FFI Forsvarets forskningsinstitutt

The Radar Cross Section of the human heartbeat and respiration

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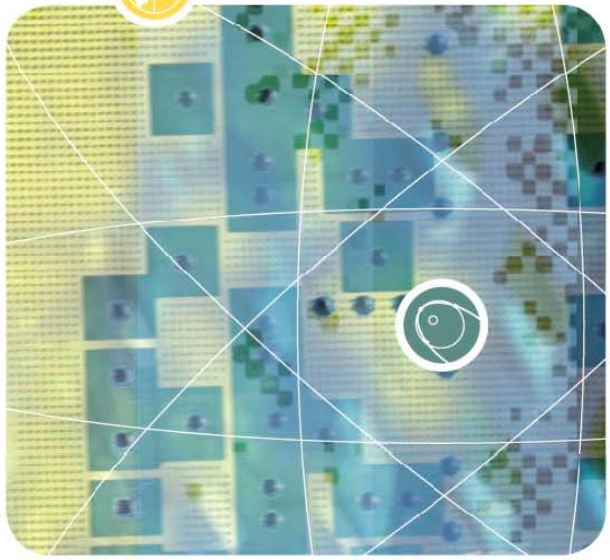
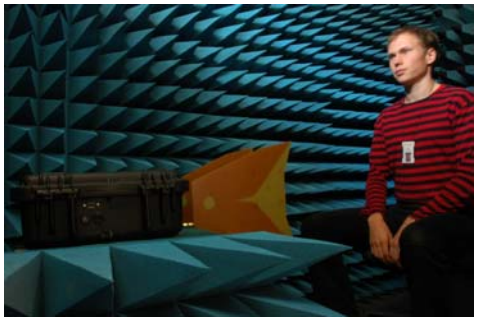
10 May 2010

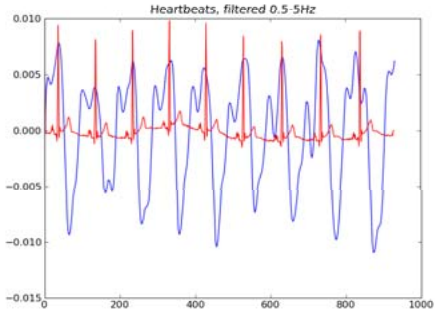


Medical UWB radar at FFI overview



Activities and laboratory

Calibration of UWB physiological recordings



Human heartbeat and respiration Radar Cross Section

Radar laboratory for low-clutter calibrated measurements

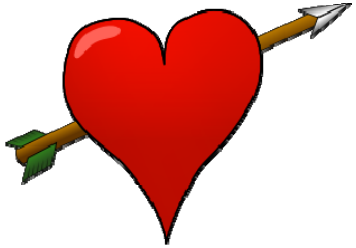
With focus on UWB, we research the use of radar for heartbeat and respiration monitoring

Ongoing research:

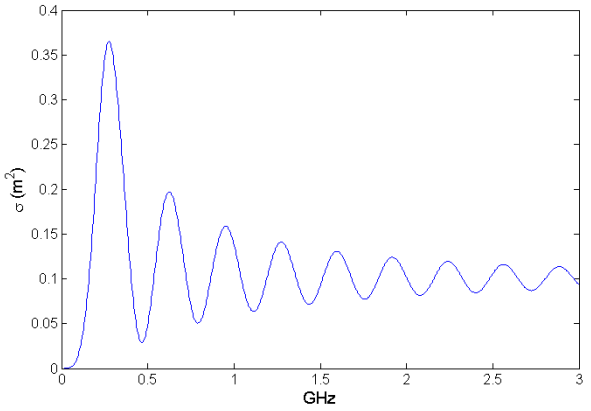
-Developing robust detection and processing algorithms.

-Determine the radar cross section (RCS) of heartbeats and respiration.

