Medical Data Over Sound for Vital Signs Monitoring

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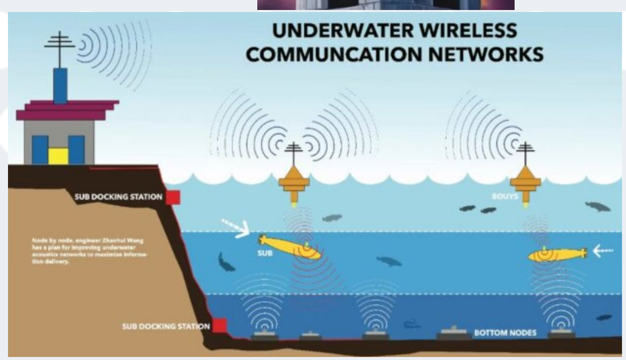
- State of the art
- Methodology/Solution/POC
- Testing and results
- Conclusion

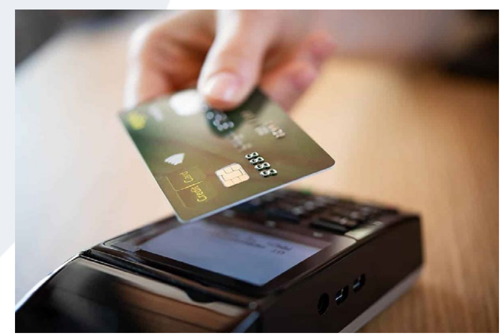
Problem definition

- **Medical Data over Sound (MDoS), Proof of Concept.**
- Can we transmit medical signals via air by sound?
- If we can, how to do it in the most efficient way by applying state of the art technologies?
- What are the advantages/disadvantages of such a solution?

State of the art

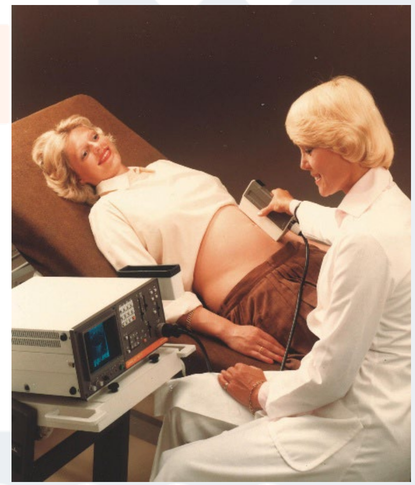
- Since the existence of civilization, information has been transmitted via sound or via image.
- Through the ages in different ways.
- Language emerged as a revolutionary means of transmitting knowledge, emotion, and culture.

