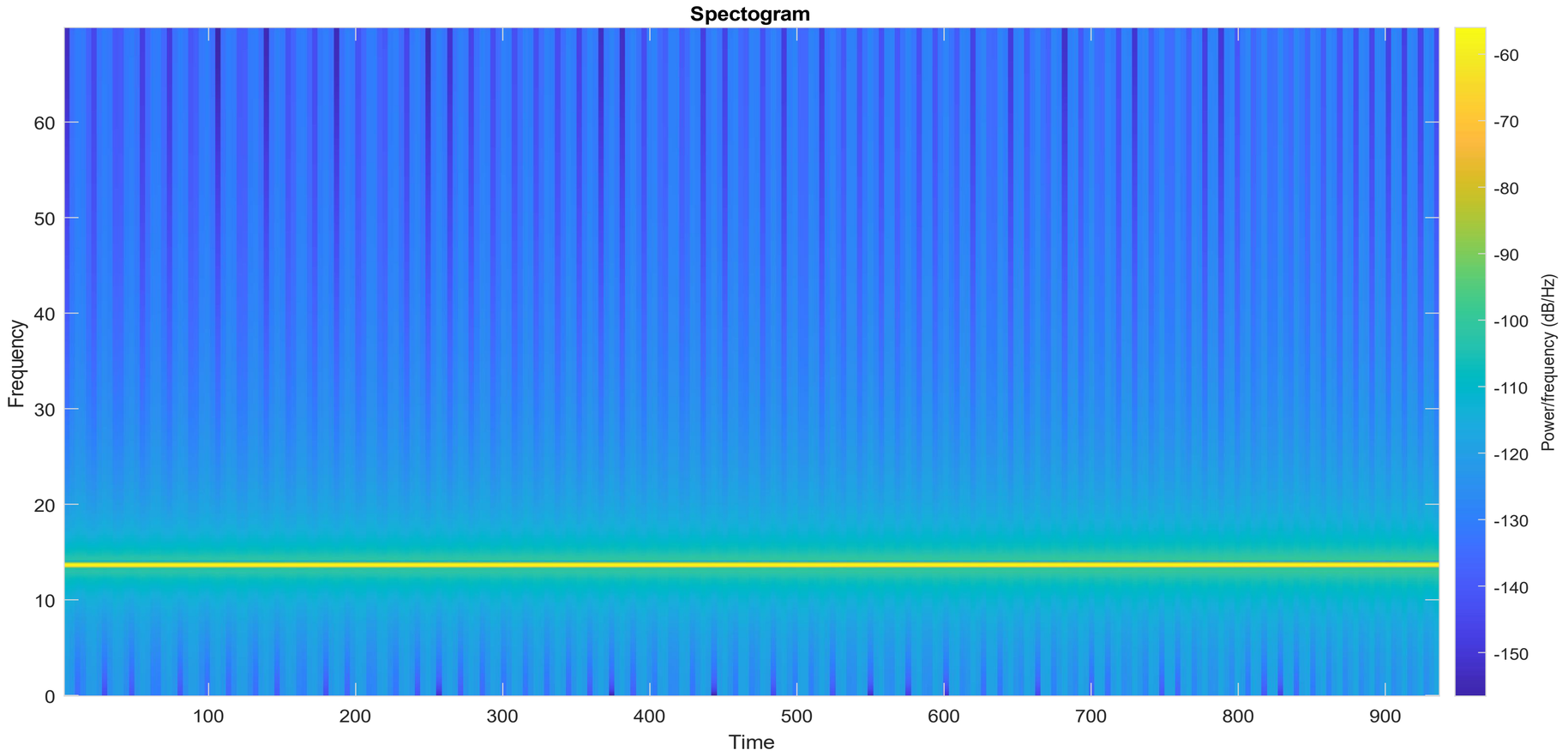


Figure 6. Spectrogram of the 60Ghz FMCW radar antenna

Experimental Setup

Figure 7.Experimental Setup of 60G FMCW Radar

Results Analysis

Equations:

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

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

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

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

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

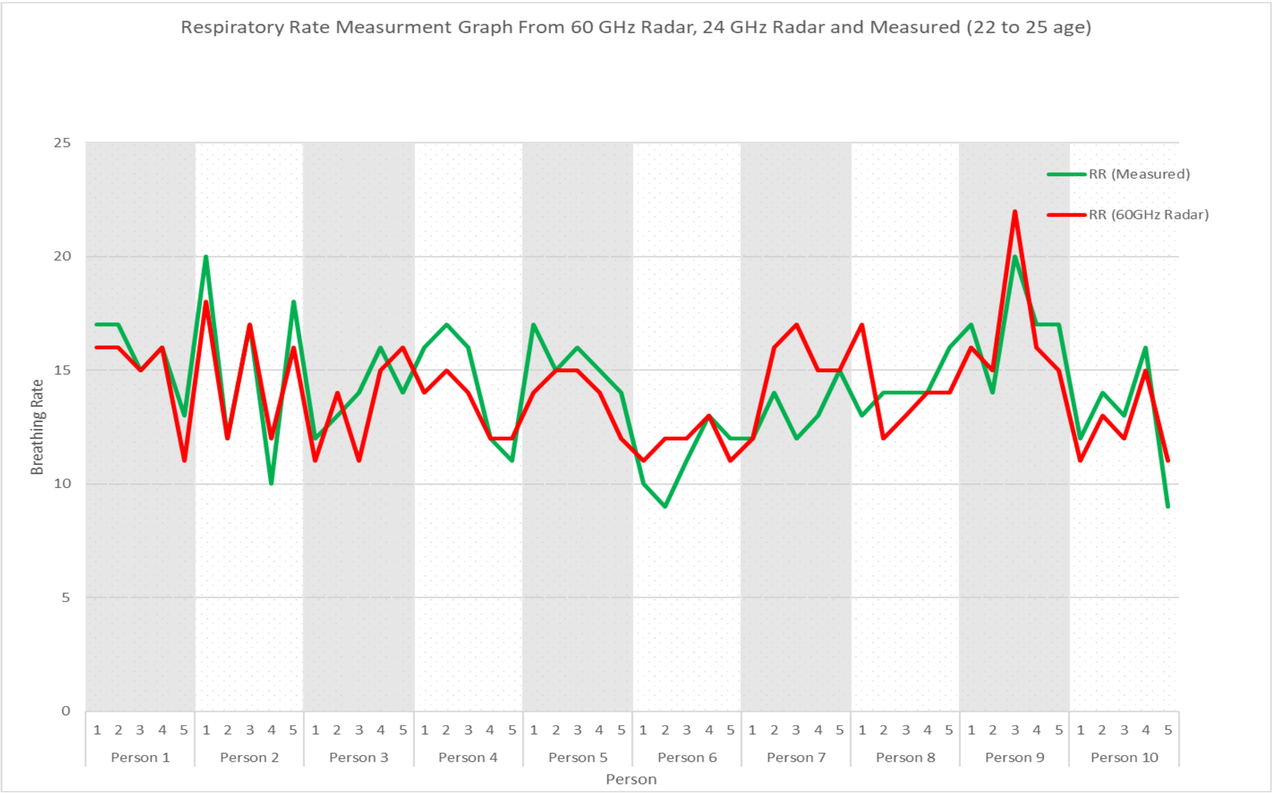


Figure 8.Respiratory Rate Age: 22-25

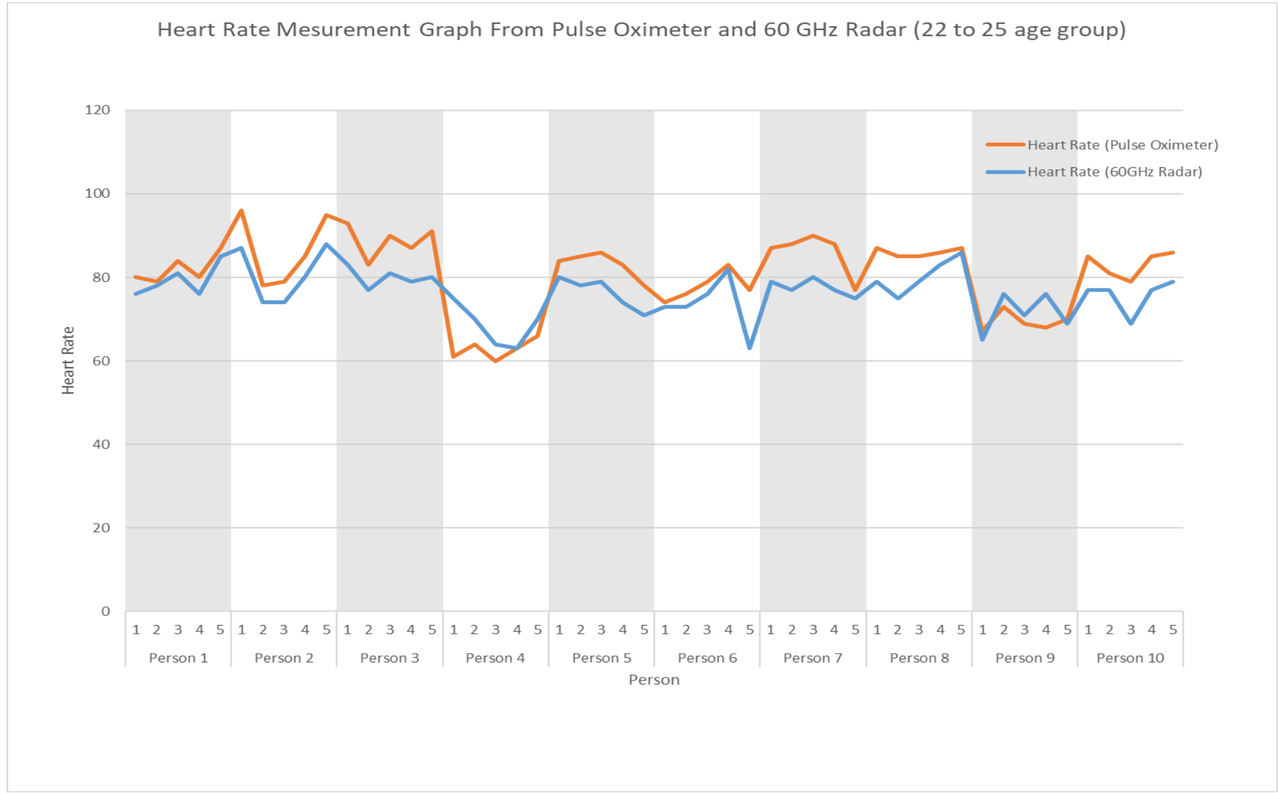