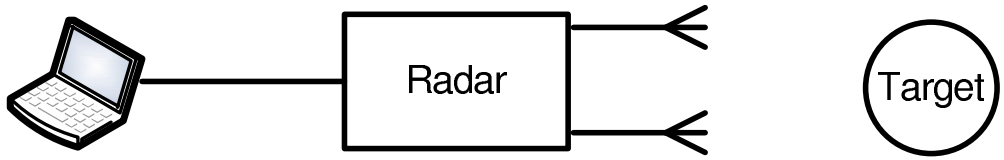
Calibrated radar recordings of physiological motion

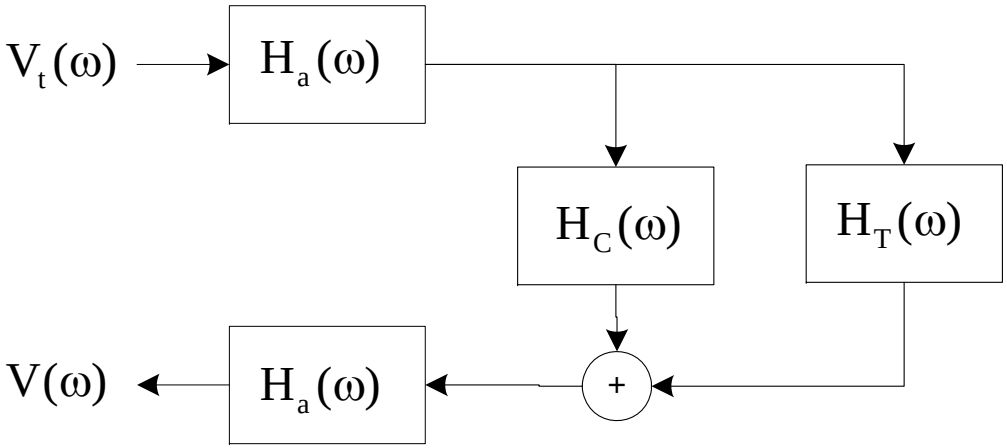


$$\sigma_H = ?$$



Frequency domain measurement model





$$V_T(\omega) = V_t(\omega)H_a^2(\omega)[H_C(\omega) + H_T(\omega)]$$

Frequency domain calibration routine

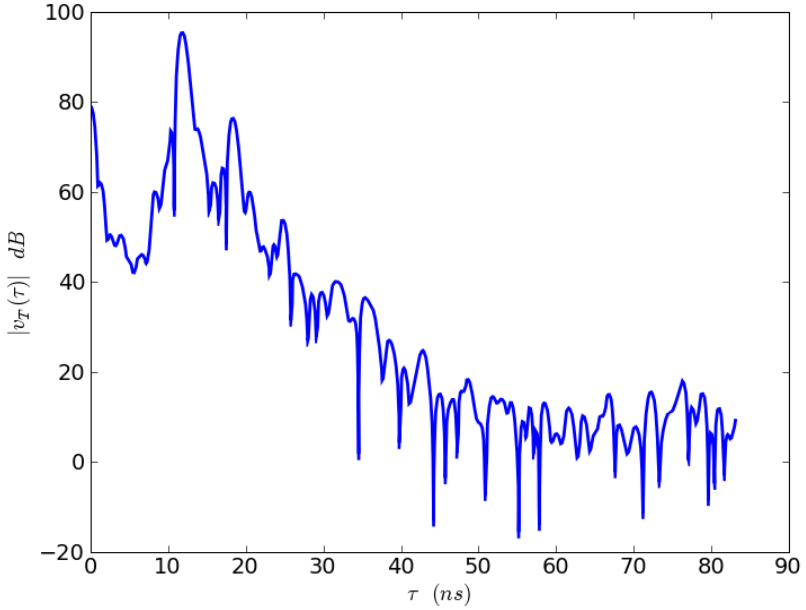
Step 1: Remove clutter from sphere and person measurements:

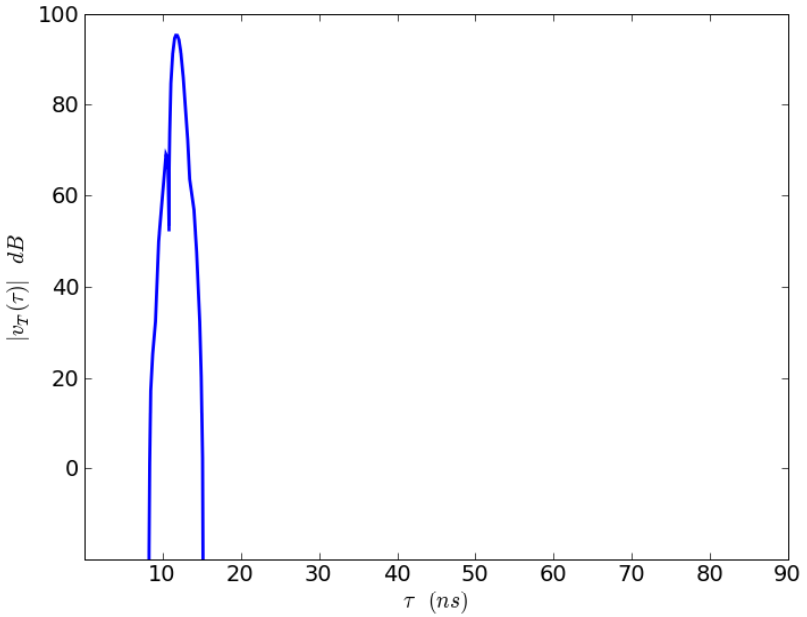
$$\tilde{V}_T(\omega) = V_T(\omega) - V_C(\omega) = V_t(\omega)H_a^2(\omega)H_T(\omega)$$

$$\tilde{V}_S(\omega) = V_S(\omega) - V_C(\omega) = V_t(\omega)H_a^2(\omega)H_S(\omega)$$

Frequency domain calibration routine

Step 2: Software gating in the fast time domain:





$\tilde{v}_T(\tau)$

$\hat{v}_T(\tau)$

Frequency domain calibration routine

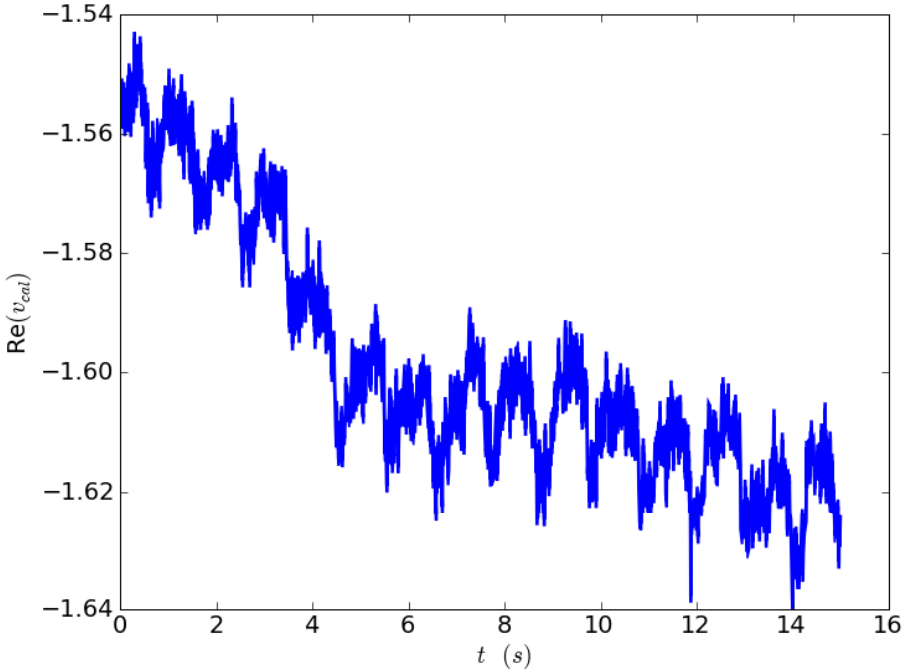
Step 3: Calibration in frequency domain:

$$V_{cal}(\omega) = \frac{\hat{V}_T(\omega)}{\hat{V}_S(\omega) + \frac{1}{SNR(\omega)}}$$