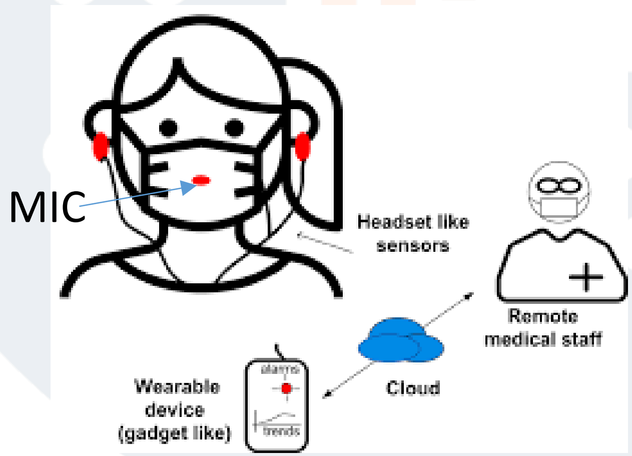




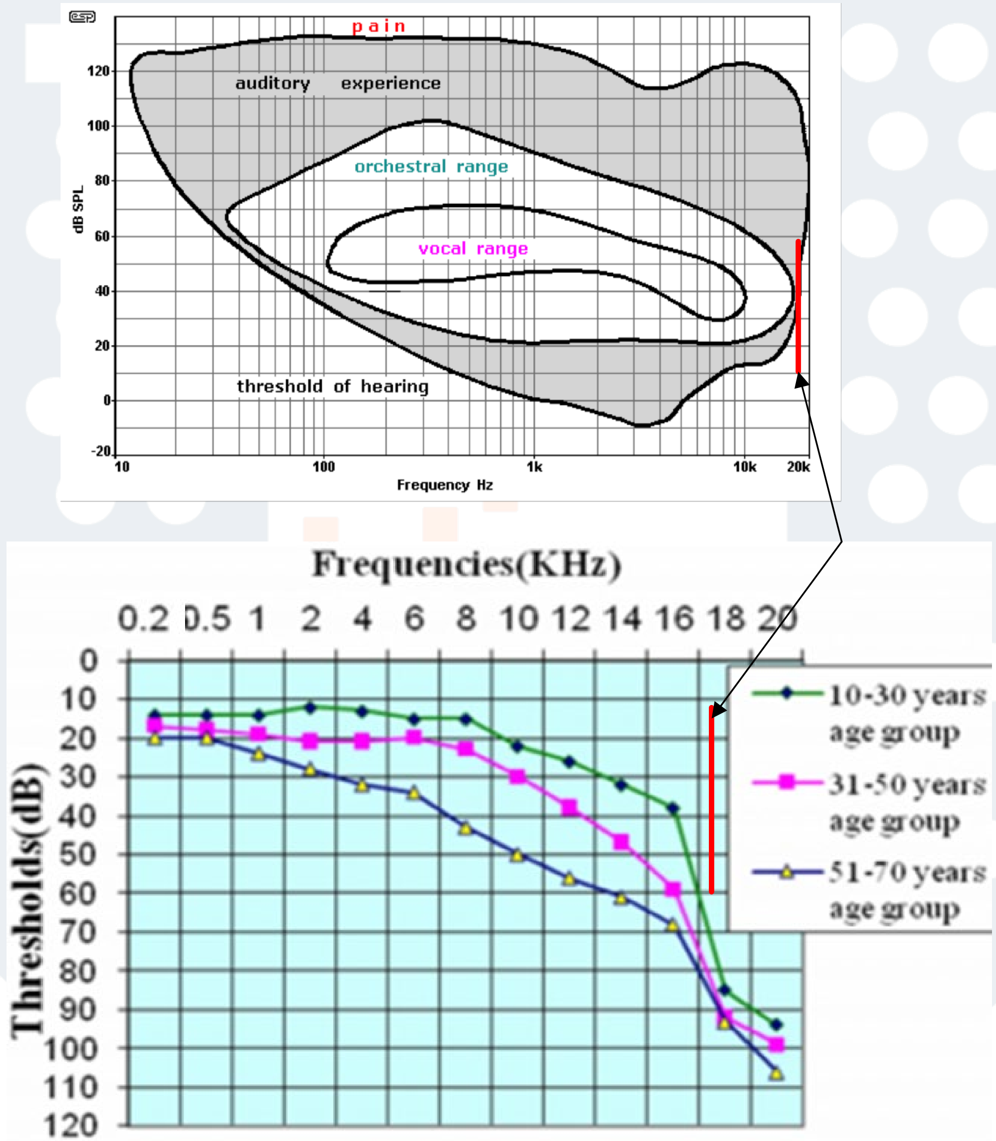
State of the art

- Using sounds in medicine is applied in many fields on direct way, as listening to respiratory and heart sounds, gastro auscultation, ultrasound, for