Warsaw University of Technology

Healthcare Radar Project

Vital Signs Measurement Using ADI CN0566 Phased Array and MATLAB

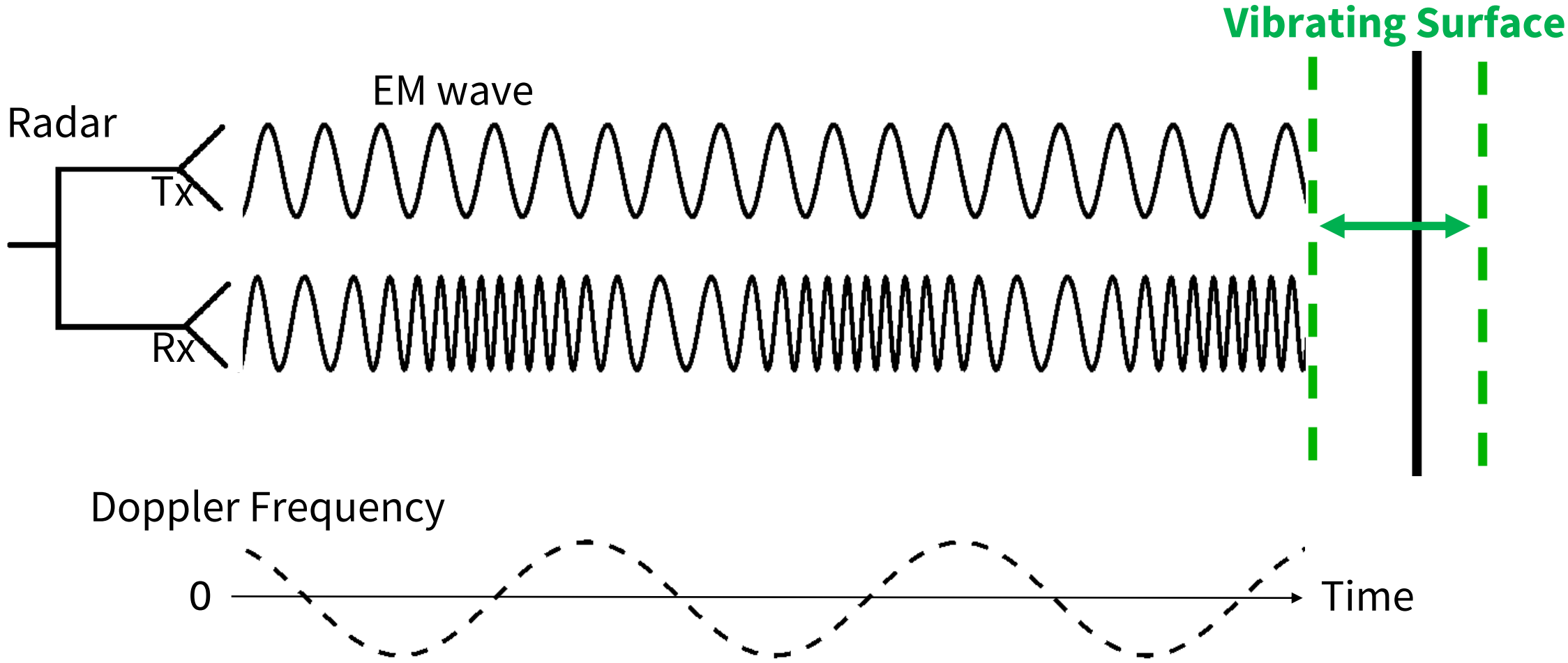
Bartosz Falęcki, Rafał Najda, Radosław Maksymiuk, Alicja Misterka, Jan Dzwonnik

bartosz.falecki@pw.edu.pl
https://github.com/bfalecki/Healthcare-Radar-Project/

October 6, 2025

Presentation Overview

Micro-Doppler Phenomenon



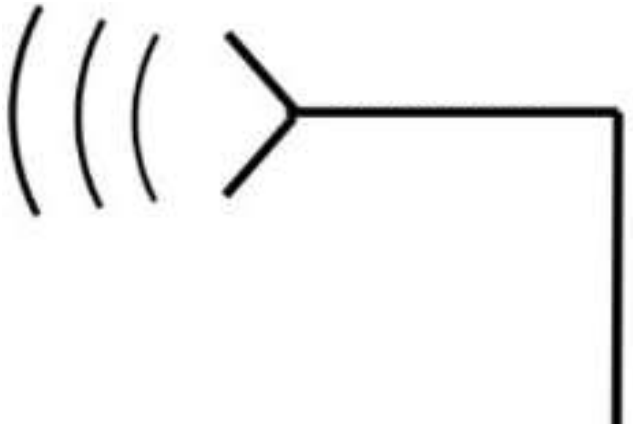
Measurement Idea

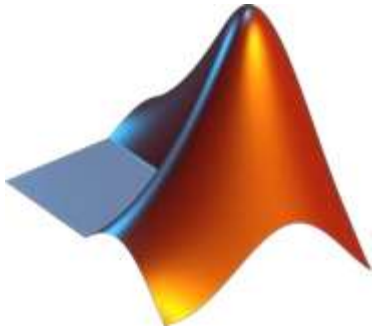
Slight movements of the human chest reveal vital signs.

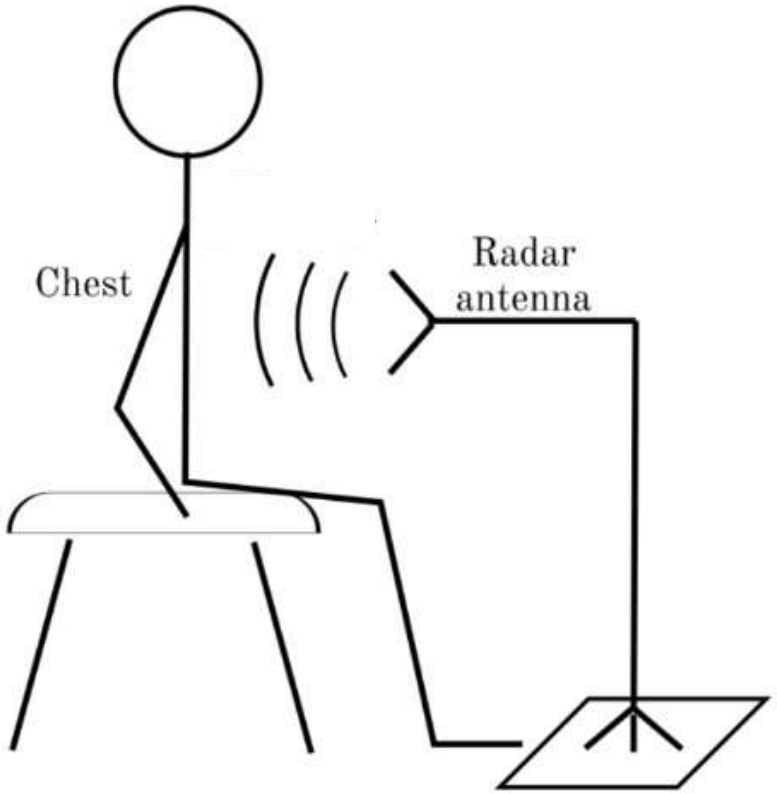
Heartbeat Component

Respiratory Component

Radar Antenna



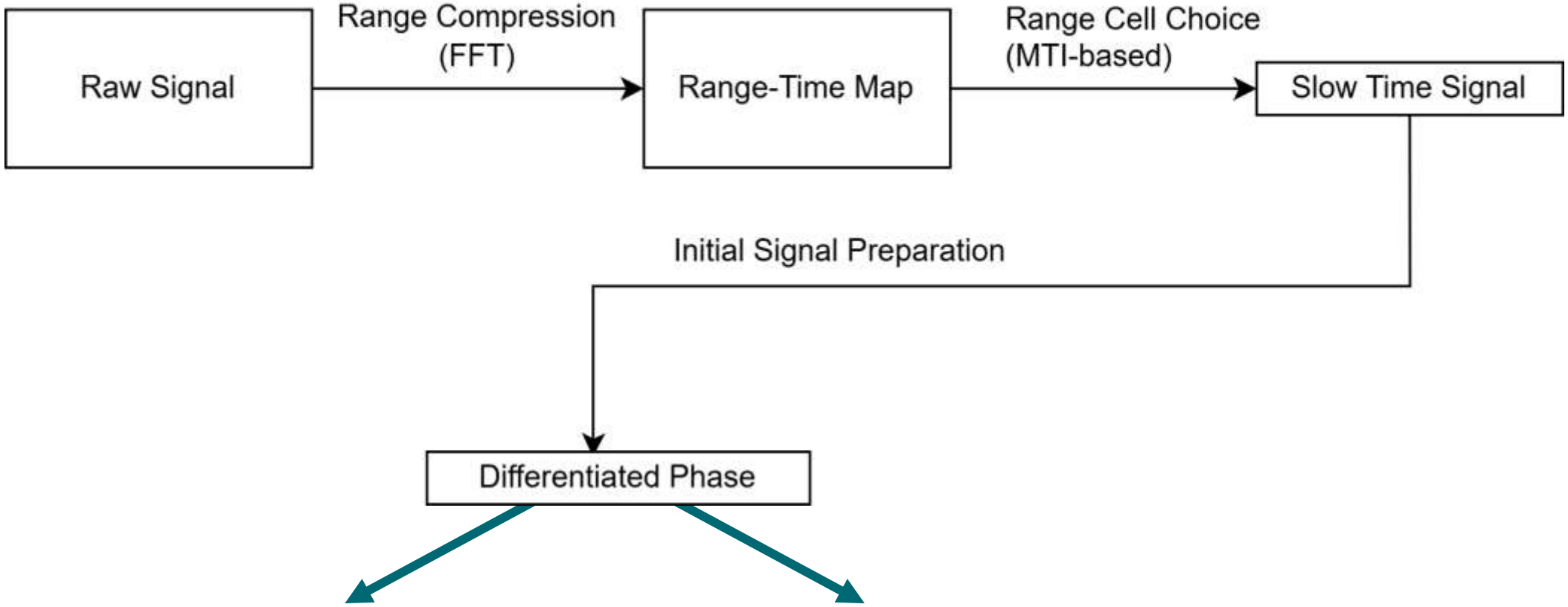




Project Goal

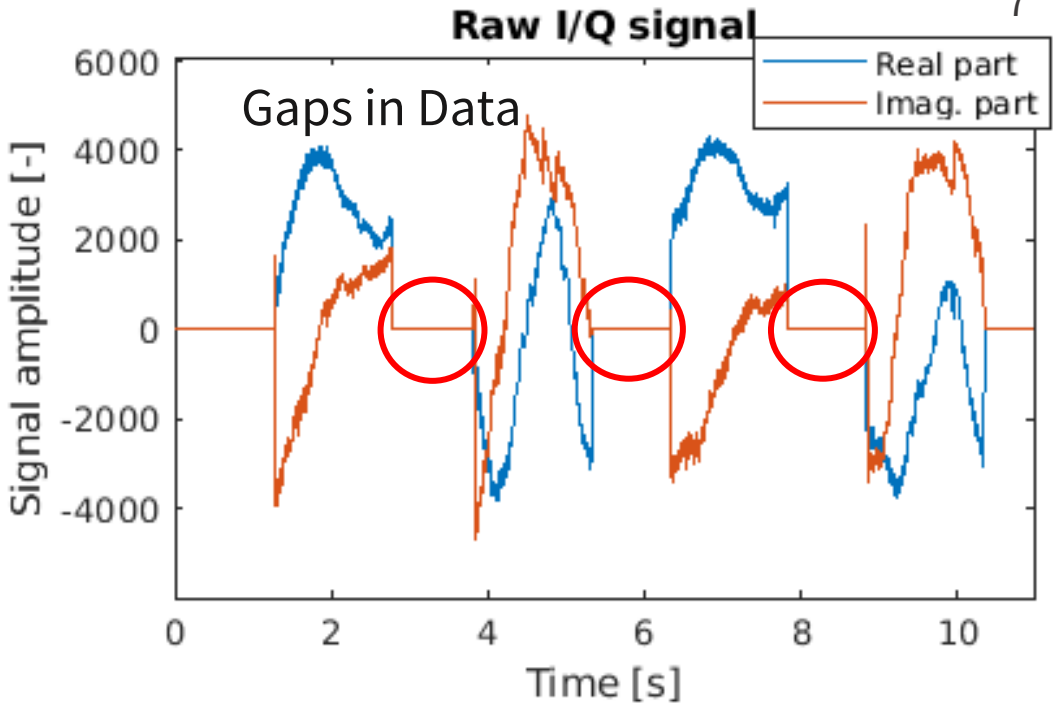
- Develop and test a platform for a non-contact measurement of **heartbeat and respiratory activity** at close distance using ADI CN0566 radar.
- The main focus of the project is on **developing a signal processing pipeline** using the MATLAB environment.

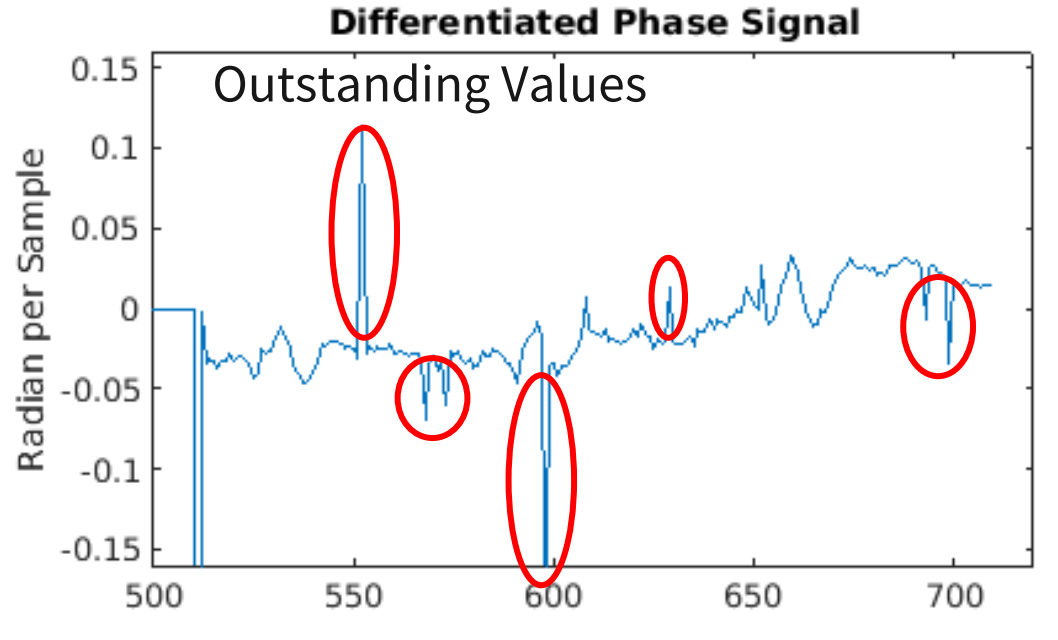
Signal Pre-Processing



Encountered Problems

- Hardware limitations prevent continuous recording of the signal. There are significant gaps between data frames.
- The slow-time signal contains slight phase discontinuities causing outstanding values after differentiation.