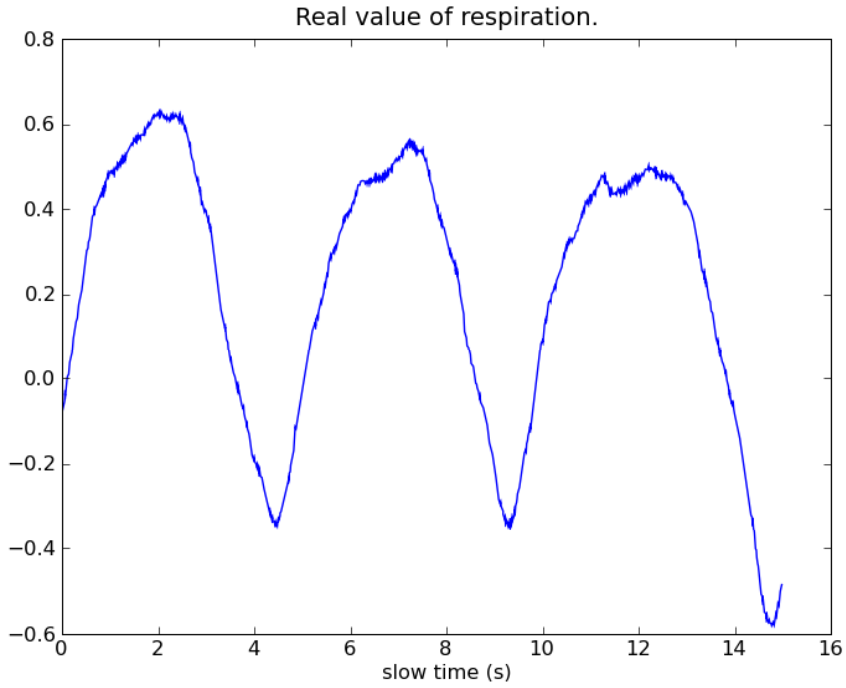
With sphere and person the same range from the radar:

$$|V_{cal}(\omega)|^2 = \frac{\sigma_T(\omega)}{\sigma_S(\omega)}$$

Slow time variations at the range where the person is sitting

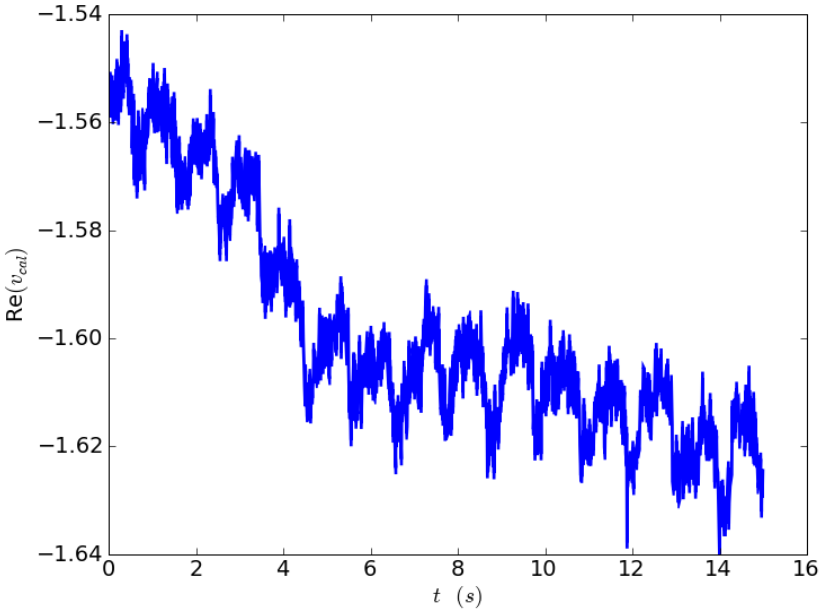


A sitting person holding his breath.