Figure 9.Heart Rate Age: 22-25

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

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

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

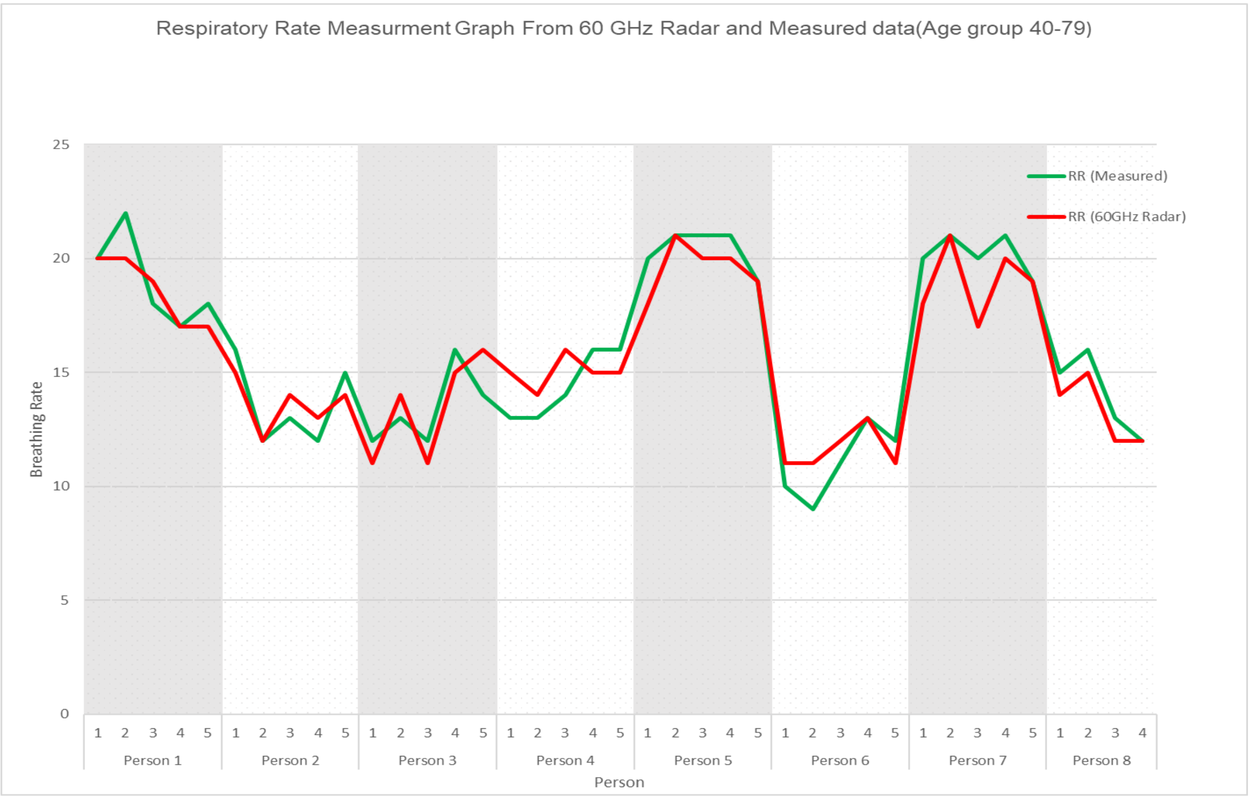


Figure 10.Respiratory Rate Age: 40-79

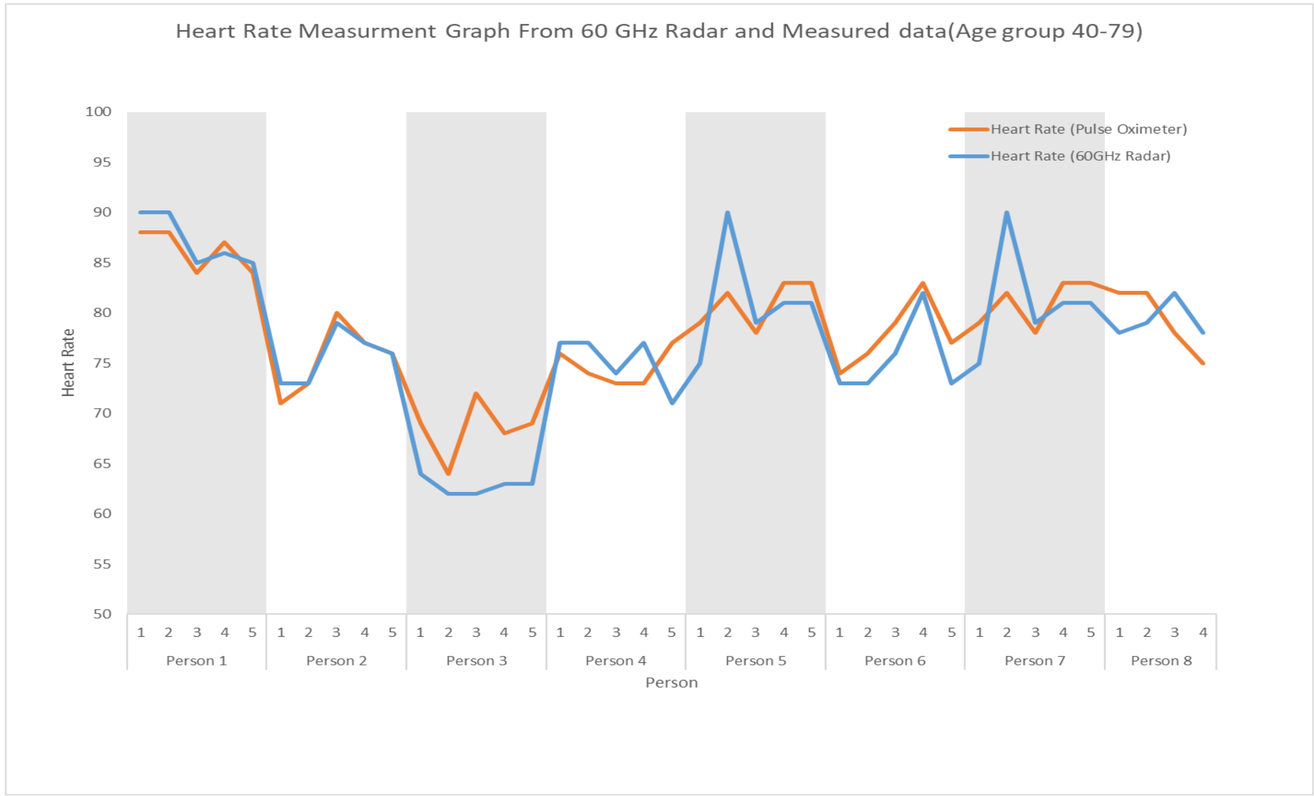


Figure 11.Heart Rate Age: 40-79

Circuit Diagram

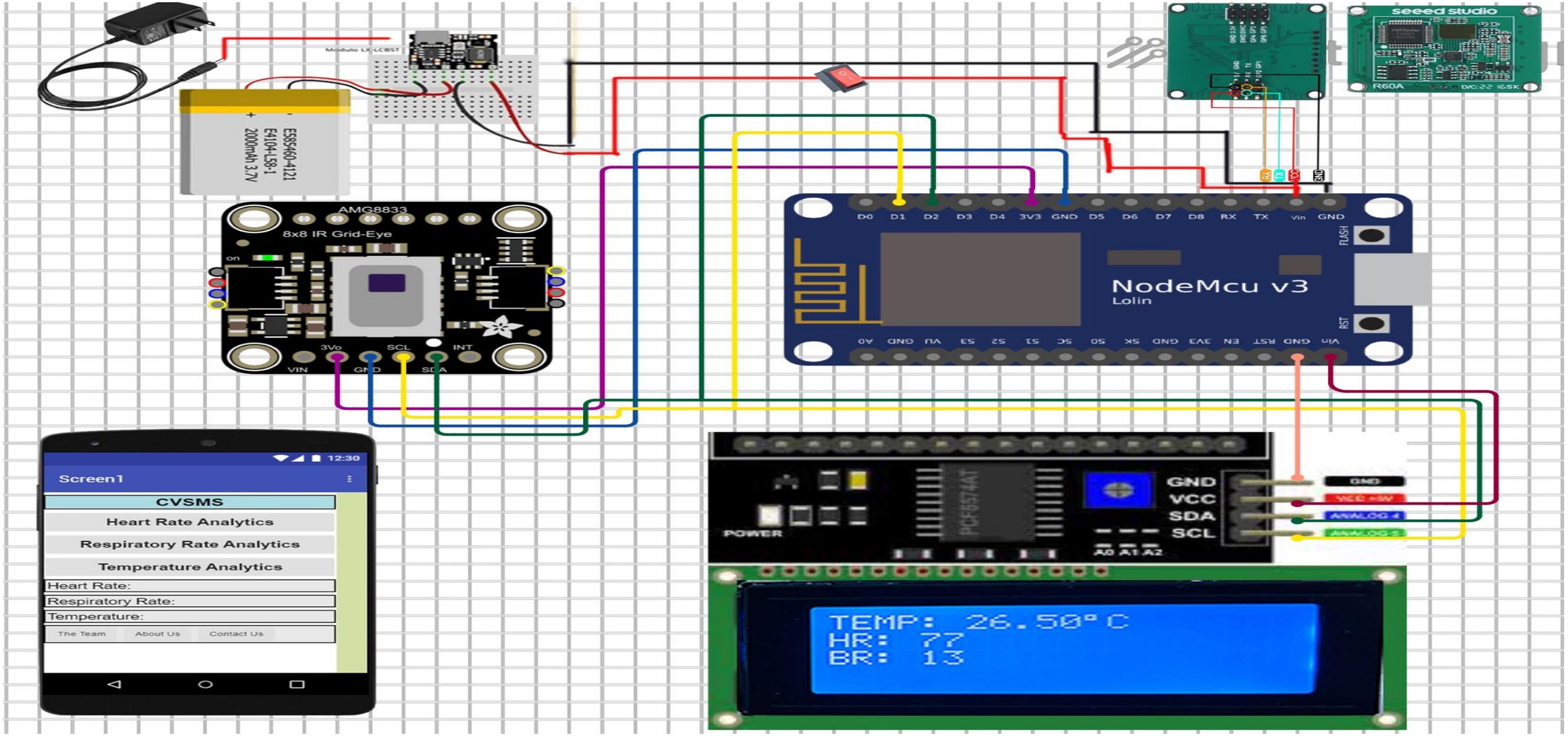