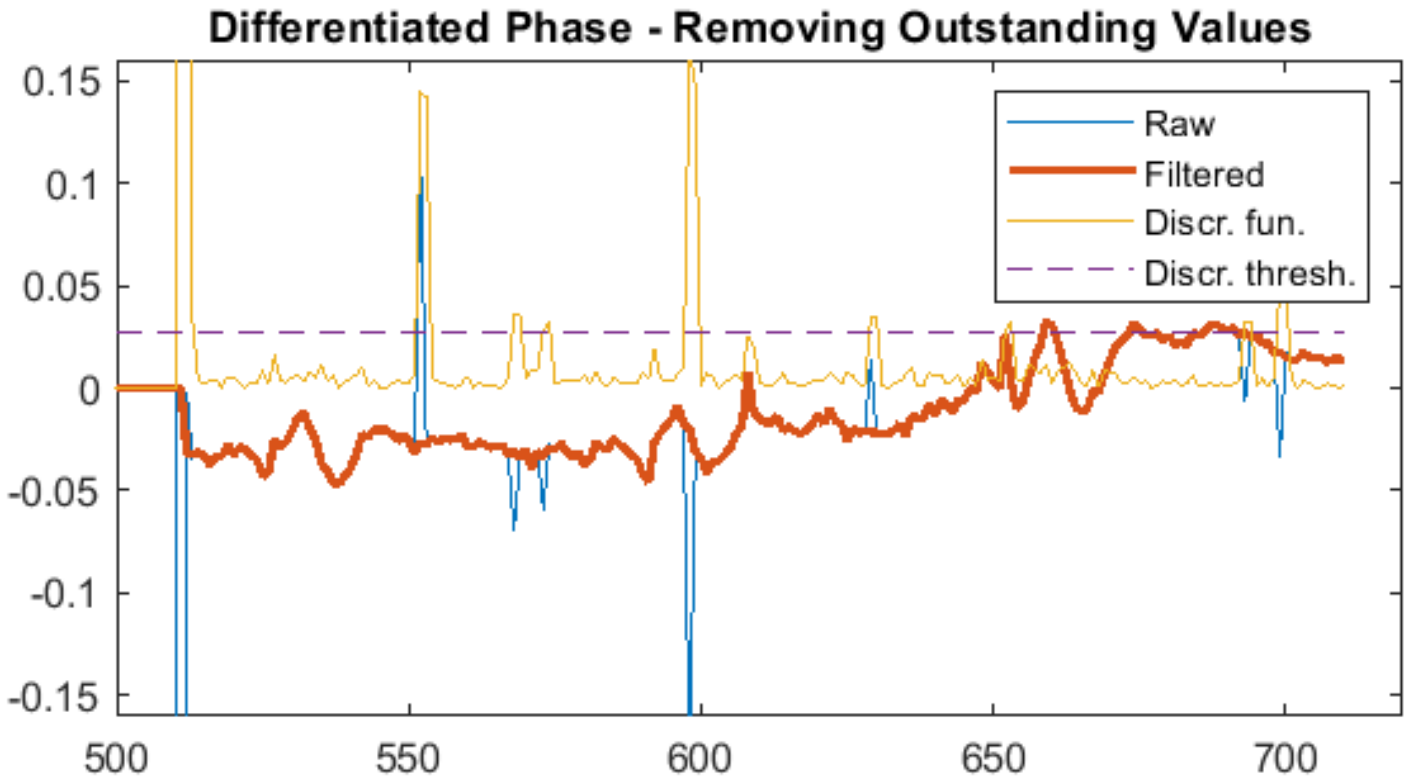


Initial Signal Preparation


```
62  [signal_filled, timeLags, segmentDuration, start_samples, end_samples] = ... % filling gaps in the signal
63      fill_signal_gaps(radarSignal, FrameStartTimes, PRF);
64  segmentsBounds = [start_samples;end_samples];
65
66  % % % phase anaylsis
67  phaseRaw = unwrap(angle(signal_filled)); % extracting unwrapped phase
68
69  phaseRaw = reset_accumulated_phase(phaseRaw, start_samples,end_samples);% get rid of big first difference sample
70
71  phaseDiffRaw = compl_diff(diff(phaseRaw));% differentiation
72  phaseDiff = phaseDiffRaw;
73
74  % outstanding vals filtering
75  phaseDiff = filter_noise_peaks(phaseDiff, "Display",0,"NeighborSize",FNP_NeighborSize,...
76              "SegmentsBounds",[start_samples;end_samples],...
77              "ThresholdMultiplier",FNP_ThresholdMultiplier,"ThresholdQuantile",FNP_ThresholdQuantile);
78
79  % fix segment edge noise (put mean values to every edge) - helpful for
80  % further linear interpolation
81  depth_samples = round(FixEdgesDepth * PRF);
82  phaseDiff = fix_edges(phaseDiff, start_samples,end_samples, depth_samples);
```

Removing Outstanding Peaks

THRESHOLD-BASED METHOD

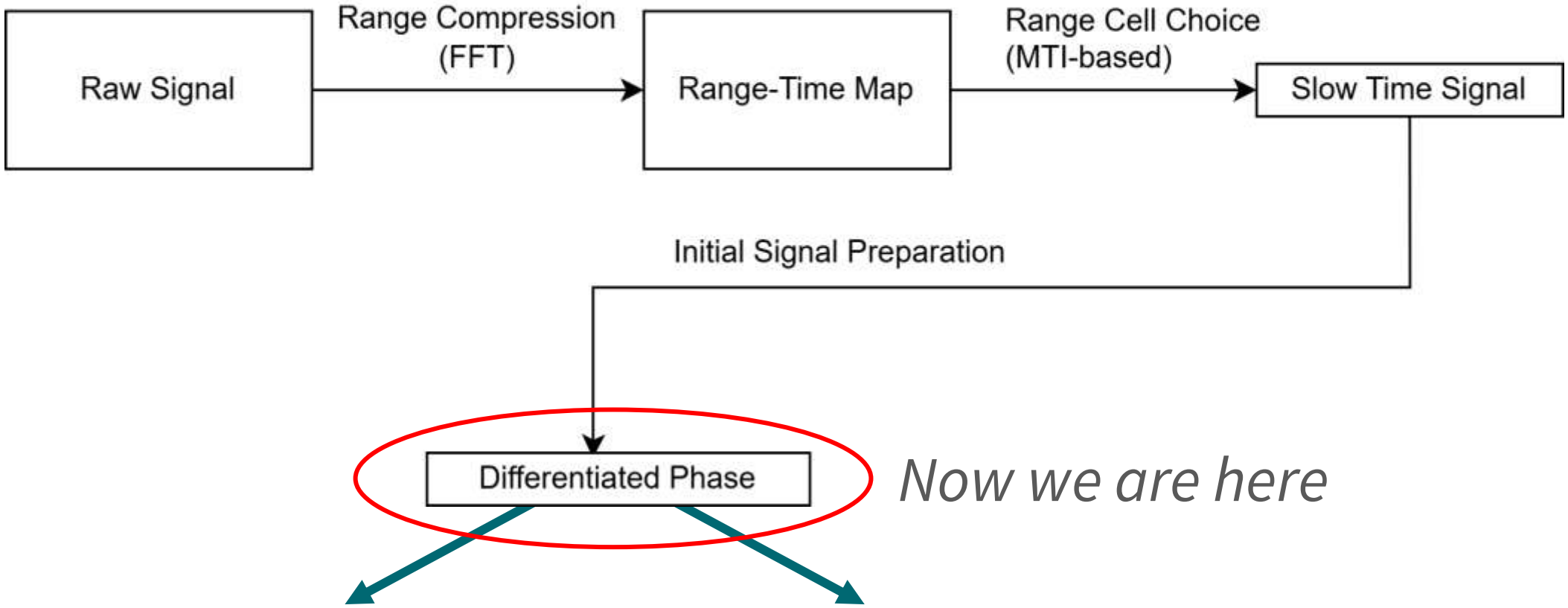


- Function replaces mismatched values with an average of adjacent ones.
- The discriminant function is an approximate derivative – **`diff()`** in MATLAB.
- Method is used to eliminate high-frequency interference.

Removing Outstanding Peaks – MATLAB Code

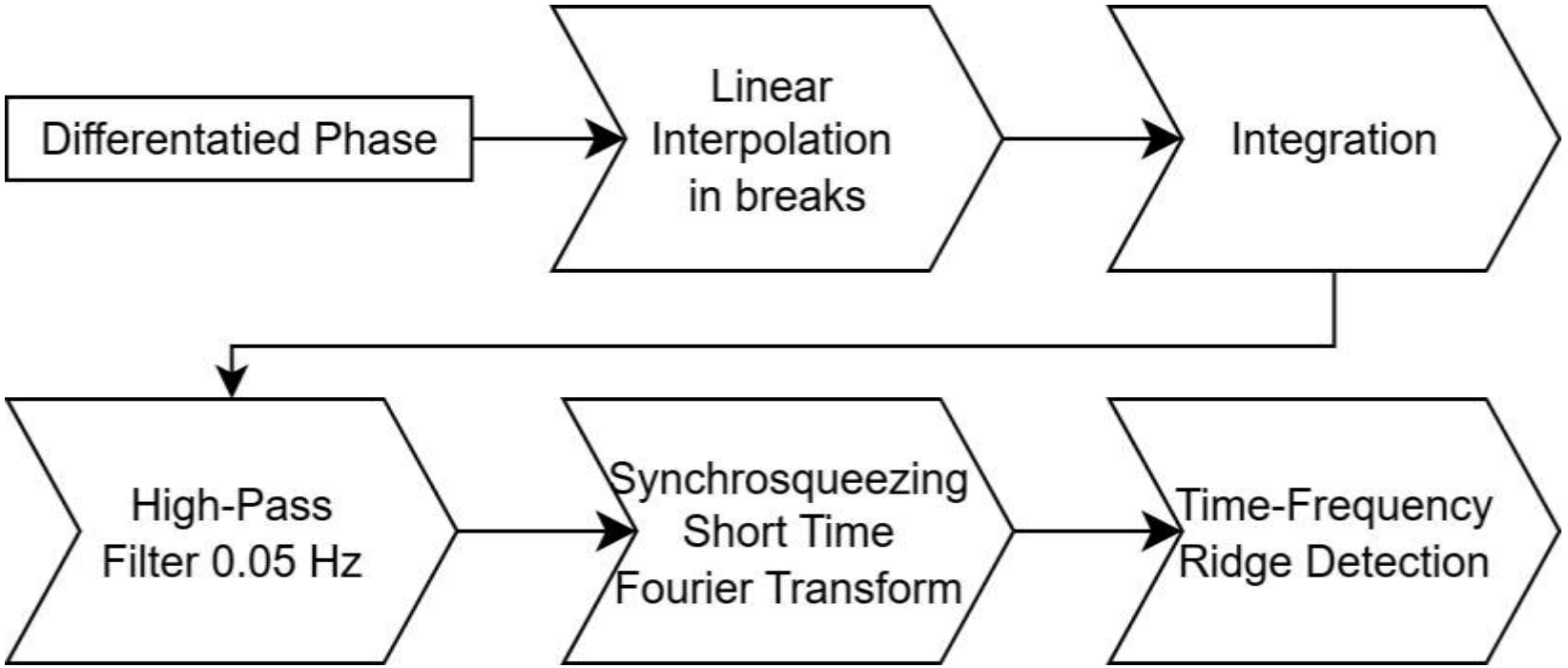
```
condition_function = abs(compl_diff(diff(signal))); % threshold based on differentation amplitude
thresh = quantile(condition_function,ThresholdQuantile) * ThresholdMultiplier;
out_idxes = condition_function > thresh;            % ...
out_idxes_found = find(out_idxes);                  % ...
idxes_to_fill_matr = zeros(length(out_idxes_found),2*neig_size); % get neighboring values
k = 1;                                                          % ...
for shift = (-neig_size):neig_size                              % ...
    if(shift ~= 0)                                              % ...
        idxes_to_fill_matr(:,k) = out_idxes_found+shift;        % ...
        k = k+1;                                                % ...
    end                                                         % ...
end                                                             % ...
idxes_to_fill_matr(idxes_to_fill_matr < 1 | idxes_to_fill_matr > length(signal)) = nan; % exclude invalid
original_size = size(idxes_to_fill_matr);                                  % set intersected to nan
idxes_to_fill_matr = reshape(idxes_to_fill_matr,original_size(1) * original_size(2),1);%...
[idxes_idxes_out] = ismember(idxes_to_fill_matr, out_idxes_found);          % ...
idxes_to_fill_matr(idxes_idxes_out) = nan;                                  % ...
idxes_to_fill_matr = reshape(idxes_to_fill_matr, original_size);
start_samples = SegmentsBounds(1,:);            %  set out-of-segments to nan
end_samples = SegmentsBounds(2,:);              % ...
valid_idxes = zeros(size(idxes_to_fill_matr));  % ...
for k = 1:length(start_samples) % works as alternative
    valid_idxes = valid_idxes + (idxes_to_fill_matr >= start_samples(k) & idxes_to_fill_matr <= end_samples(k));
end                                             % ...
valid_idxes = logical(valid_idxes);             % ...
idxes_to_fill_matr(~valid_idxes) = nan;         % ...
nan_idxes = isnan(idxes_to_fill_matr); %  count nans
Nnans = sum(nan_idxes, 2);                    %  ...
idxes_to_fill_matr(nan_idxes) = 1; % nan to any valid
values_used = signal(idxes_to_fill_matr); % take values
values_used(nan_idxes) = 0; % take average from non nan
predicted = sum(values_used, 2) ./ (2*neig_size - Nnans);
predicted(isnan(predicted)) = 0; % replace remaining nans with zeroes
signal_filt = signal;
signal_filt(out_idxes_found) = predicted; % finally place the proper values
```