COVID-19 detection etc.



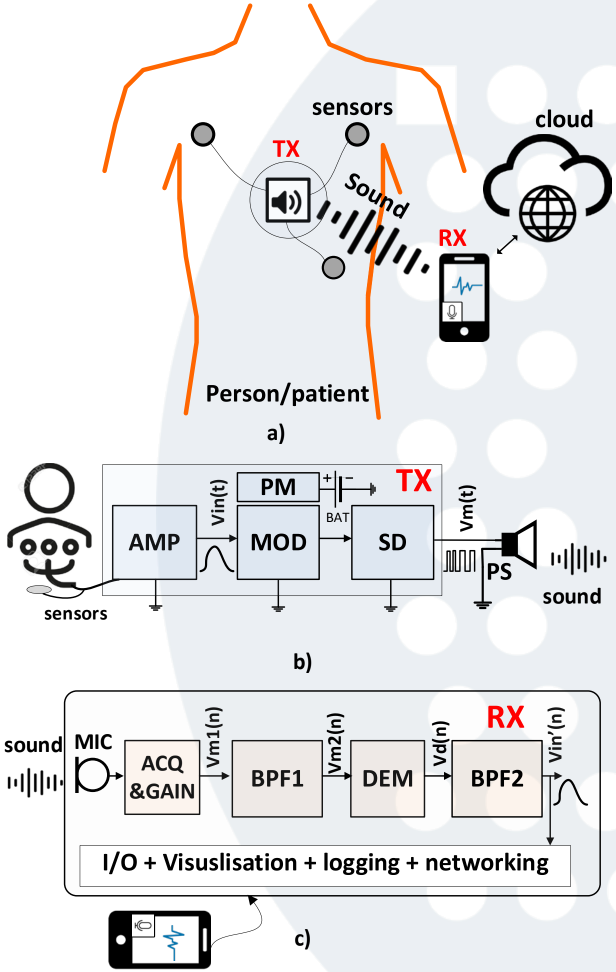


Methodology/Solution/PoC



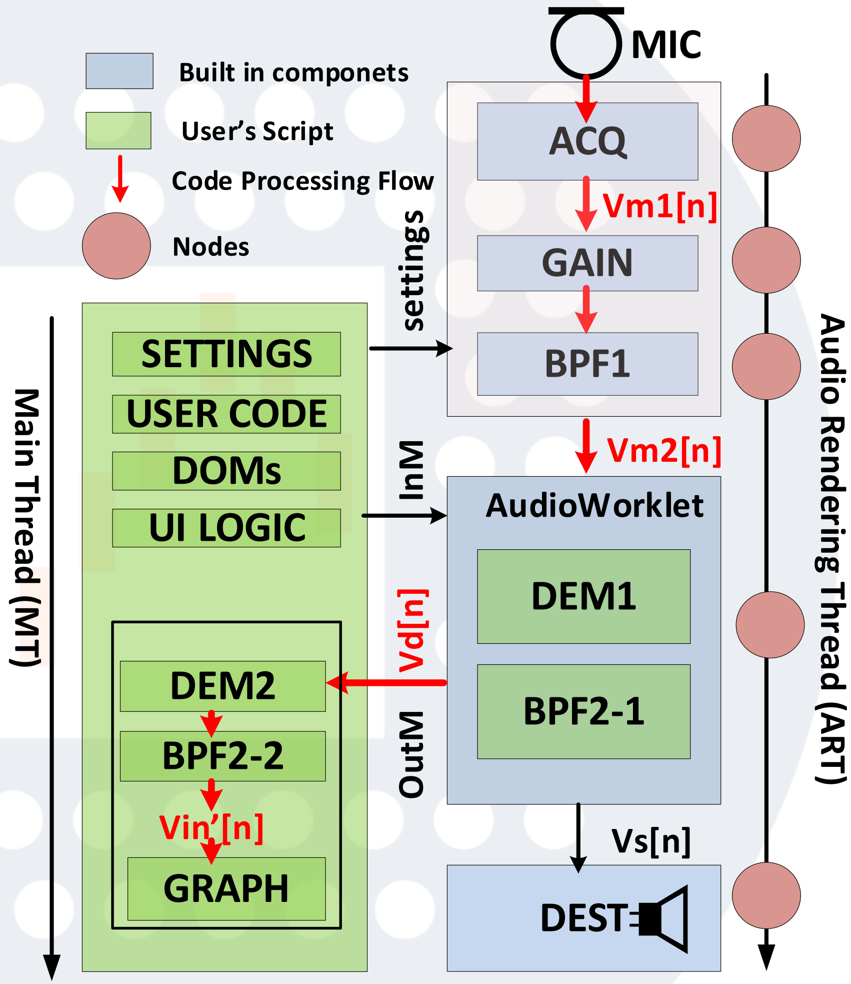
Selection of the working conditions.
In a range 16kHz:18kHz with adequate transmission power