Figure 12: Circuit Diagram of Contactless Vital Sign Monitoring System

Hardware Implementation

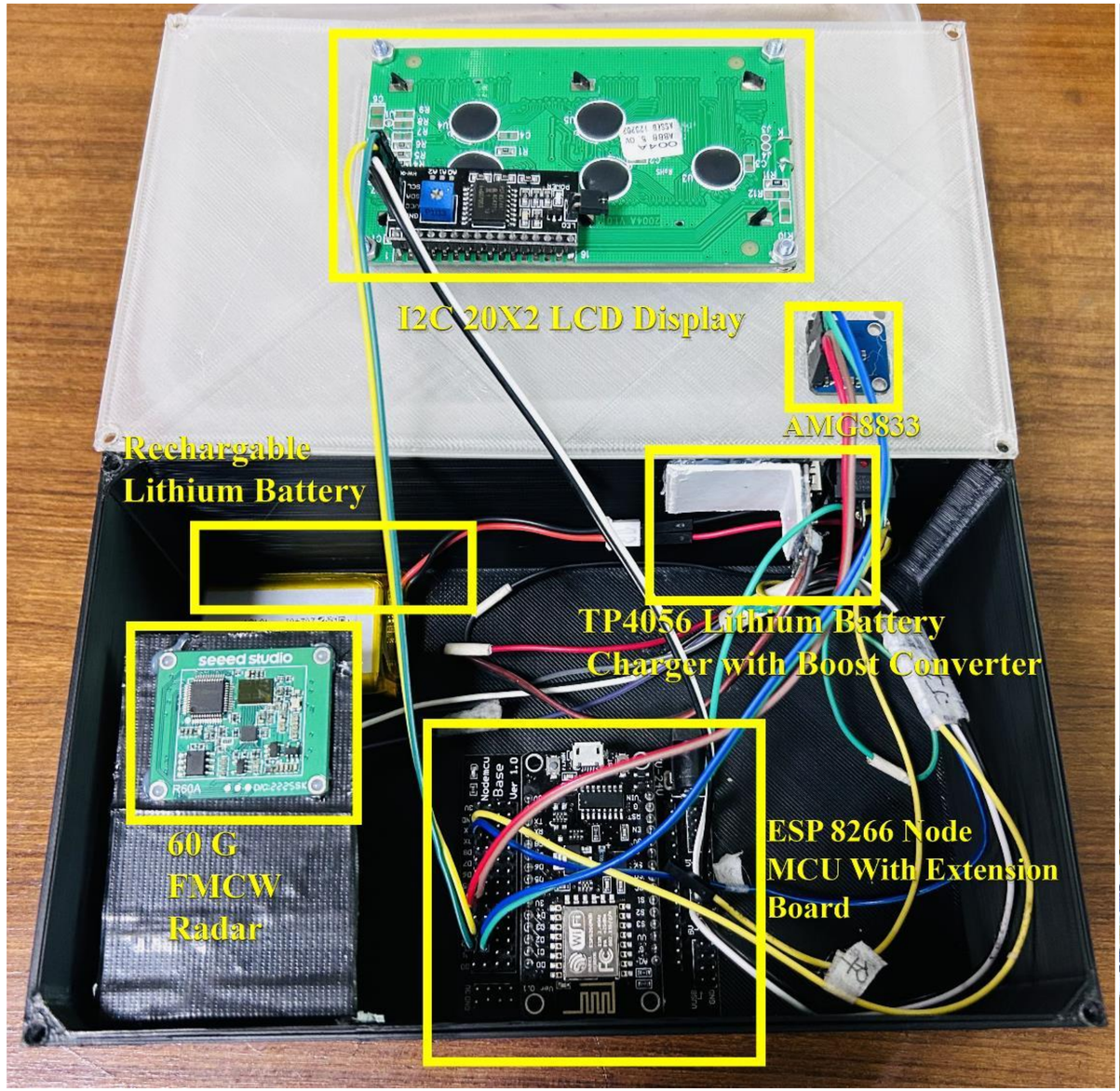
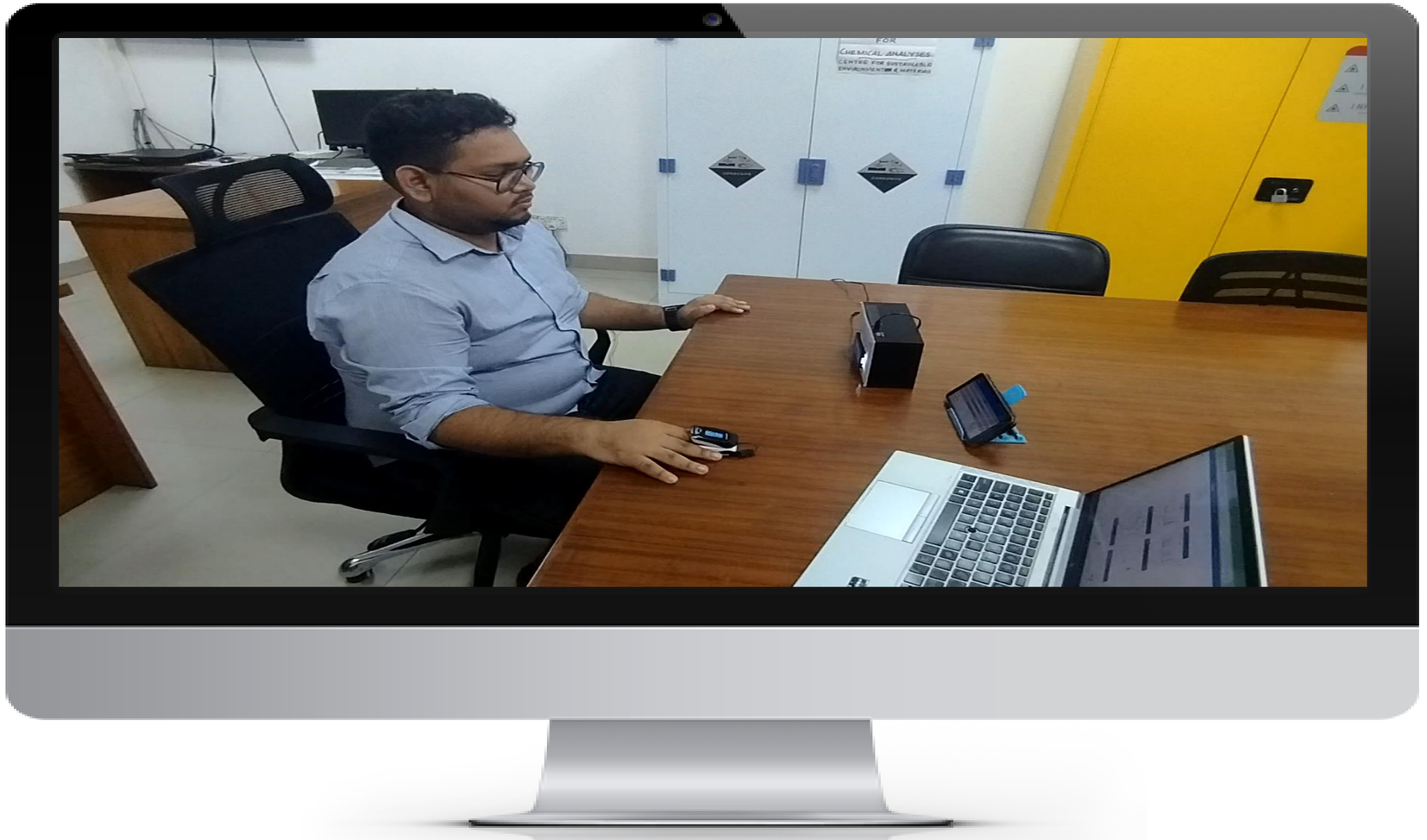