Vital Signs Extraction Pipeline



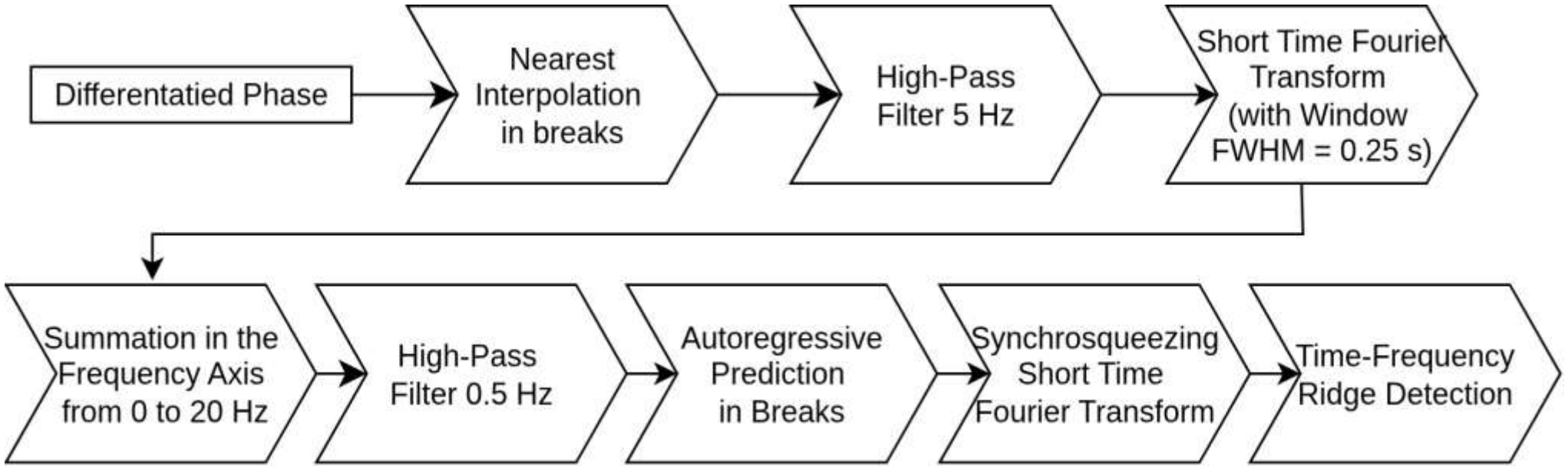
Breath Extraction Pipeline

OUTPUT: HOW BREATH RATE CHANGES IN TIME

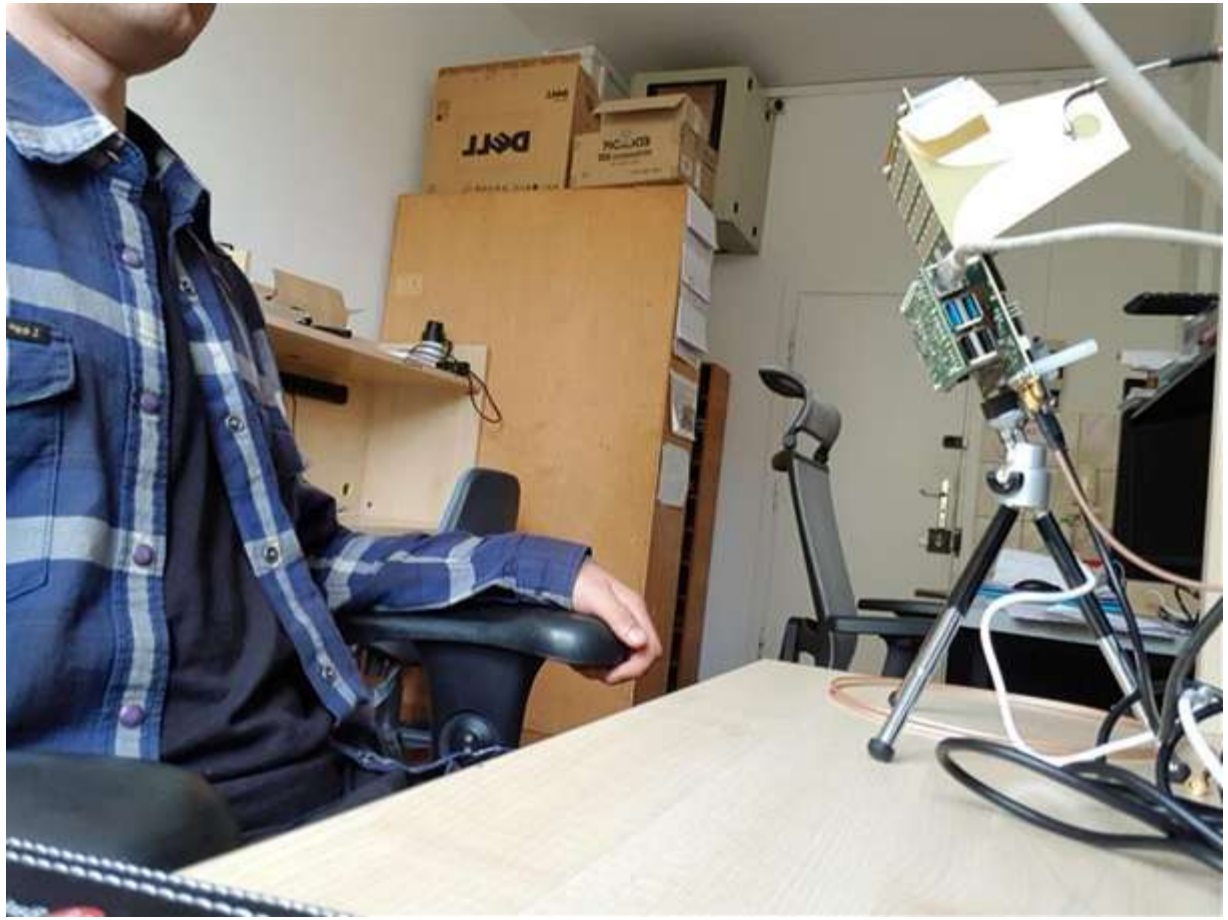


Heartbeat Extraction Pipeline

OUTPUT: HOW HEART RATE CHANGES IN TIME



Measurement Scenario

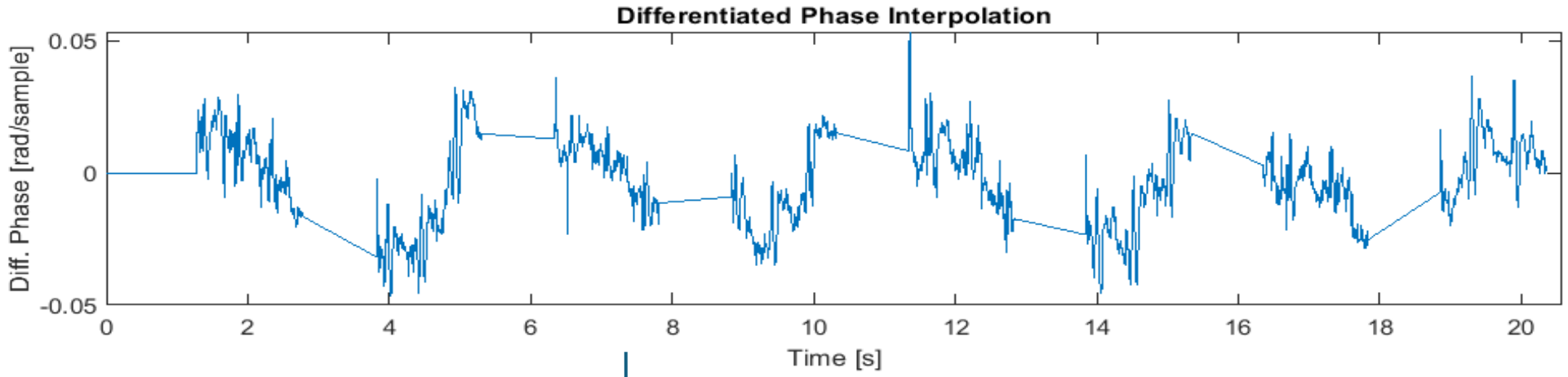


Sitting, motionless position, 40-50 cm chest-to-antenna distance.

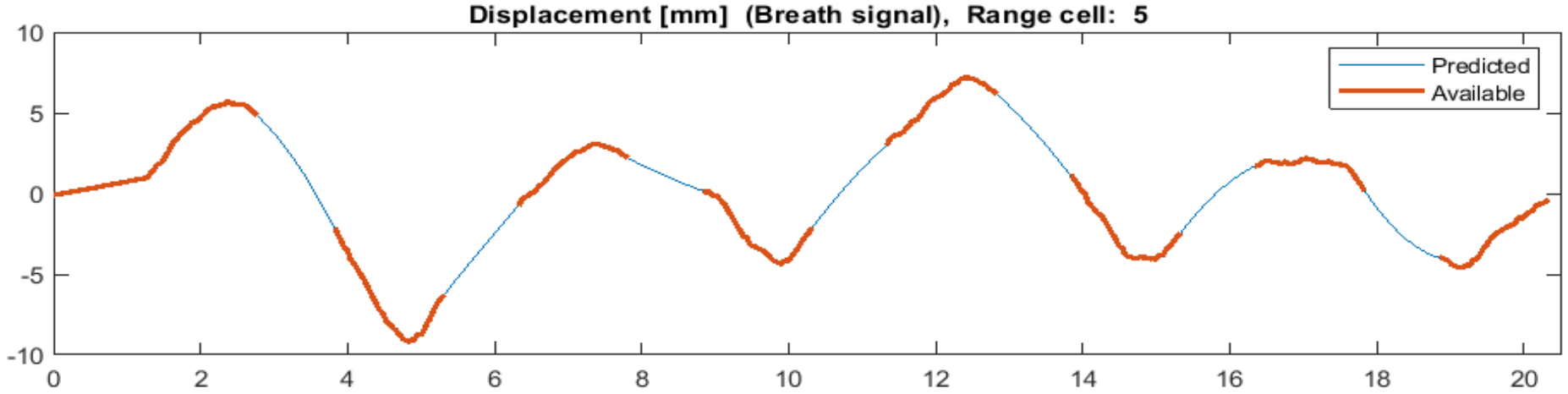
ADI CN0566 Radar Parameters

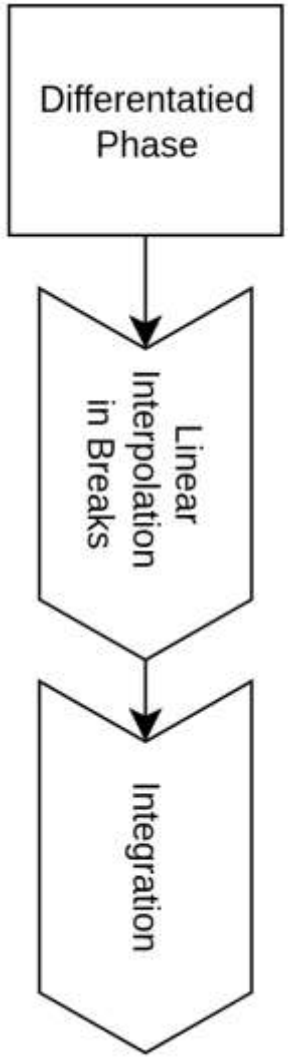
- Pulse Repetition Frequency: 133 Hz
- Carrier Frequency: 10 GHz
- Single Frame Duration: 1.87 s (max. possible)