PoC-1Ch



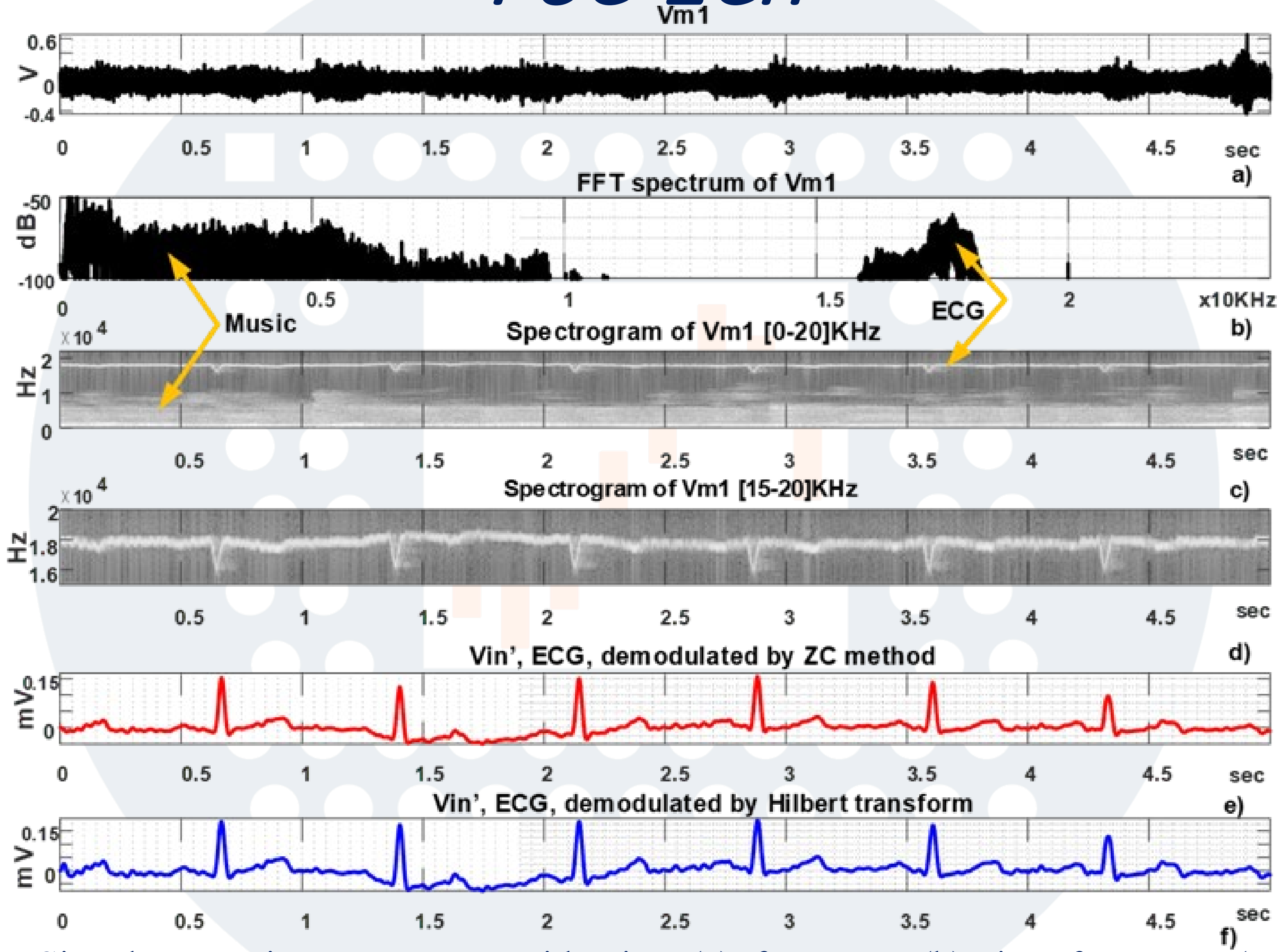
Architecture of 1Ch version

a) general b) electronics



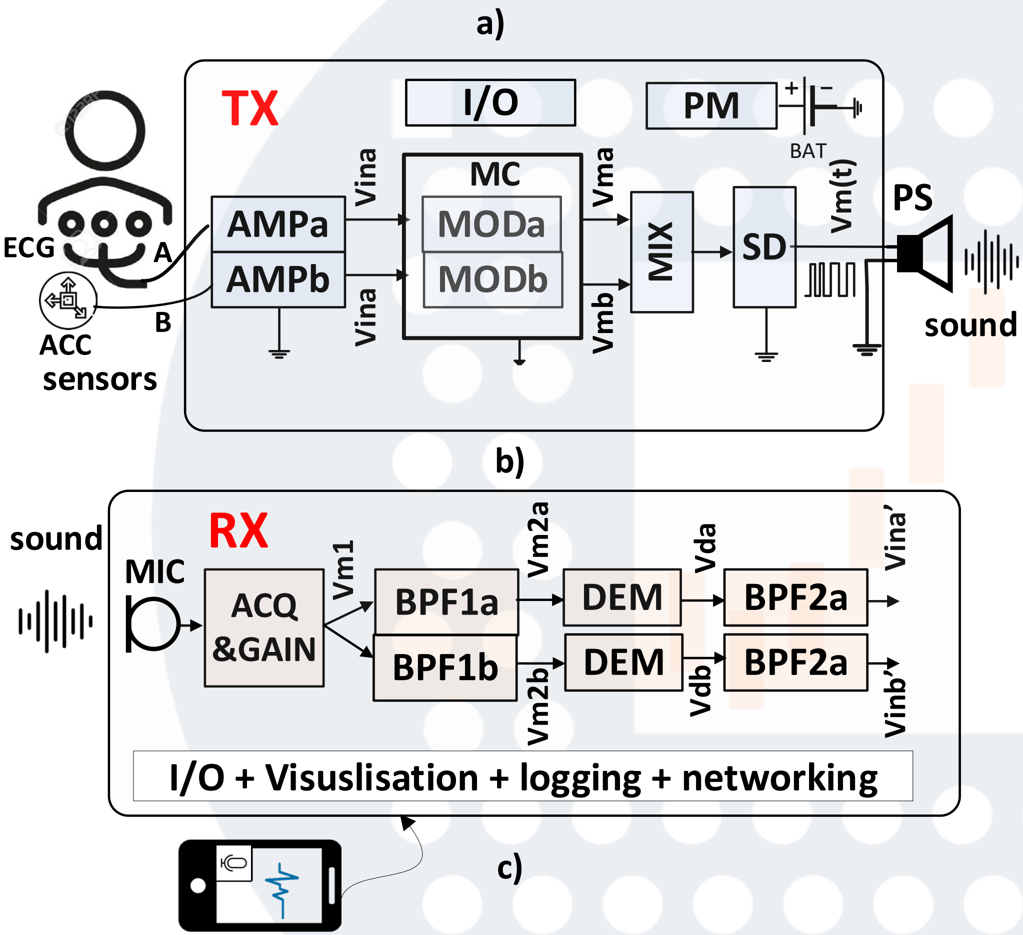
Software decoding architecture (JavaScript+HTML+CSS+AudioAPI, 1Ch)

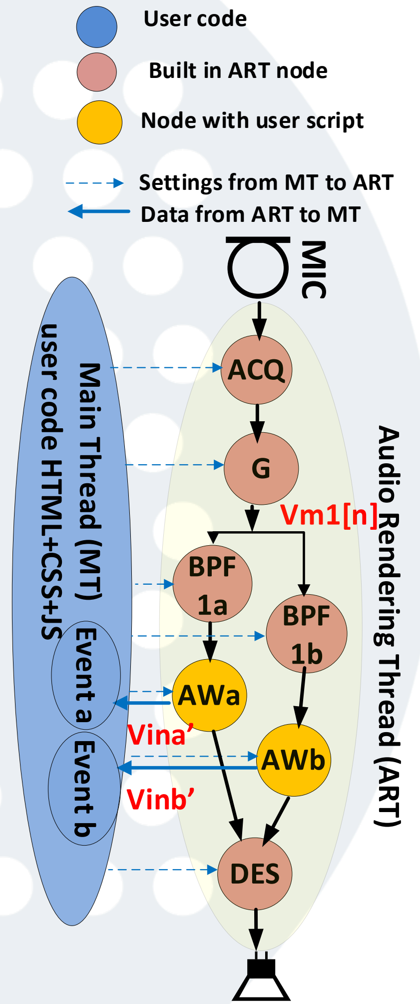
PoC-1Ch



Signal processing steps on RX side, time (a), frequency (b), time-frequency (c,d) domains and demodulation by ZC and Hilbert