Figure 13.Inside View of the Device

Figure 14. Outer View of the Device

Project Demonstration Video



Project Finance

Components	Quantity	Projected Price (Tk)	Total Price (Tk)
60 GHz Radar	1	5500	5000
Thermal Sensor	1	6500	6700
ESP 8266 Node MCU	1	400	420
BMS Circuit	1	450	295
LCD Display with I2C module	1	600	548
Battery	3	300	270
Node MCU ESP8266 Extension Base Board	1	250	260
Battery Adapter	1	350	350
3D printing		1800	1500
Miscellaneous		500	400
	Total	16,650	15,743

Total Estimated Project Cost = BDT.16,650/-

Total Actual Cost of Project = BDT. 15,743/-

% of Error in Cost Estimation = (Projected cost-Actual Cost)/Projected cost ∗100%
(16,650−15,743)/16,650∗100 %

% of Error = -0.054%

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 & Ethical Concerns

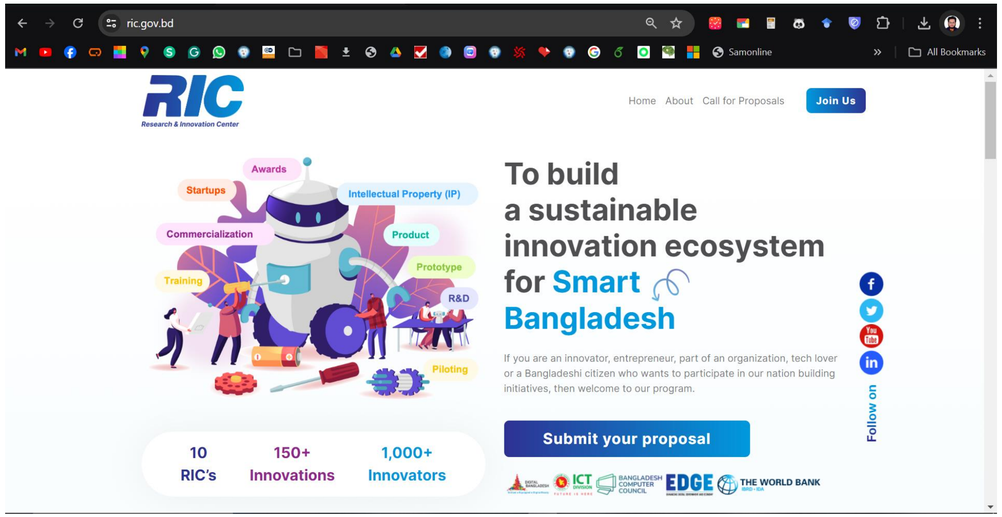
Minimum Separation between Users:
It can not detect multi person heart rate and respiratory tracking. CVSMS utilizes FMCW to distinguish between reflections from different users. For ideal point reflectors, FMCW can separate objects if they are at least $C/2B$ apart (where C is the speed of light and B is the bandwidth).

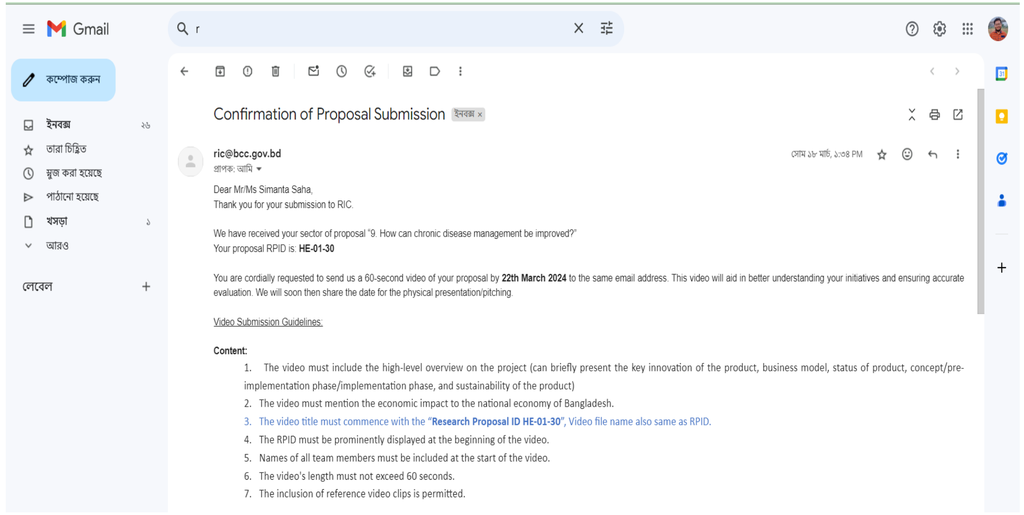
Monitoring Range:
CVSMS requires a minimum signal-to-noise ratio (SNR) for accurate signal extraction. The maximum distance at which users can be detected is 1.5 meters, as the SNR diminishes with increasing distance from the device.