Breath Extraction Results

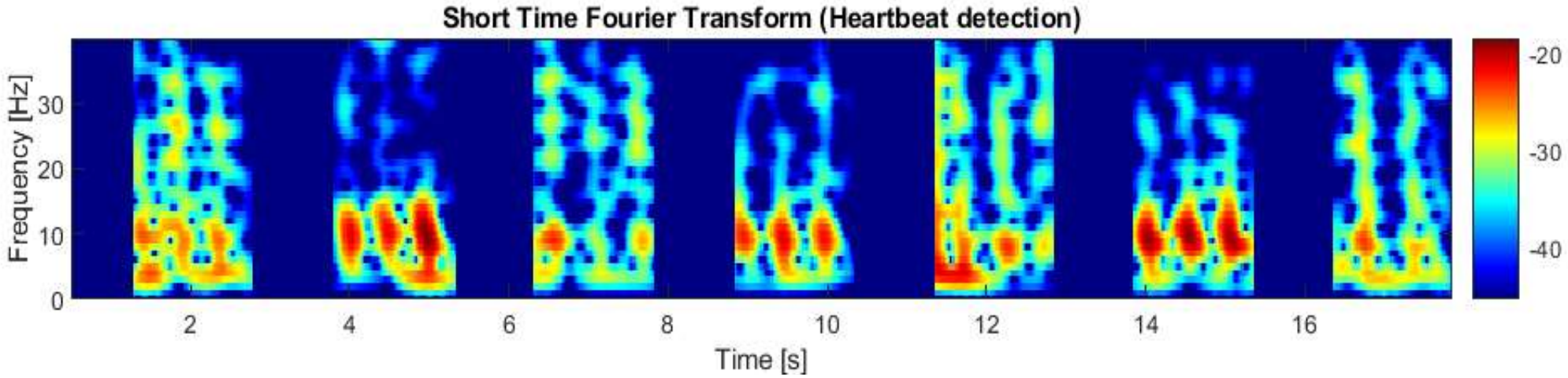


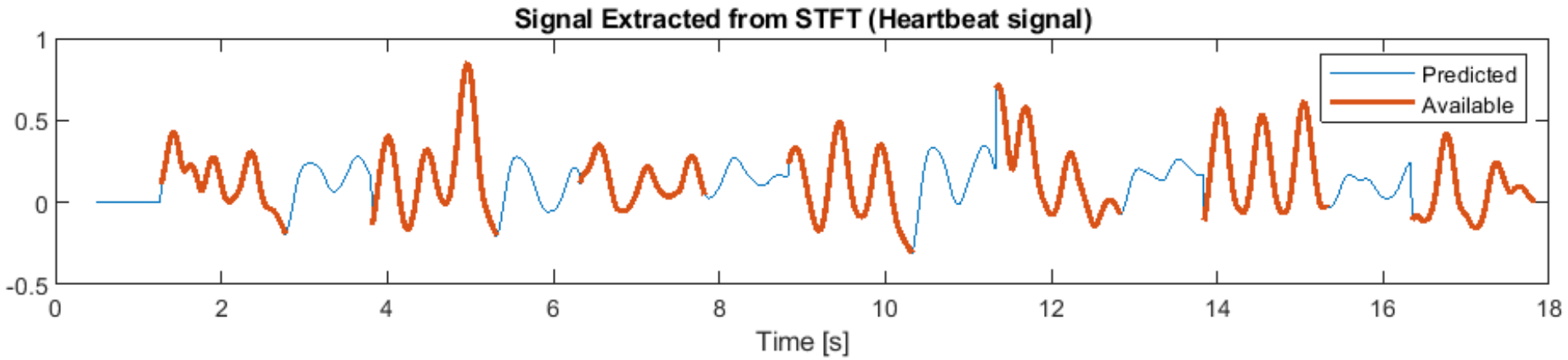
Integration – **`cumsum()`** function

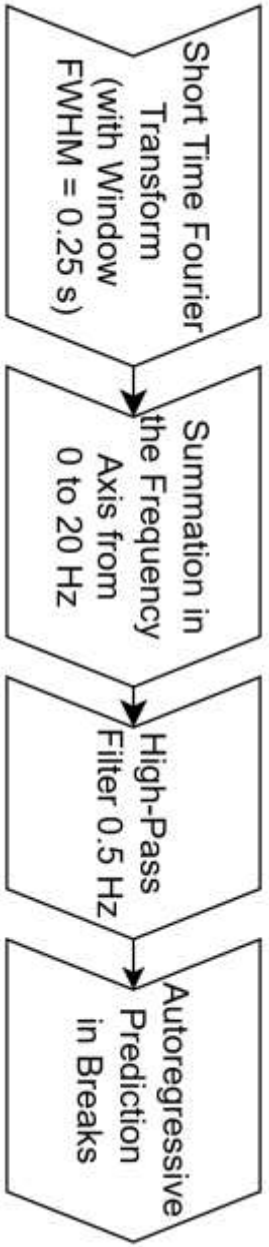




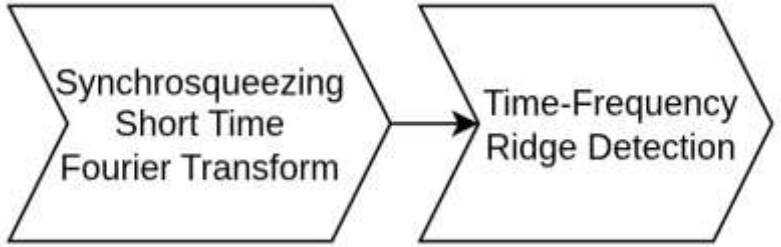
Heartbeat Extraction Results



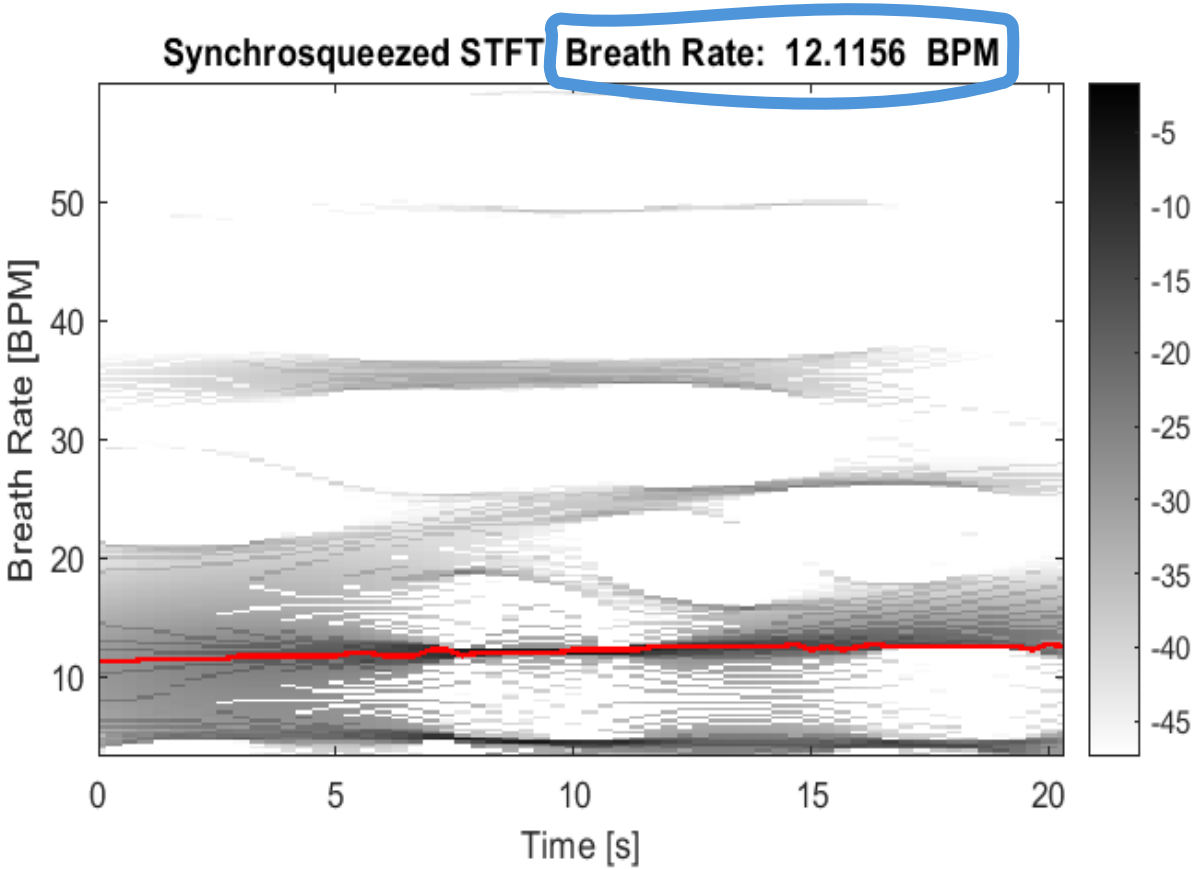


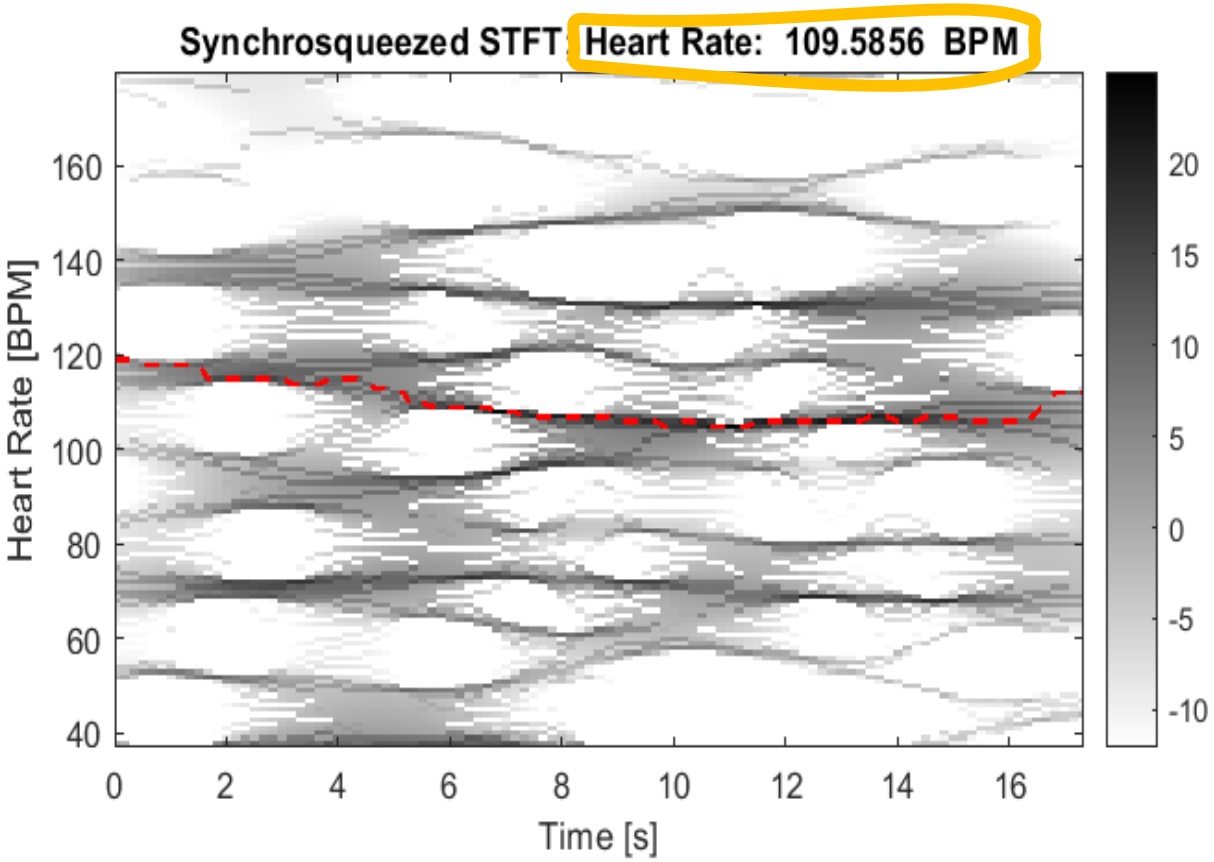


Final Results – Breath Rate and Heart Rate

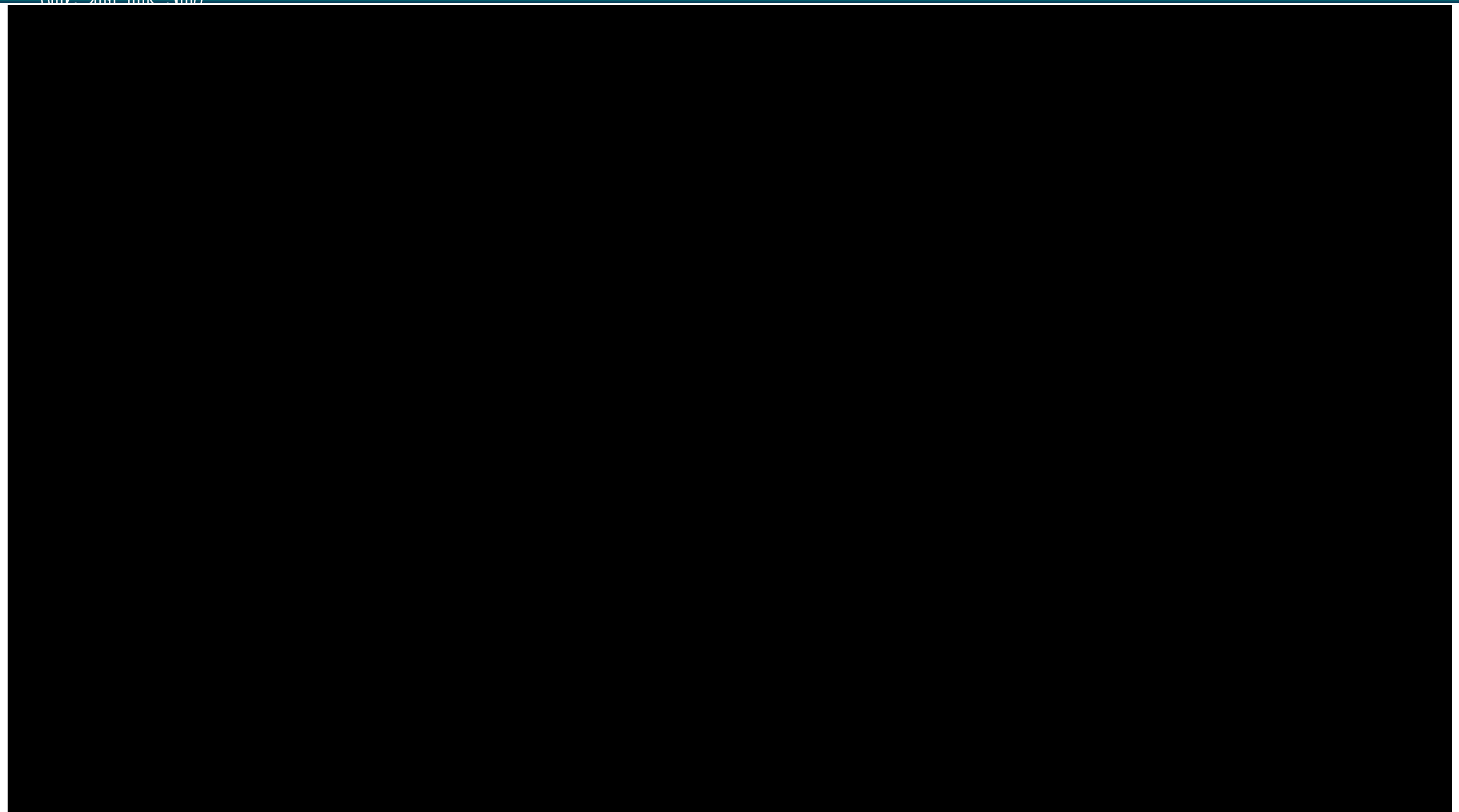


MATLAB **`fsst()`** and **`tfridge()`** functions.