PoC – 2Ch





Architecture of CW, 2CH version

a) general b) electronics

Software decoding architecture (JavaScript+HTML+CSS+AudioAPI

PoC-2Ch

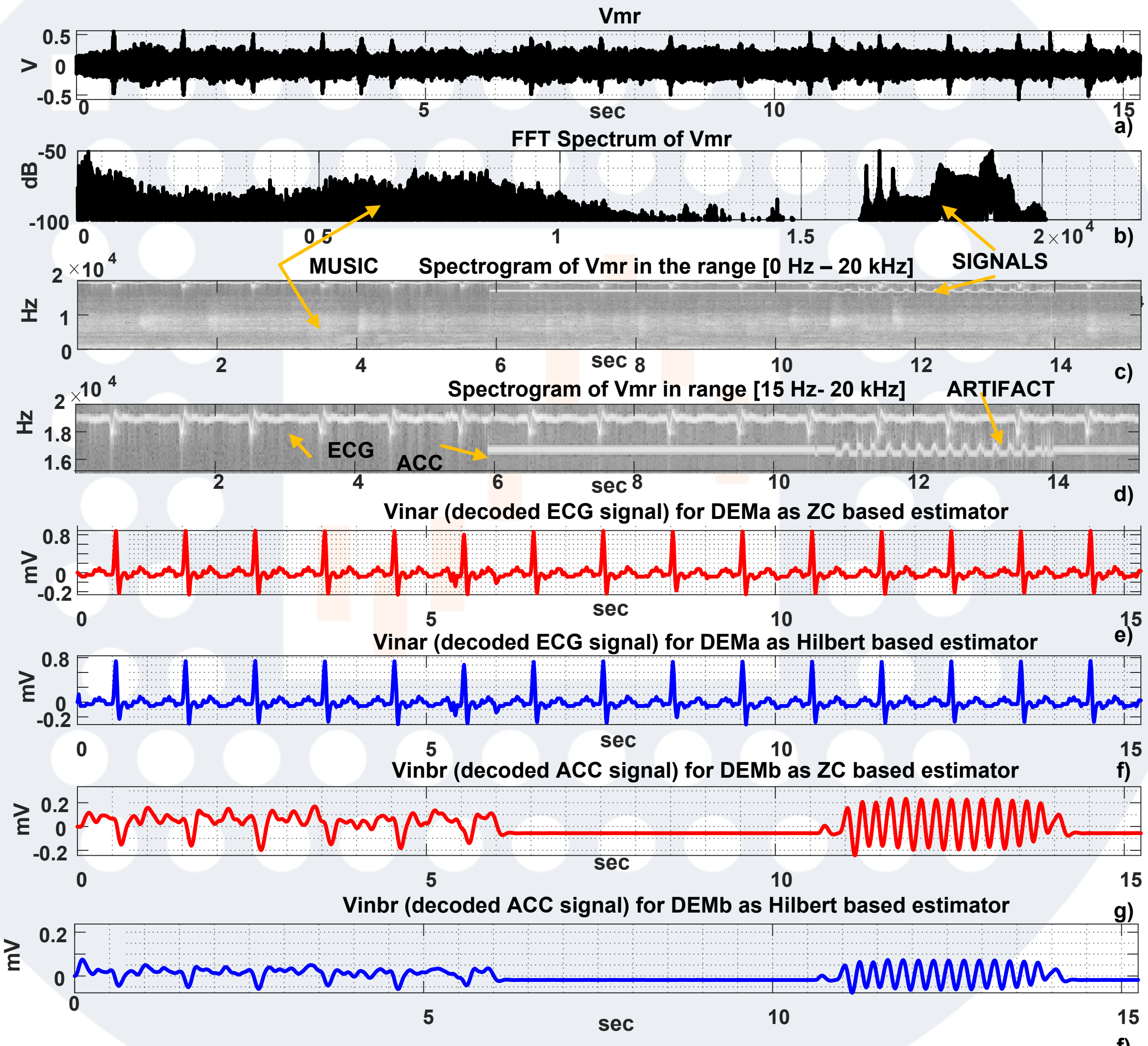


Illustration of the signal processing steps on RX side, implemented on real ECG and ACC signals.

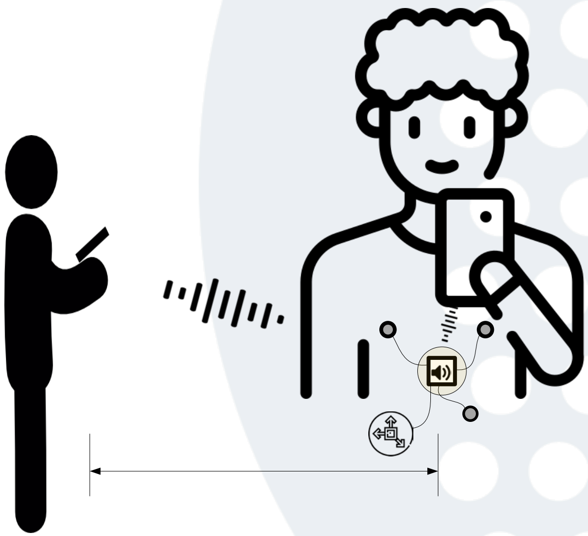
Testing & results

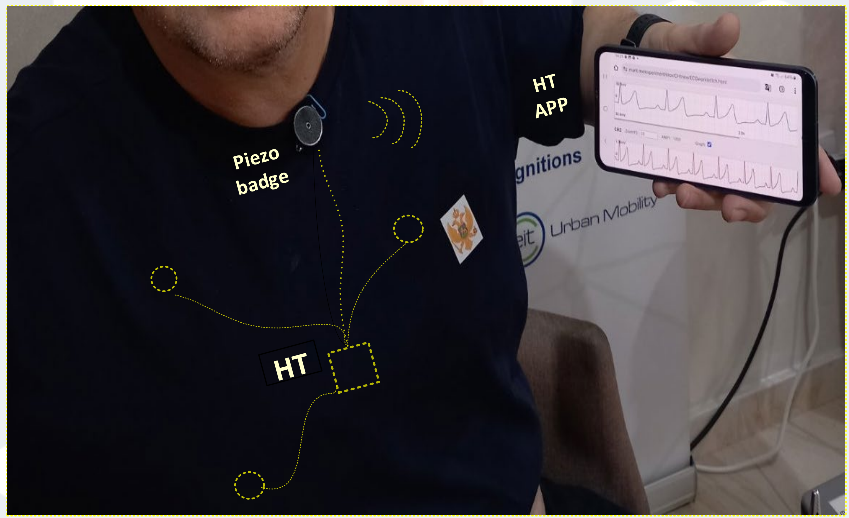
- Development environment

The experimental setup demonstrating the CardiaWhisper system. (1) The CardiaWhisper device acquires ECG signals using standard disposable Ag/AgCl electrodes and transmits data via sound. (2) A mobile phone displays the signal's spectral content for system verification. (3) Another phone runs custom JavaScript software for real-time demodulation and ECG visualization. (4) A desktop computer receives and analyzes the same signal simultaneously for development, testing, and debugging purposes.