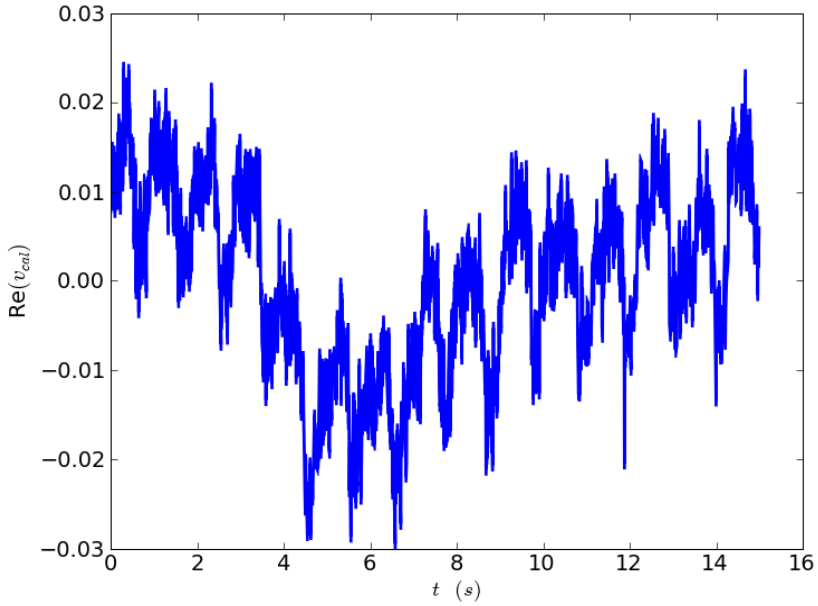
A sitting person breathing.