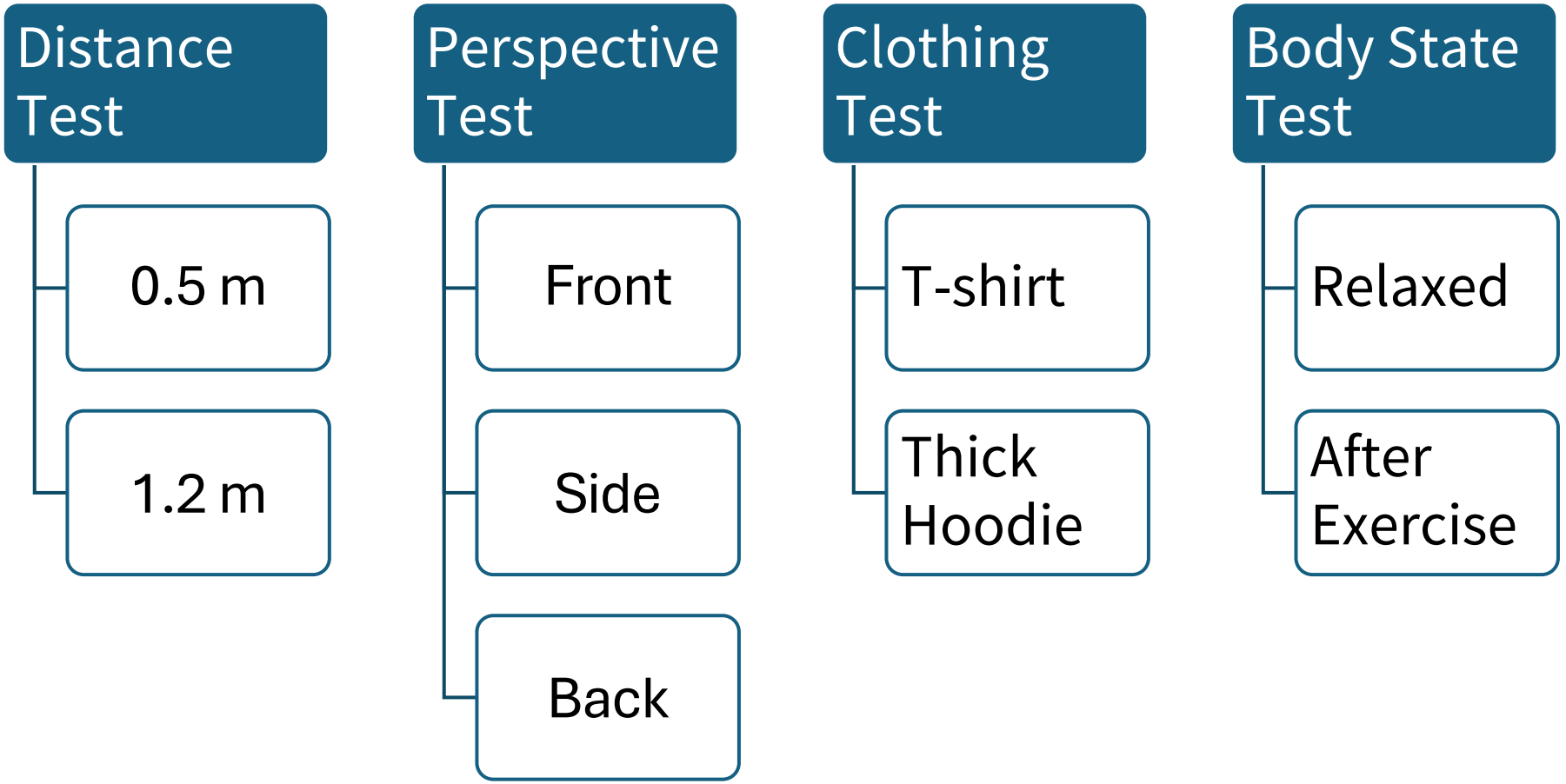




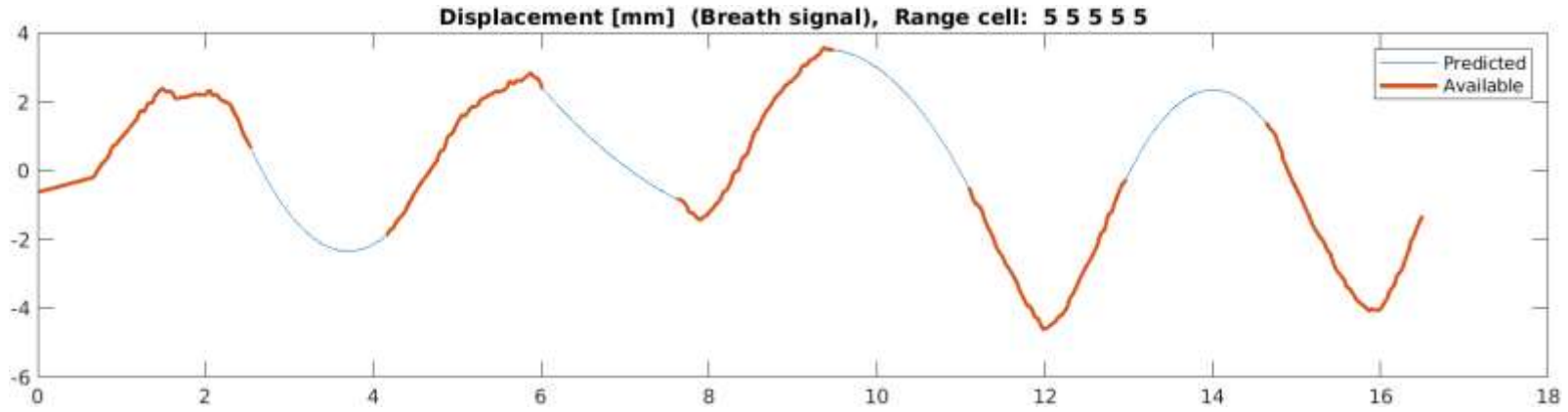
Near Real-Time Application

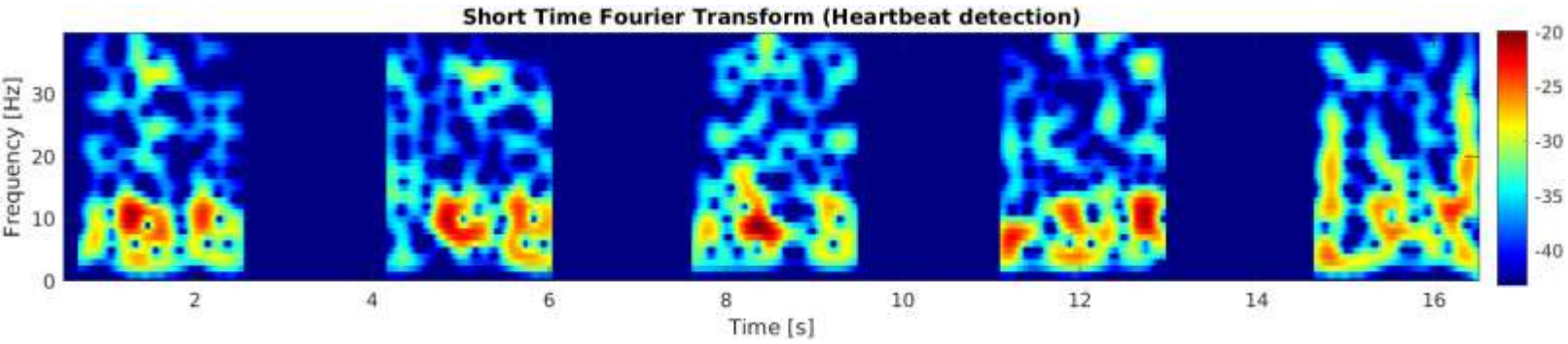


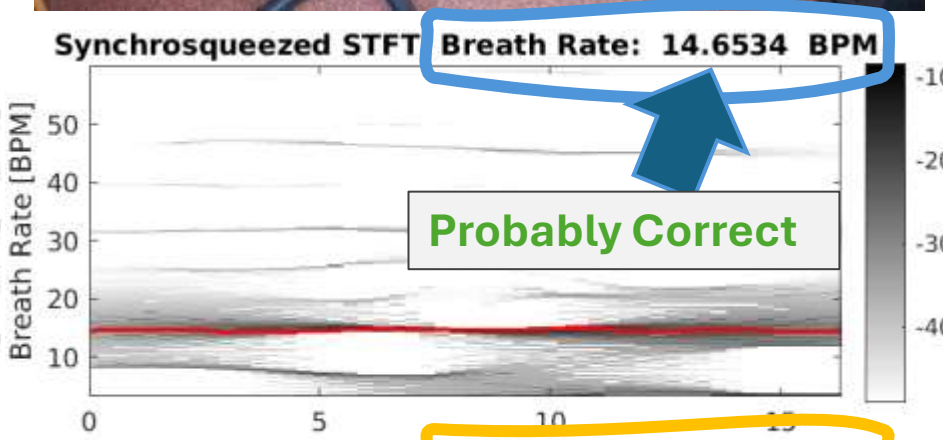
Conducted Experiments

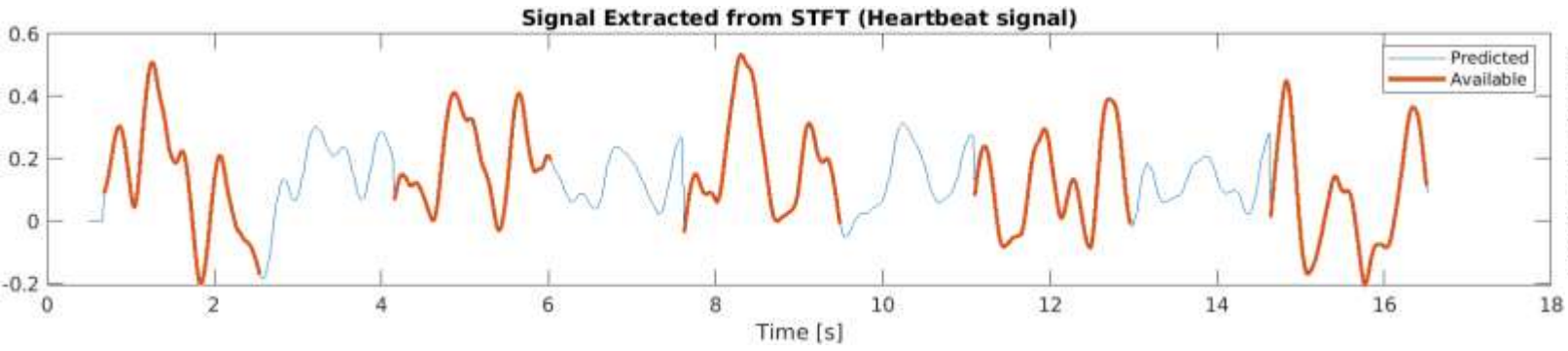


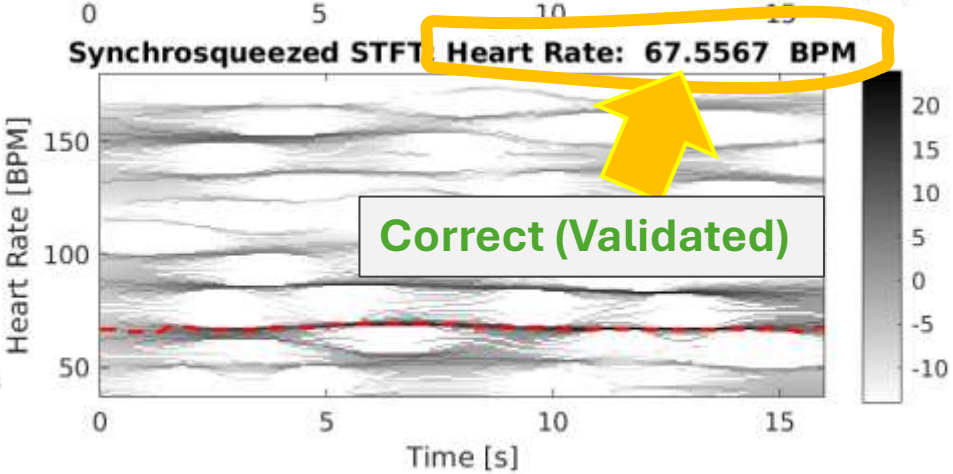
Distance Test – 0.5 m



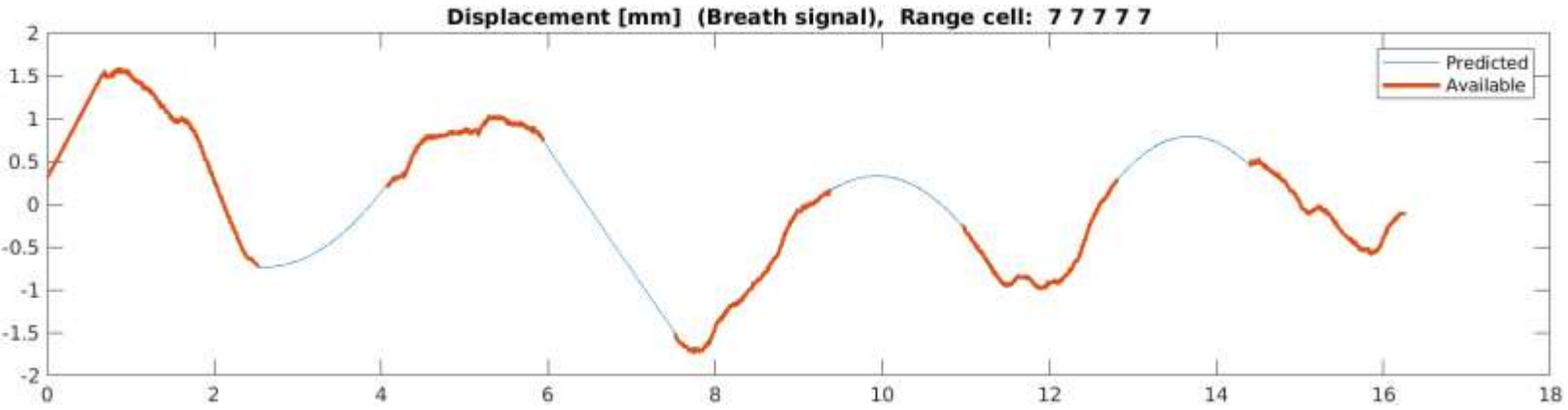


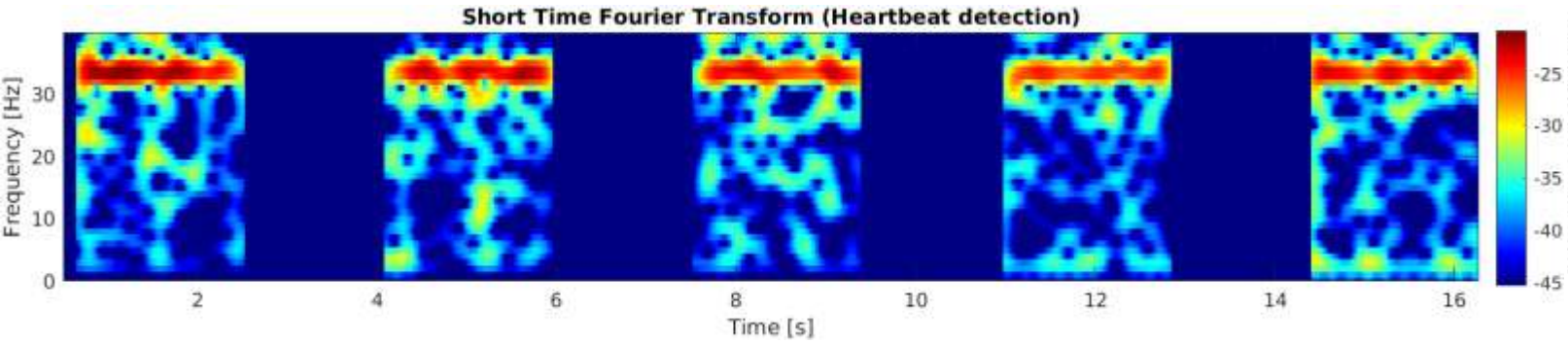


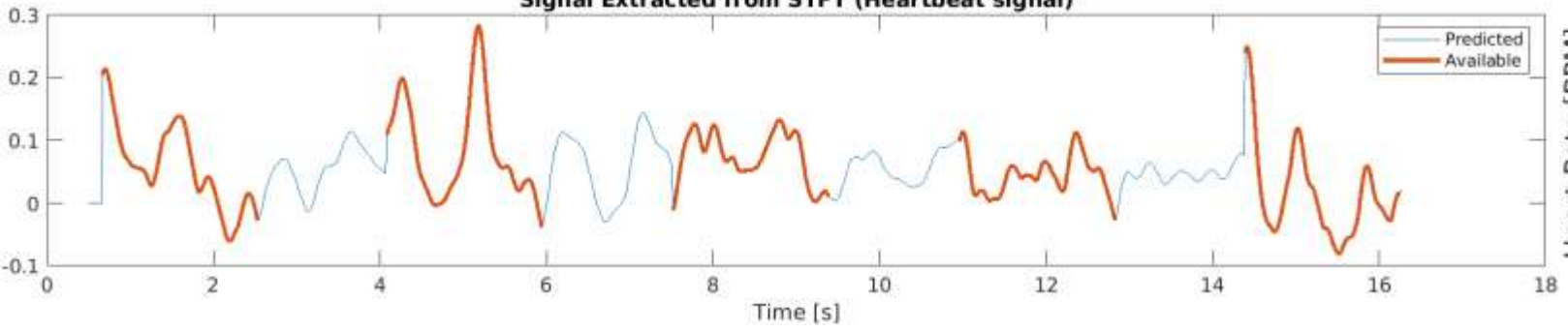


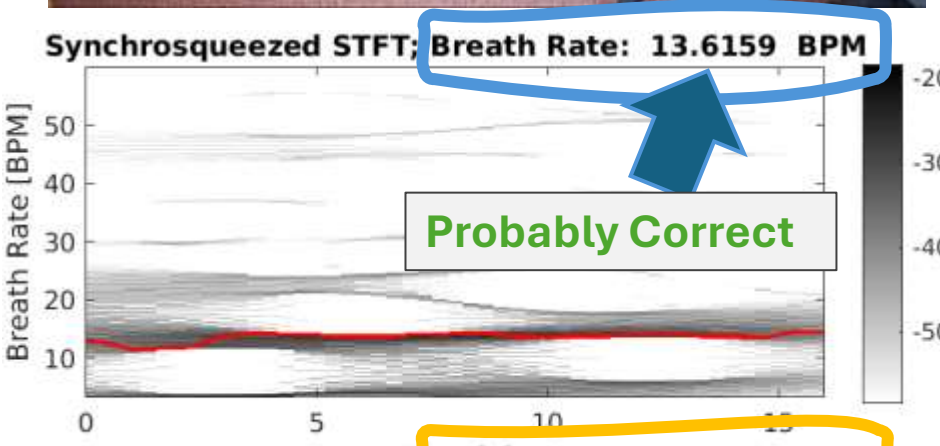


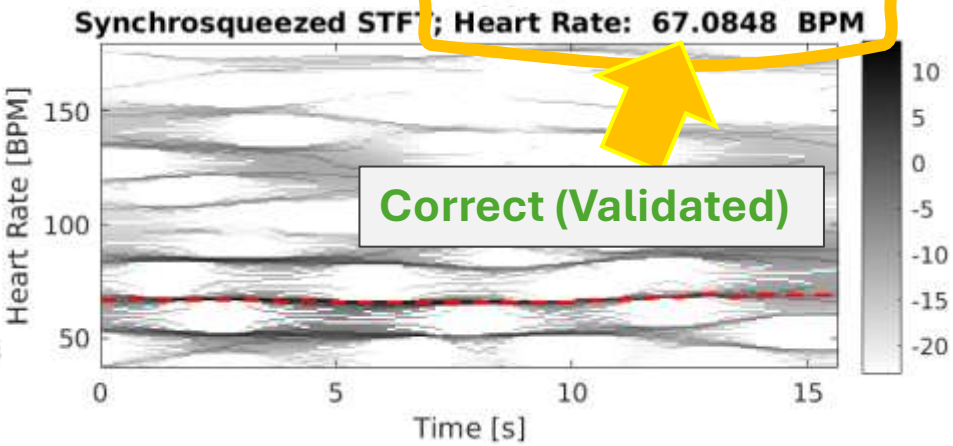
Distance Test – 1.2 m



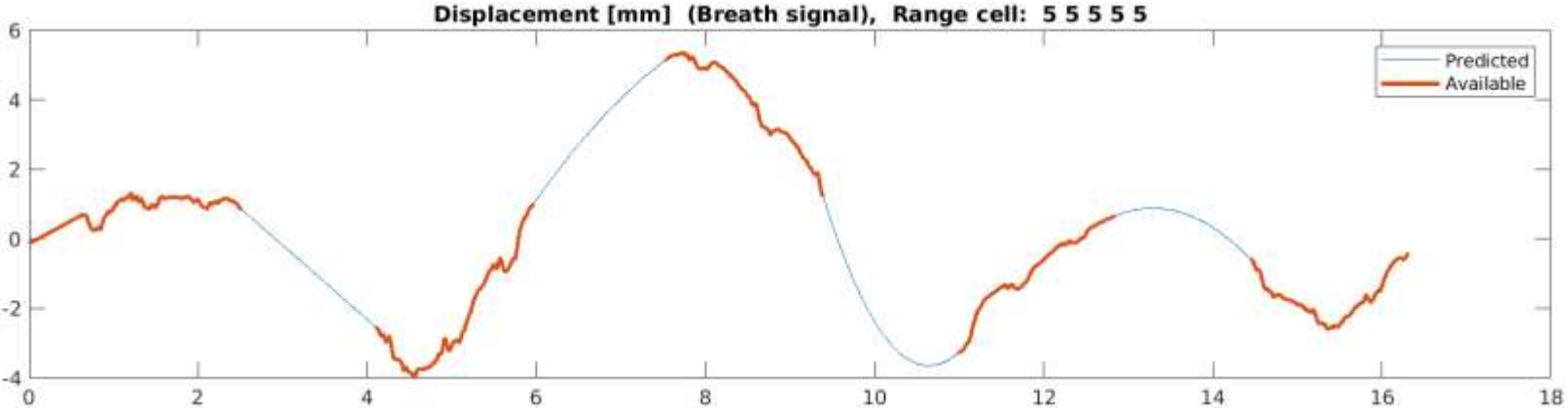


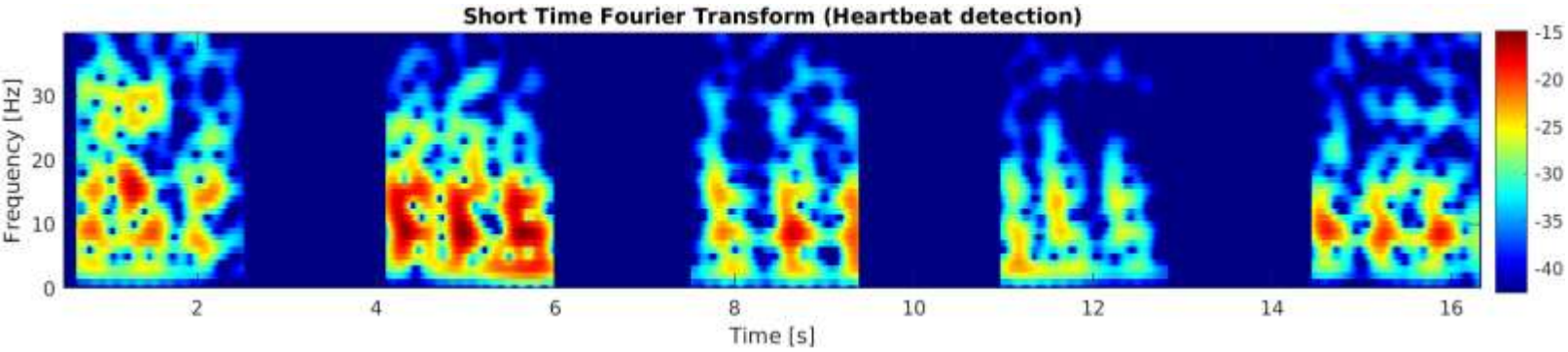


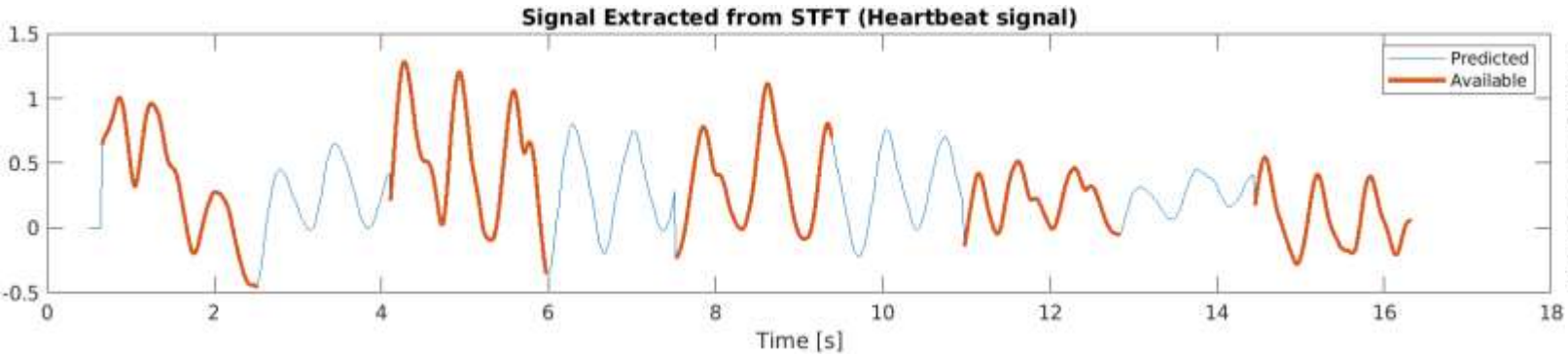


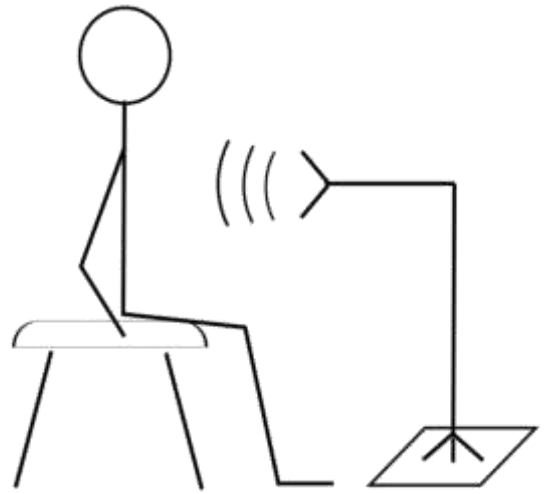


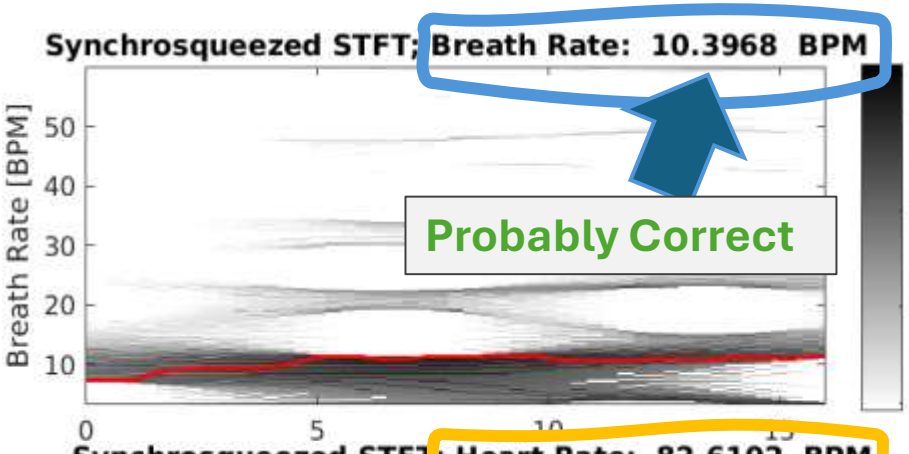
Perspective Test – Front

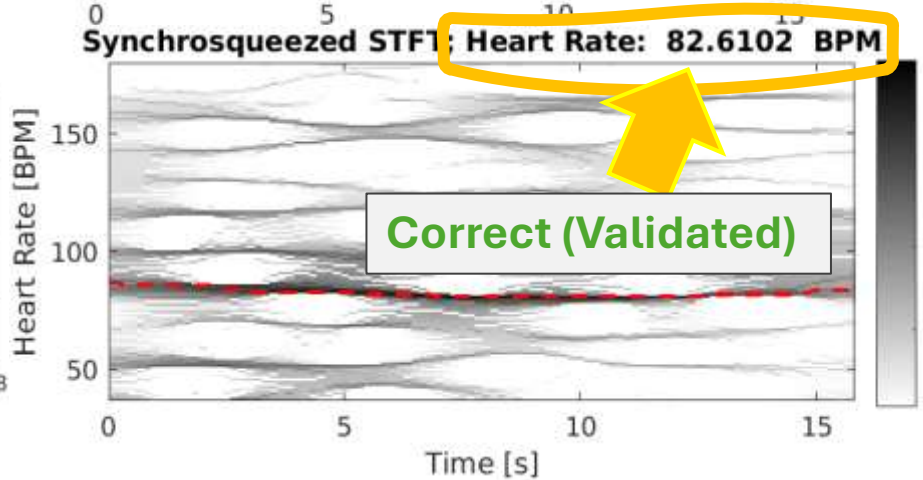