Testing & results…

- Experiment environment



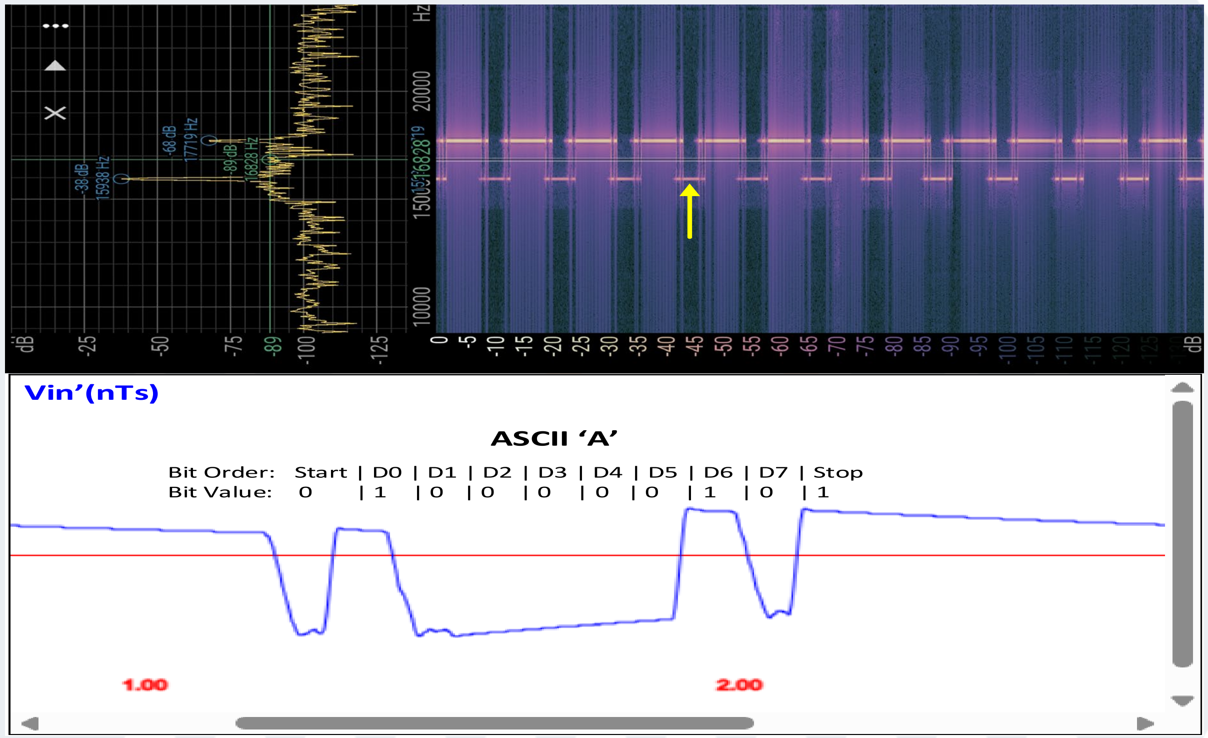


c)

Testing scenario a), system demo b), c) prototype

Testing & results…

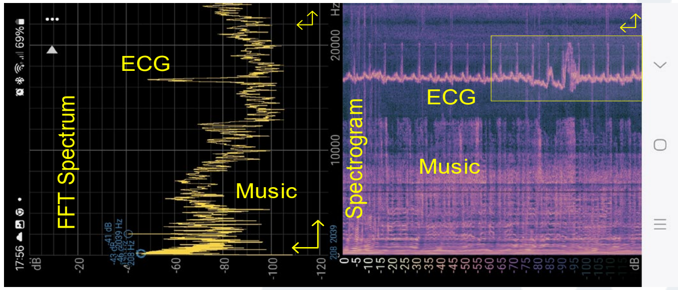
- Functionality testing, the simplest case, sending only alarm



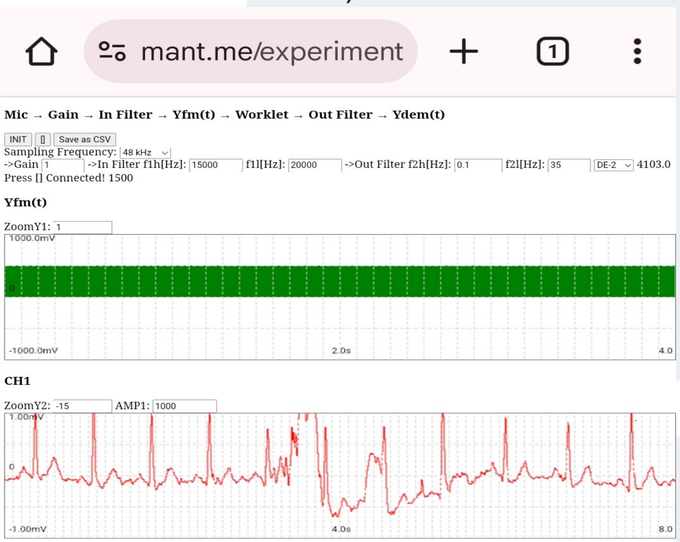
"A" – Alarm, sent over sound

Testing & results...