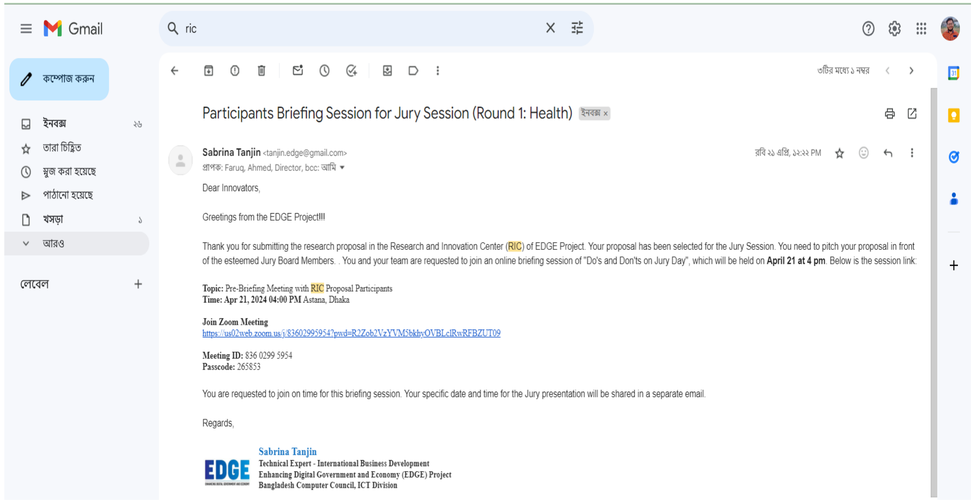
Quasi-static Requirement:
The device measures vital signs only for quasi-static users (e.g., those who are sitting Infront of the device) because full body movements can overwhelm the small variations caused by vital signs, hindering accurate capture of these minute movements.

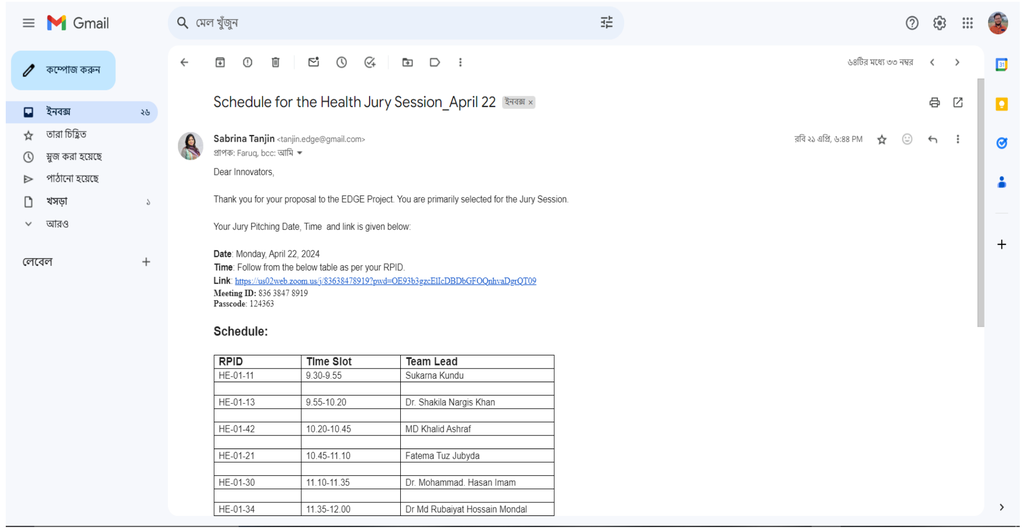
Non-human Motion
CVSMS can distinguish reflections from various moving objects, including humans, fans, and pets, using FMCW. It detects breathing by analyzing the periodicity of reflections, which differs from the periodicity of non-human objects like fans.

RIC Round 3-Clearing Project:









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 100 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. Also developed 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.

Acknowledgment

Md. Sayzar Rahman Akash, a research assistant at Center for Biomedical Research(CBR),American International University-Bangladesh (AIUB), has our sincere gratitude for his essential advice and assistance during the course of our study.

References

[1]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.

[2]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.

[3]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.

[4]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.

[5]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.

[6]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.

[7]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, p. 6505, Nov. 2020, doi: 10.3390/s20226505.

[8]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, p. 7543, Oct. 2022, doi: 10.3390/s22197543.

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