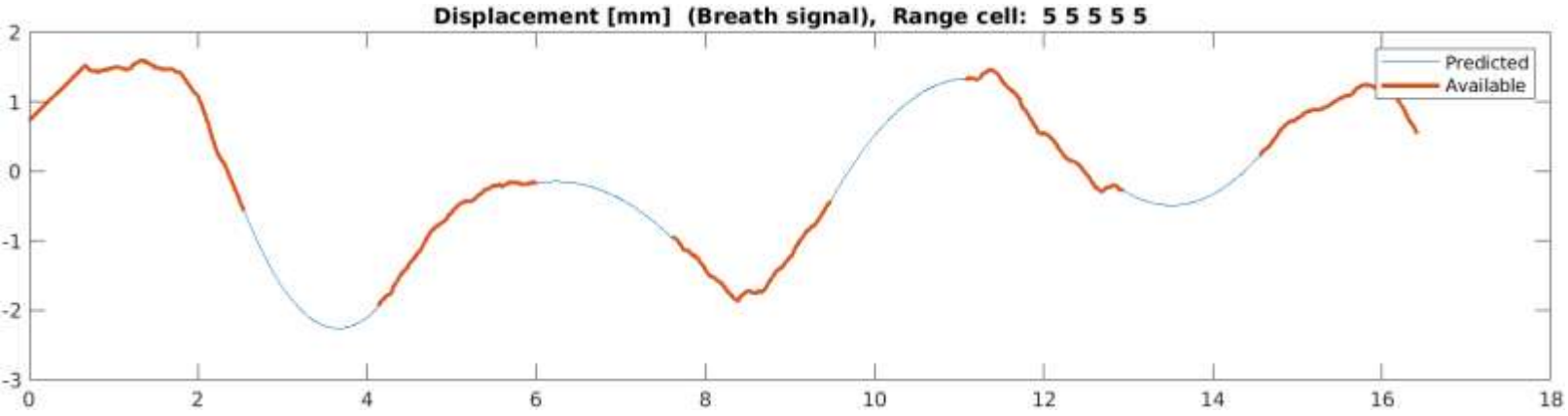


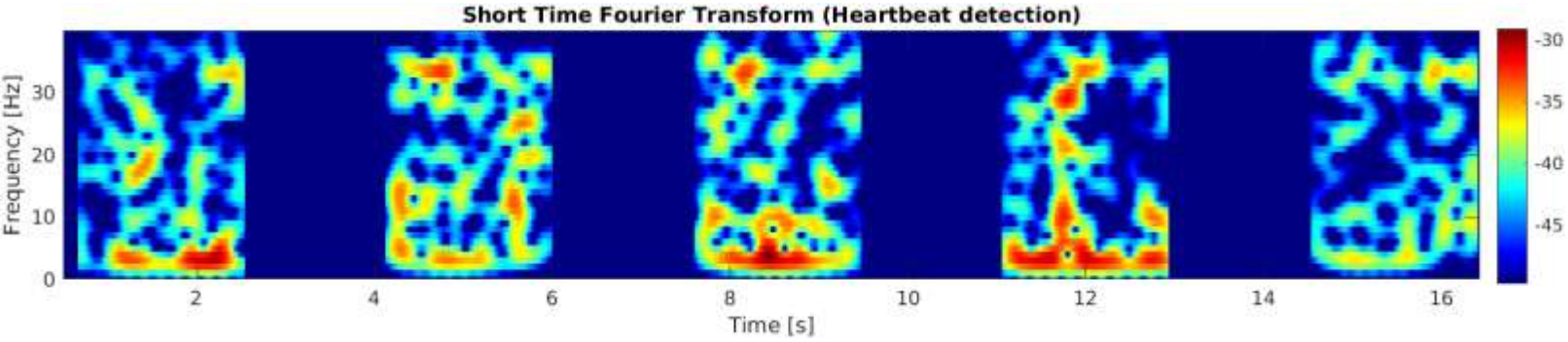


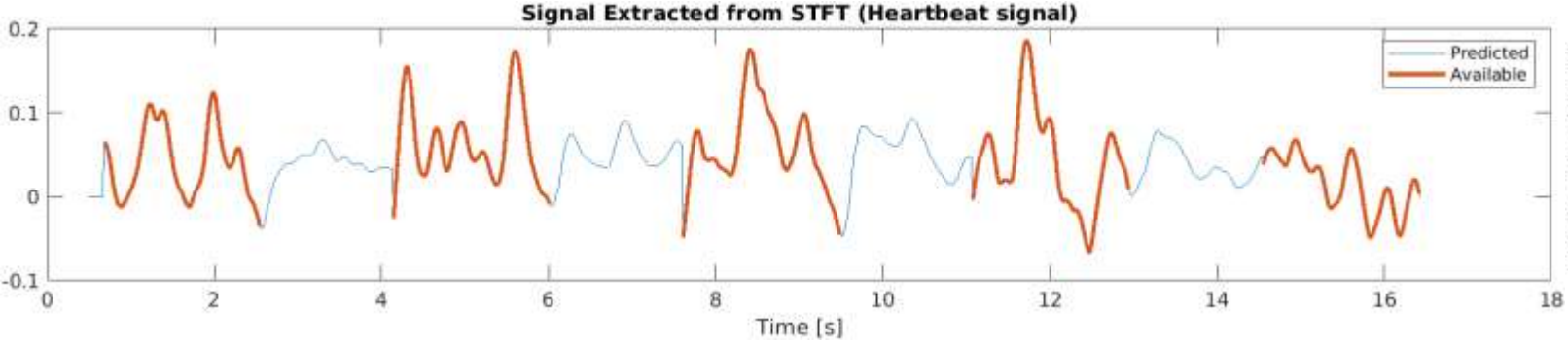


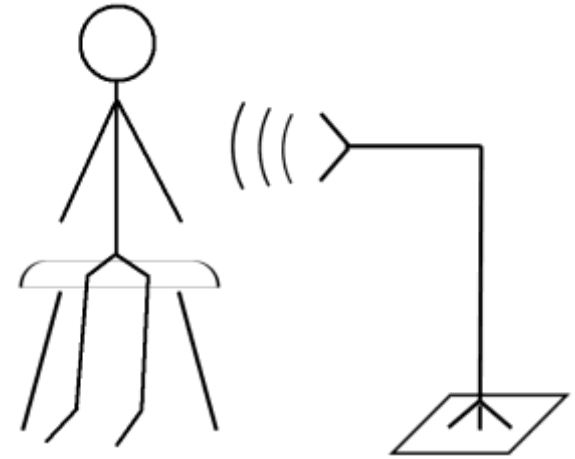


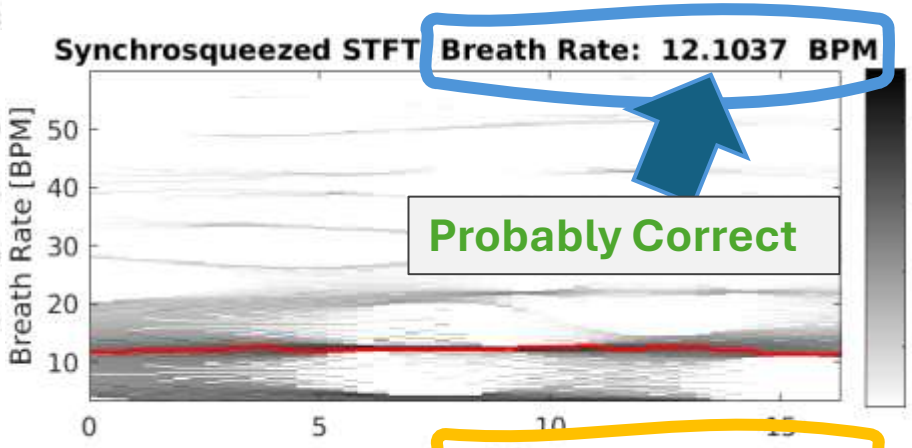
Perspective Test – Side

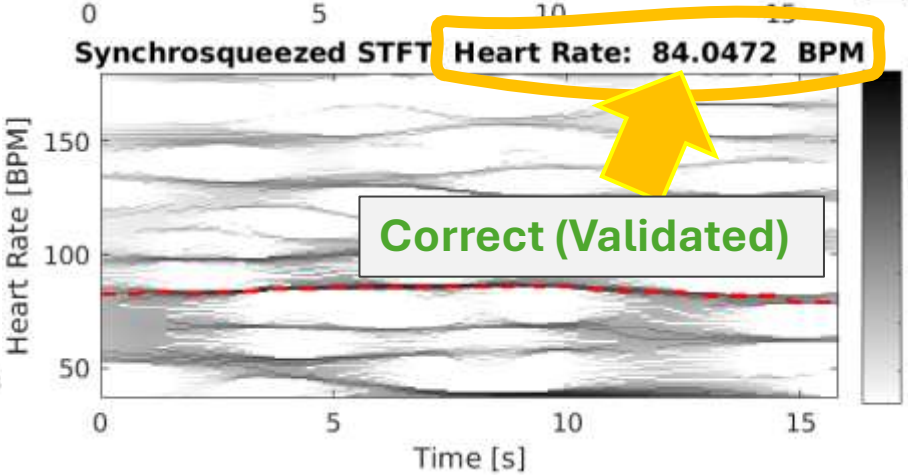




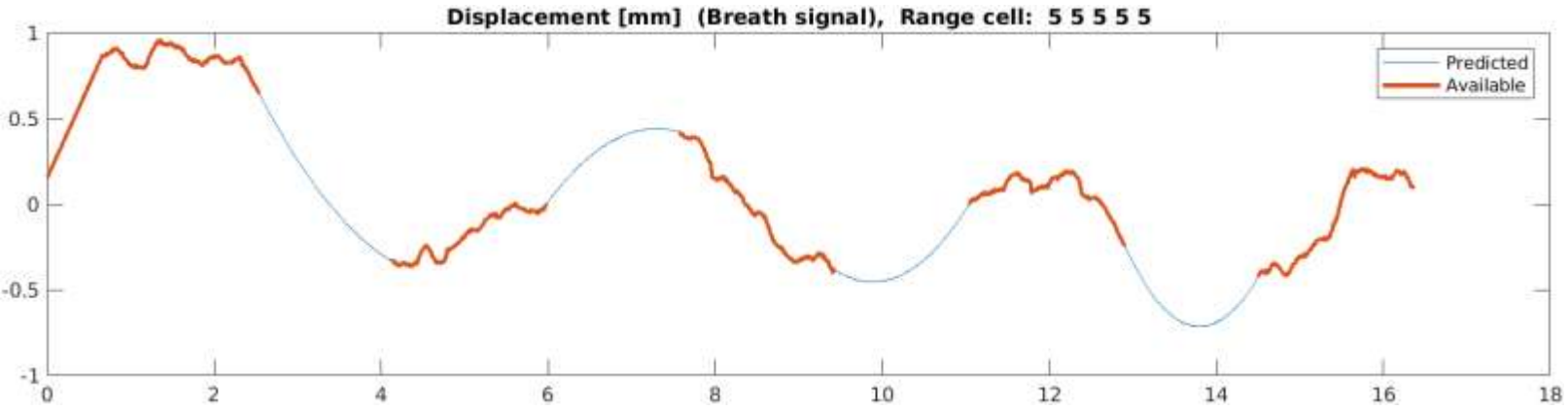


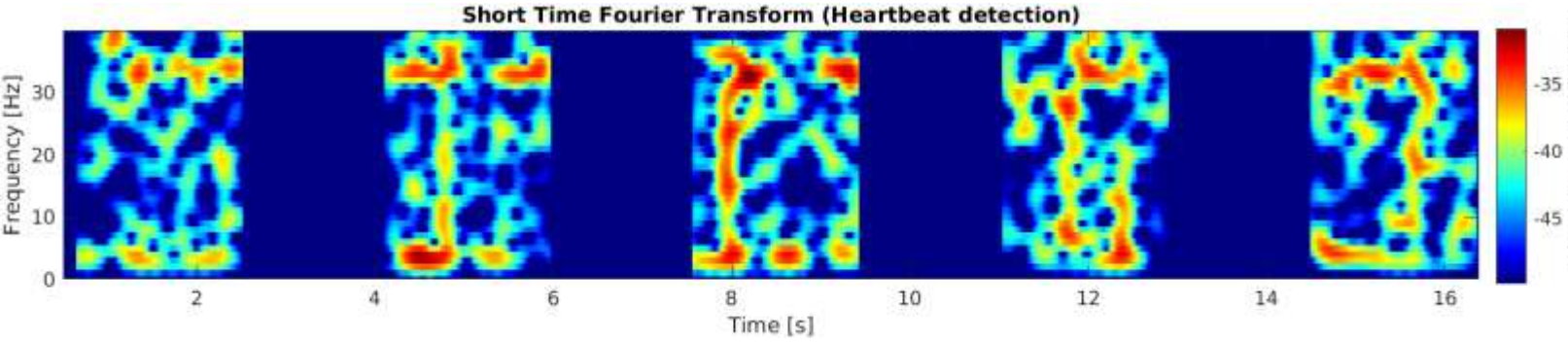


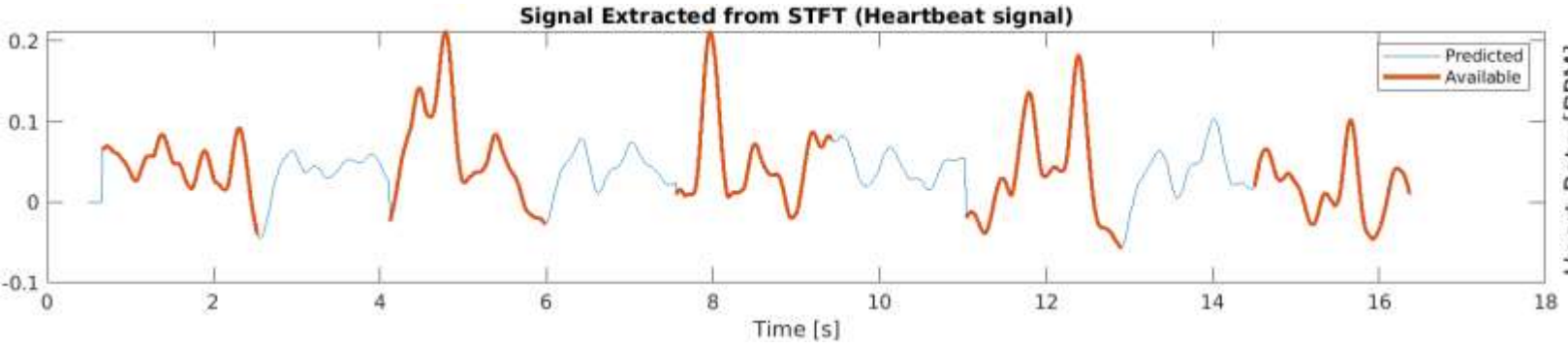


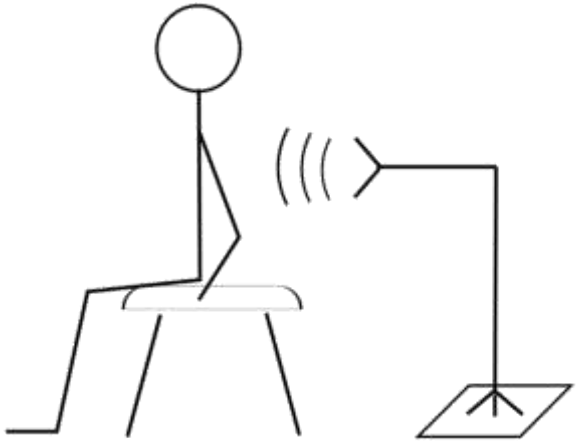


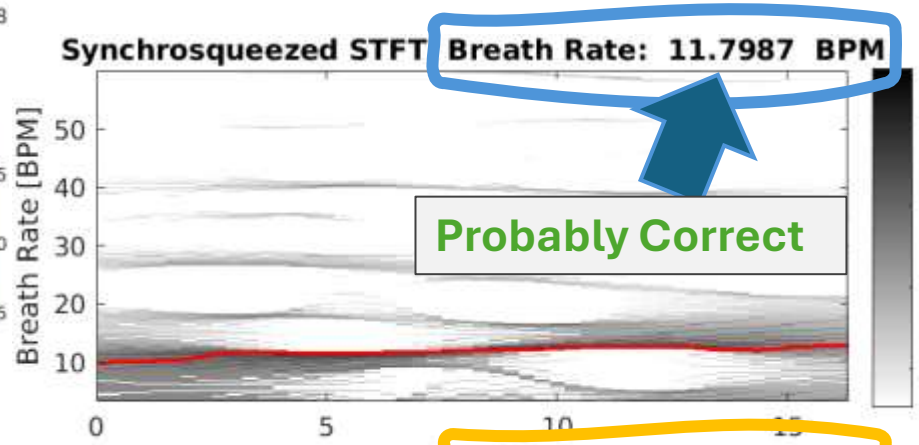
Perspective Test – Back

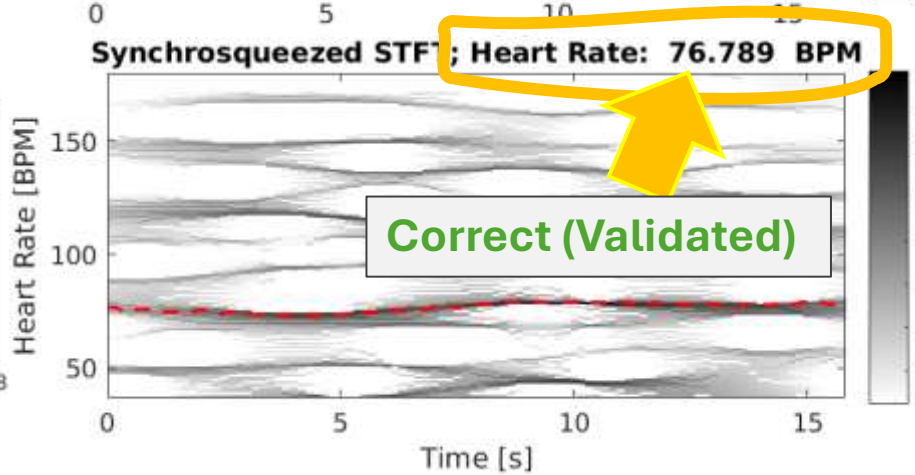




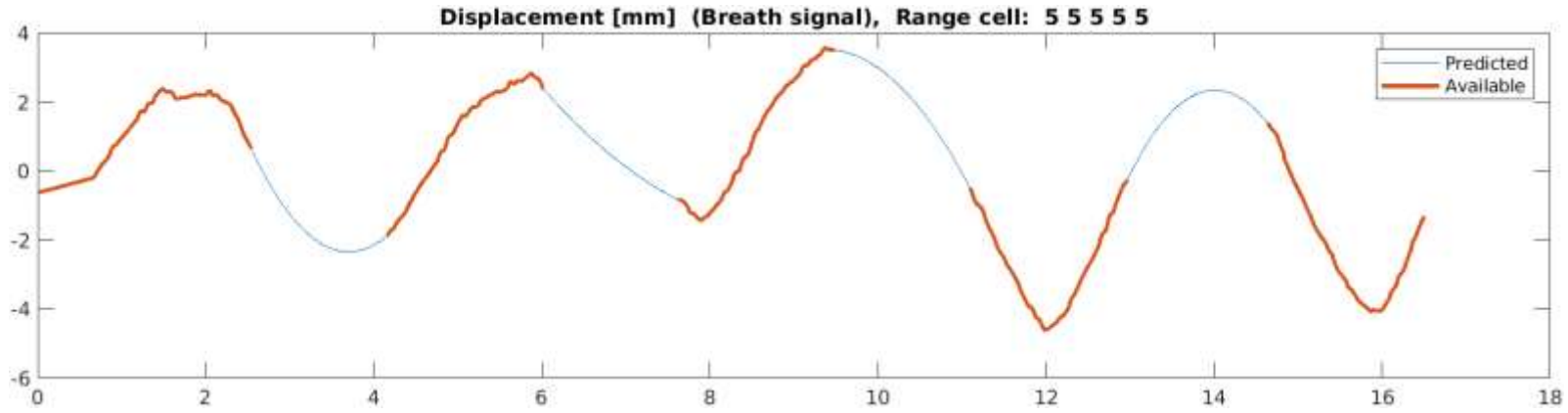


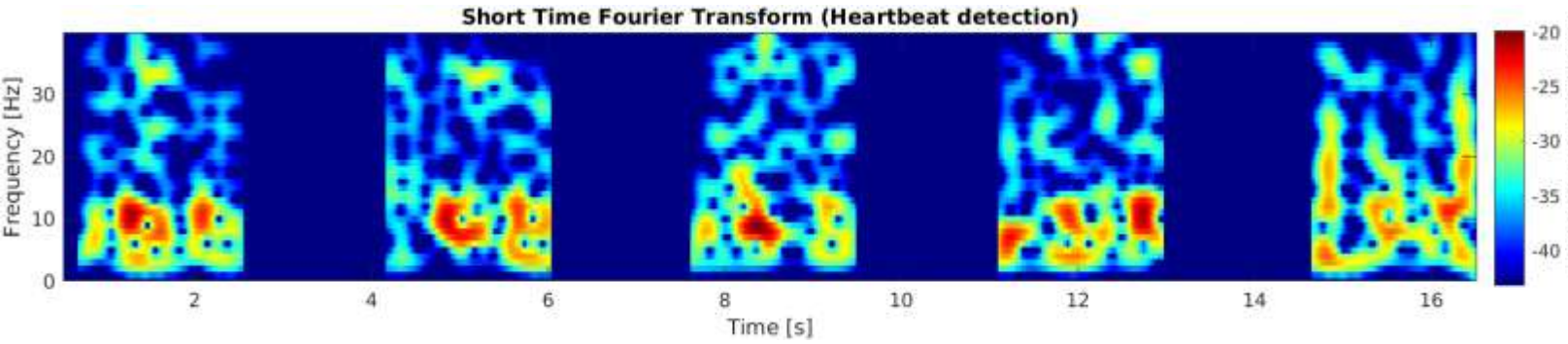


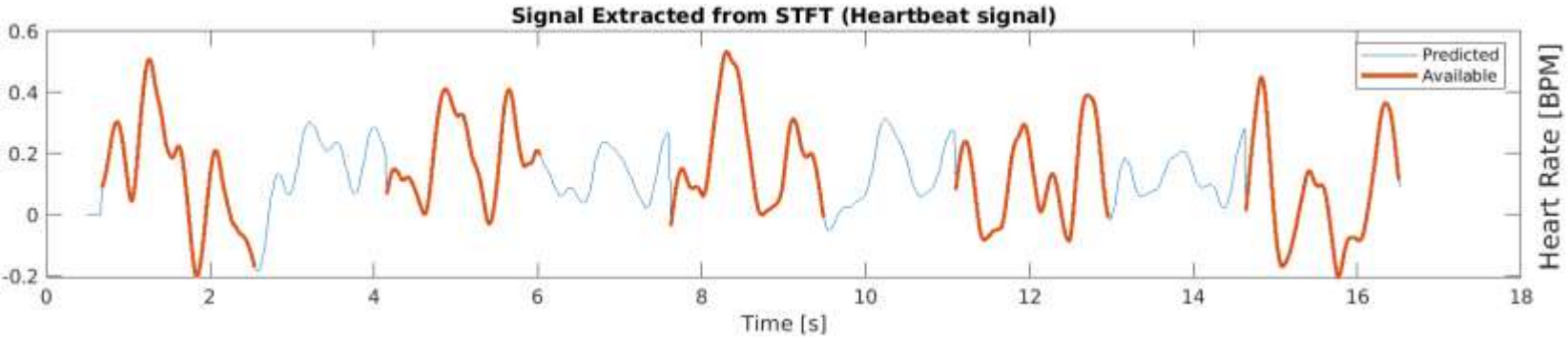


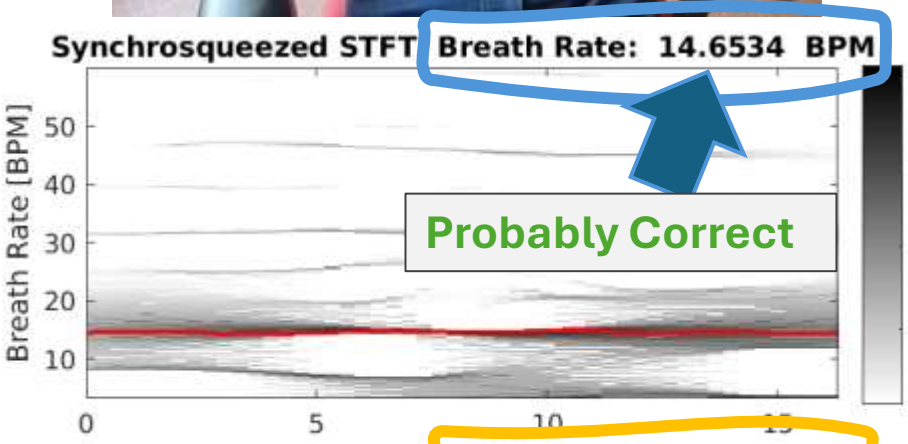


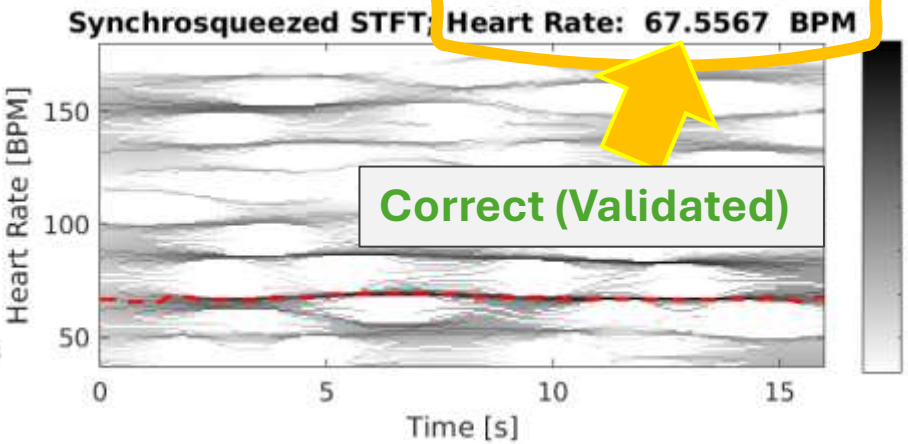
Clothes Test – T-shirt



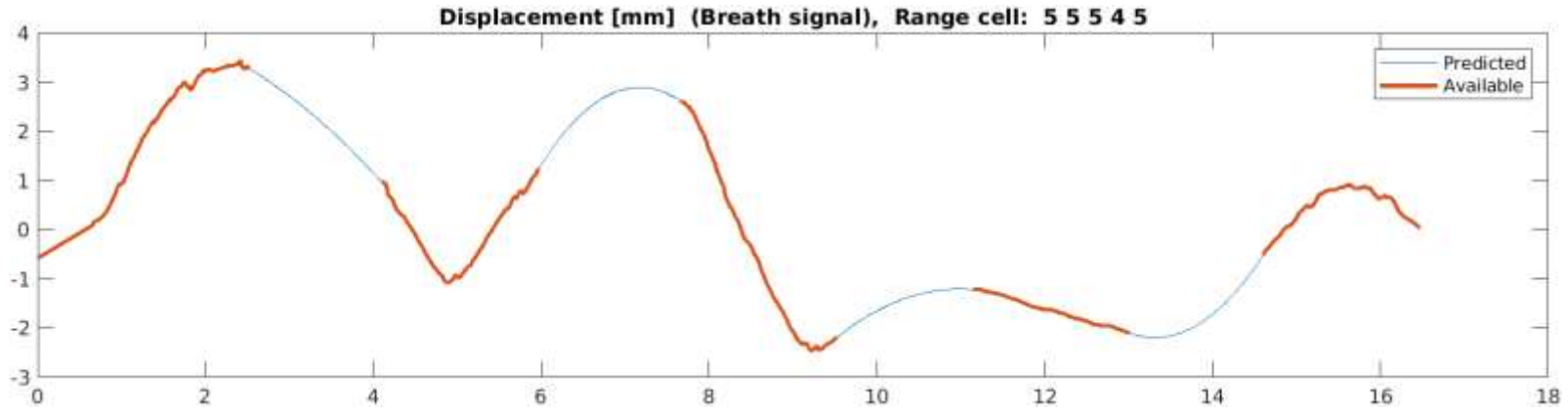


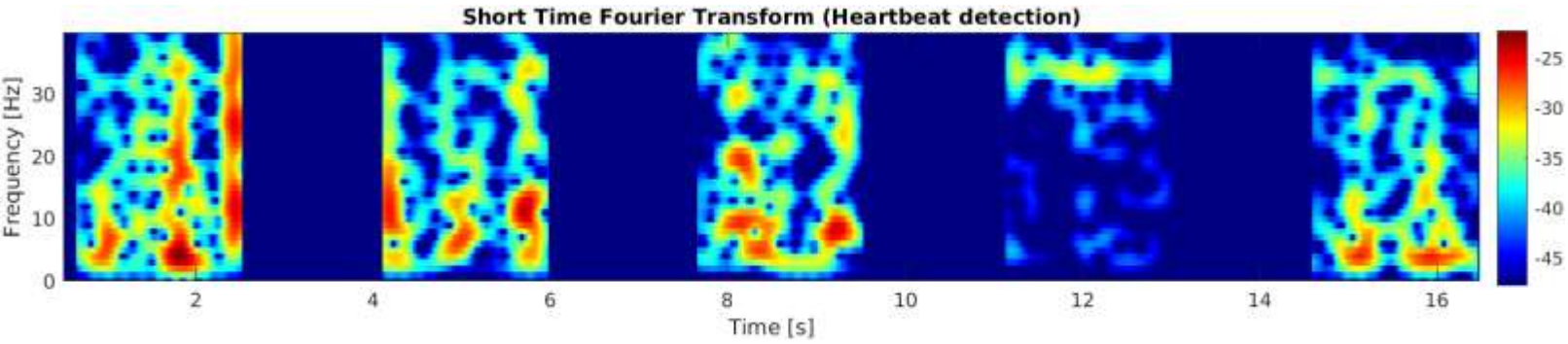