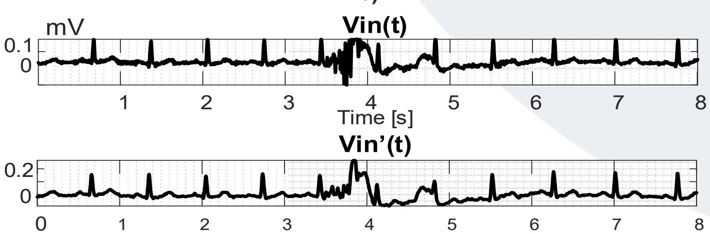
- Functionality testing, Vital signs, 1Ch Version, ECG or PPG

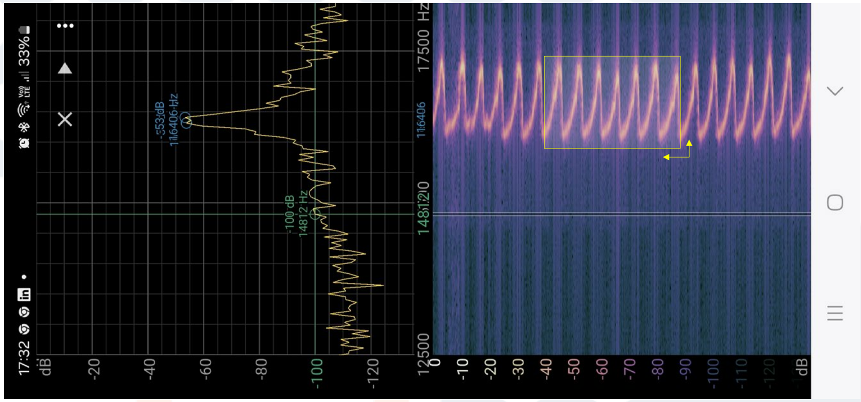


a)

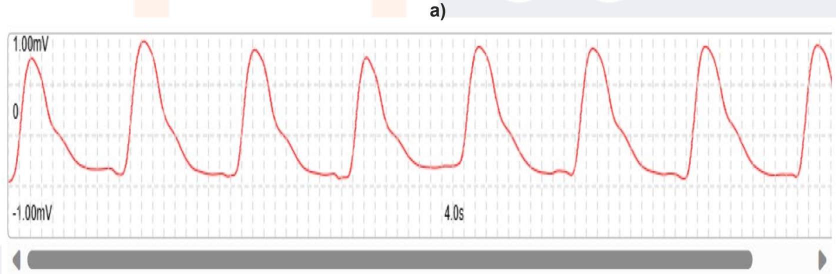


b)





a)



b)

Time, frequency and time-frequency domains are considered, left ECG case, right PPG

a) FFT and STFT spectrums,
b) demodulated signal by HT APP,
c) up original ECG signal on the input of transmitter,
d) down reconstructed ECG signal on the output of receiver.