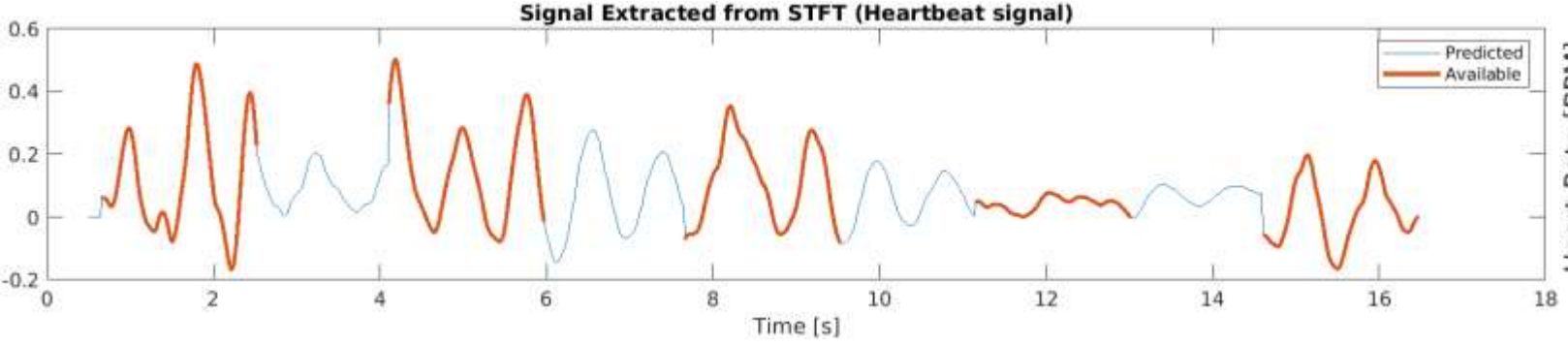


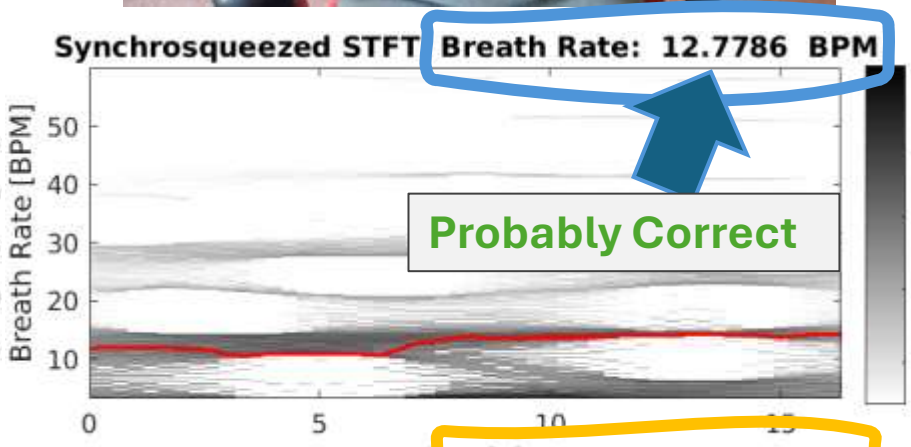


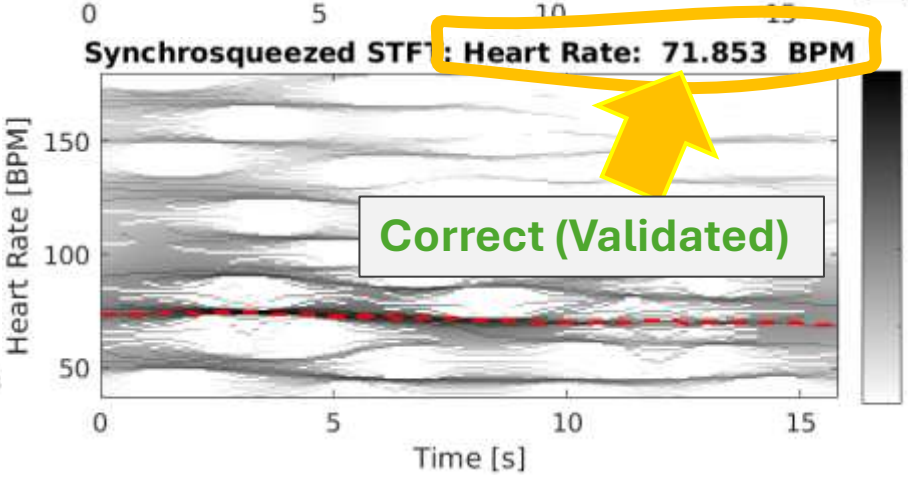
Clothes Test – Thick Hoodie



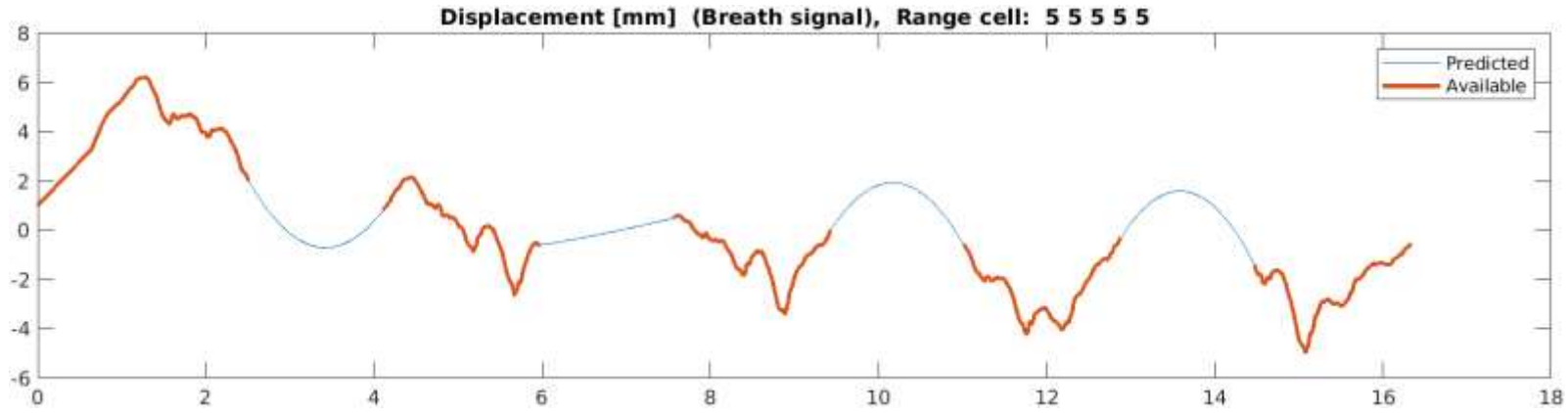


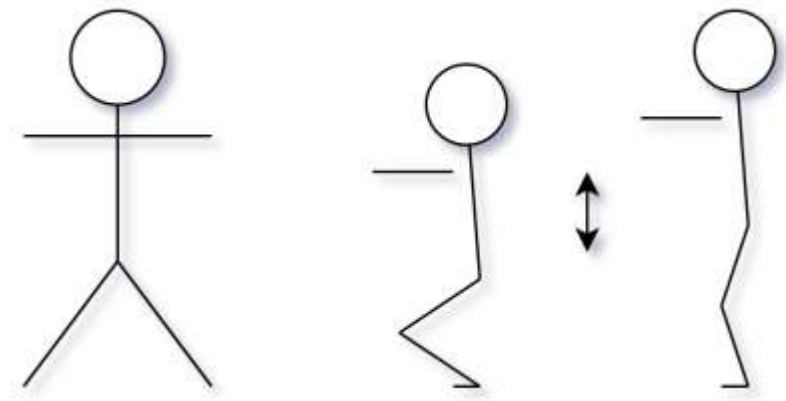


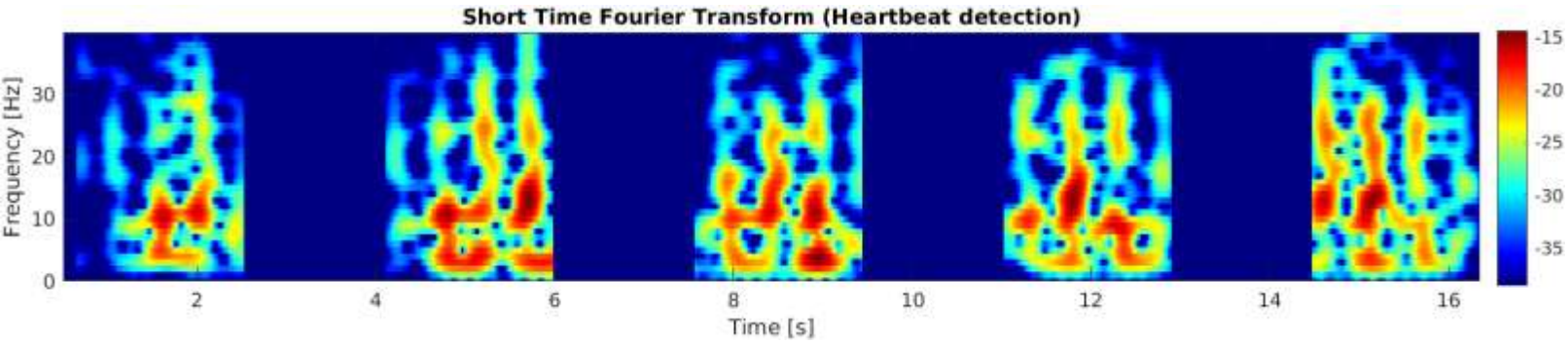


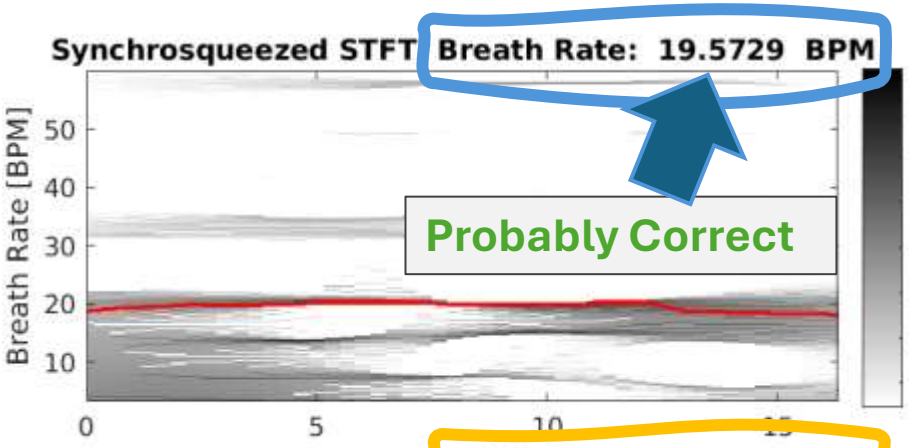


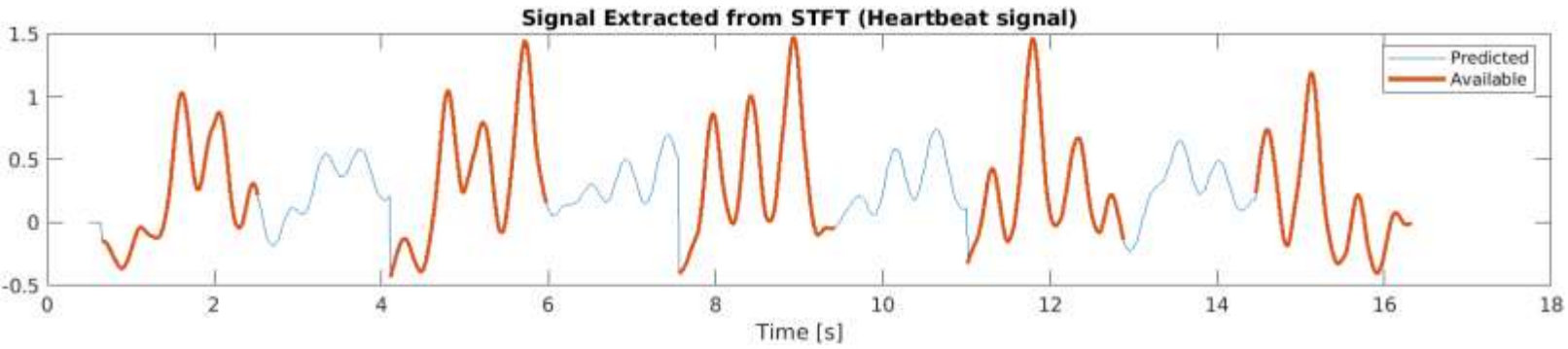
Body State Test – After Exercise

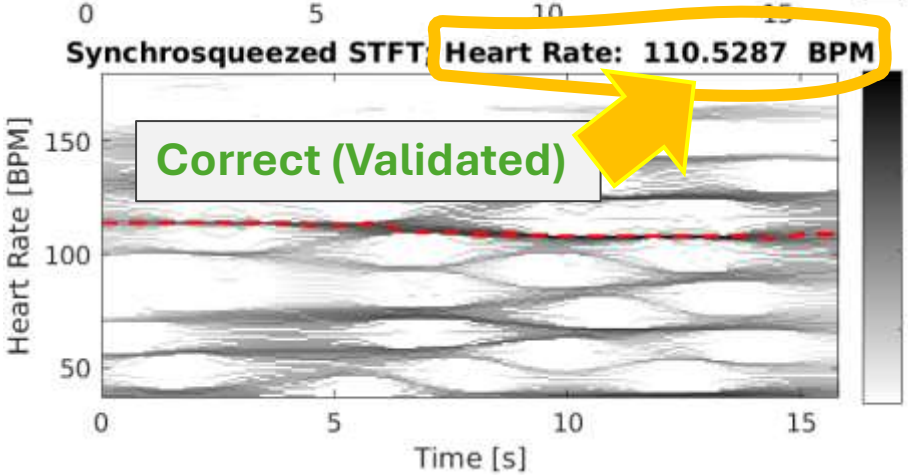












Conclusions from the Experiments

- In all tests shown, at least heart rate radar measurement was approximately correct (validated using pulse oximeter, ± 5 BPM).
- Respiration measurement is often disrupted by breaks in the signal, but in all tests shown, the breath rate is most probably correct.
- Proper aiming of radar antennas is critical.
- Random body movements cause the system to malfunction.
- Range cell choice algorithm often gives incorrect results. In some tests, it needed to be hard-fixed.

ACHIEVEMENTS

New, noise resistant vital signs extraction **algorithms** have been developed, optimized for ADI CN0566. The MATLAB app can run in **near real-time** and gives valid results **in various conditions.**

PROBLEMS

- **Respiration** signal is often distorted by **breaks in data.**
- **Proper aiming** of radar antennas is **critical.**
- **Random body movements** cause the system to **malfunction.**

FUTURE PLANS

- Developing better **method for range cell choice** by detection of vital signs presence.
- Also, **app improvements** are planned to run more smoothly.

Thank you

Bartosz Falęcki, Rafał Najda, Radosław Maksymiuk, Alicja Misterka, Jan Dzwonnik

bartosz.falecki@pw.edu.pl
https://github.com/bfalecki/Healthcare-Radar-Project/