Testing & results…

- Functionality testing, Vital signs, 2Ch Version, ECG and PPG

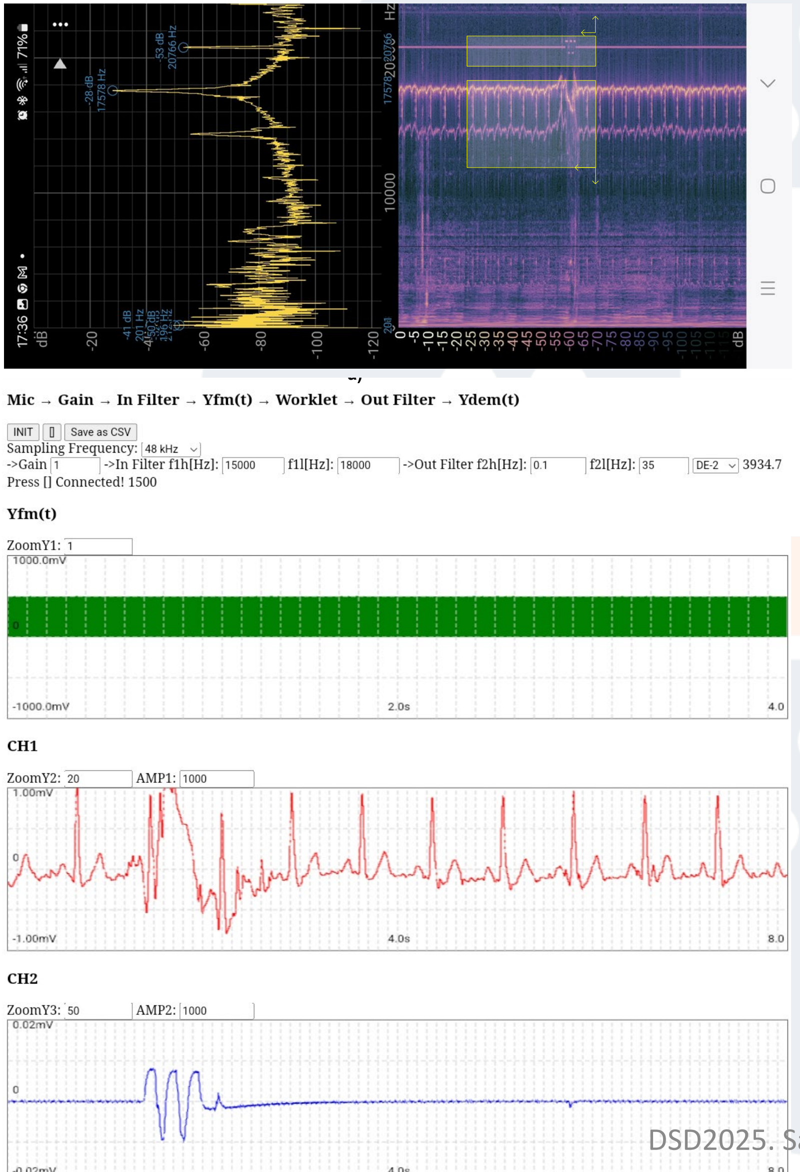
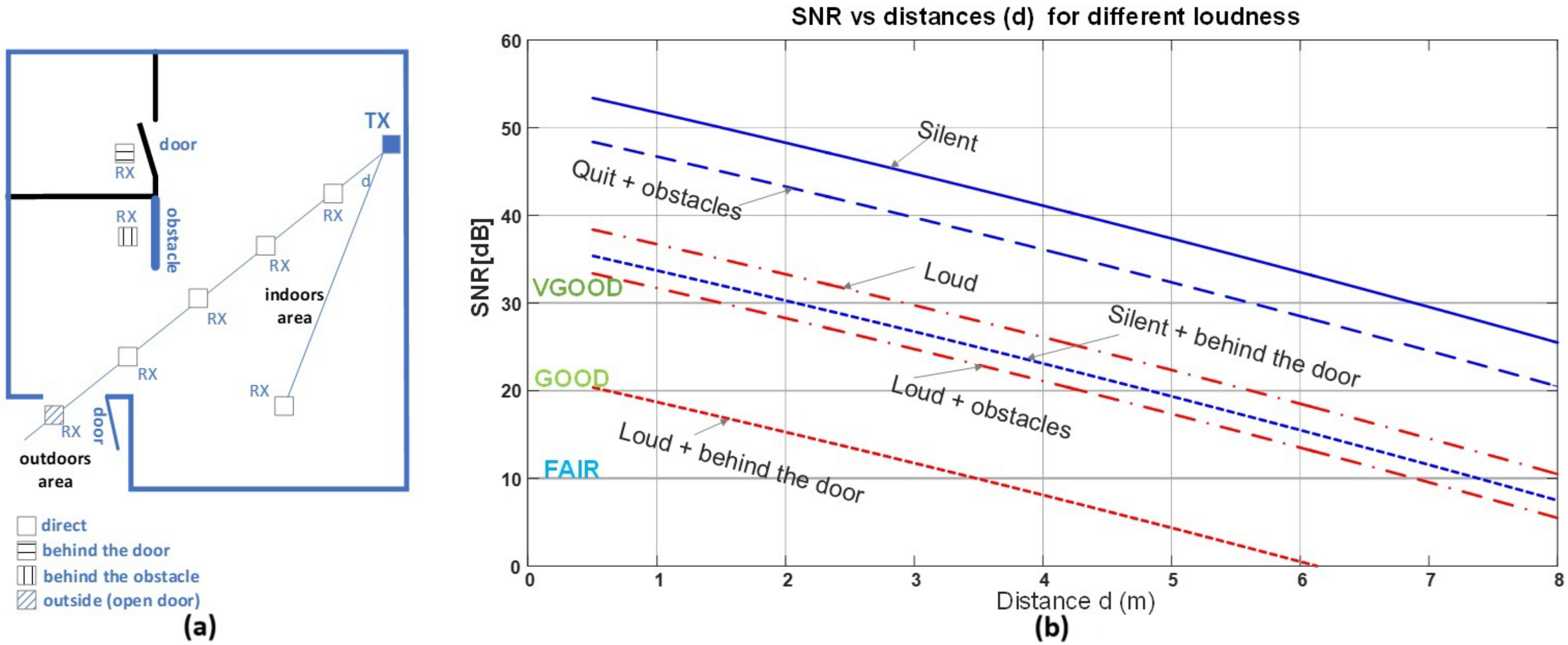


Illustration of FFT and STFT spectra of ECG and ACC signals in Spectroid APK. b) Demodulation and visualization of ECG and ACC signals directly in HT JavaScript+HTML+CSS APK.

Testing & results

- *SNR and range*



The floor plan and measurement scenario: The transmitter (TX) is placed indoors, while receivers (RX) are positioned at various locations—direct line of sight, behind obstacles, behind a door, and outdoors (with an open door). (**b**) The signal-to-noise ratio (SNR) as a function of distance d for different environmental loudness conditions and receiver positions. Scenarios shows the measured SNR as a function of distance for different scenarios. The accepted thresholds for signal quality were defined as follows: VERY GOOD (SNR ≥ 30 dB), GOOD (20 dB < SNR < 30 dB), and FAIR (10 dB < SNR < 20 dB). As can be observed, even under “Loud + obstacles” conditions, VERY GOOD signal quality (SNR ≥ 30 dB) is achieved within a radius of d = 1.5 m from the TX, and GOOD quality is maintained up to d = 4.2 m. These results demonstrate the robustness of the system in real-world indoor environments.

Testing & results

- Consumption

BAT Voltage/ Power consumption in mW	VCO 4046 based modulator	ATMEGA328 based modulator
9V, 3.3 Vpp on piezo speaker	15.5 mW	34 mW
9V, 5 Vpp on piezo speaker	20 mW	70 mW
9V, about 9 Vpp on piezo speaker	35 mW	90 mW

Even in 2mA TX consumption the communication is possible

Conclusion

- **MDoS** suppress the gaps in **Edge IoT** where traditional wireless tech is impractical, costly, or restricted.
- **Advantages:**
  - ultra-low consumption, enhanced comfort, passive transmission, short-range, hard-to-hack, transmit analog and digital data with the same tool, good for sensitive environments like ICUs, MRI rooms, Cars, Airplane, by default compatibility, zero setting, works in RF-restricted areas as water, underground facilities, eco friendly, no health risk
- **Disadvantages:**
  - lower bandwidth than BLE/Zigbee (limited data rates), limited channels, shorter range, in audio range sensitivity to ambient noise (not case for ultrasonic), line-of-sight or controlled environment often needed for reliable transmission.

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Thank you, Q&A?