Processing to separate physiological movement from stationary targets



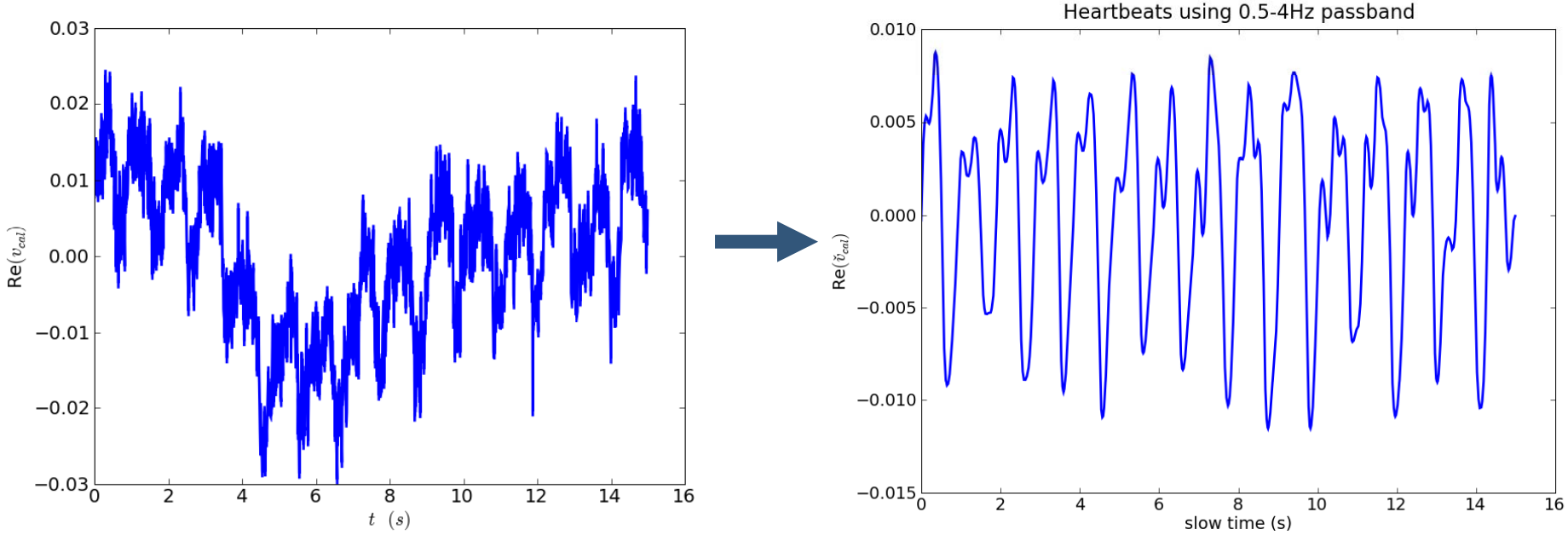
$v_{cal}(\tau)$

Raw signal



Linear trends removed

Processing to separate physiological movement from stationary targets



$$\hat{v}_{cal}(\tau)$$

Further processed by bandpass filtering in slow time

Radar Cross Section (RCS) of human heartbeat and respiration

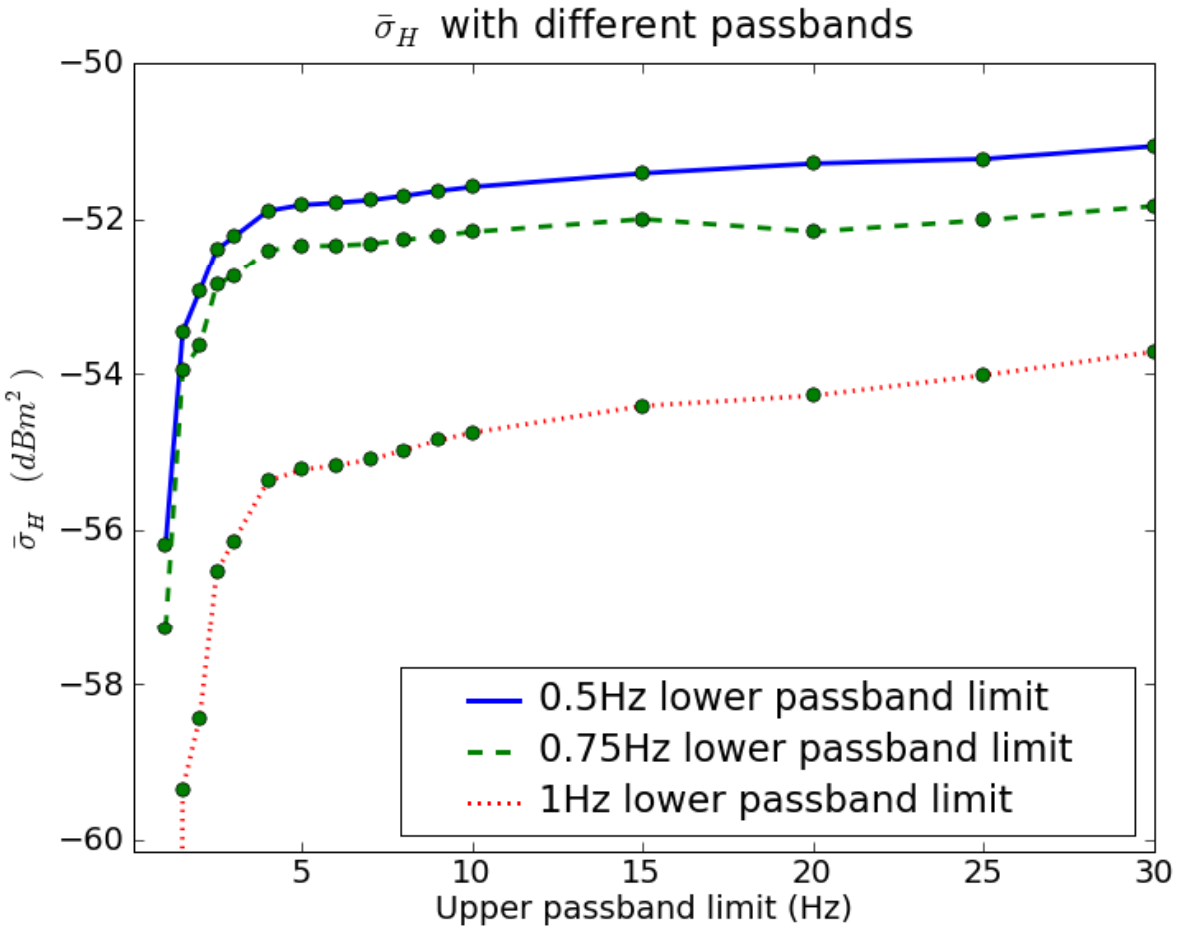
$$\sigma = |\hat{v}_{cal}(\tau)|^2 \, \sigma_S$$

Remember:

$$|V_{cal}(\omega)|^2 = \frac{\sigma_T(\omega)}{\sigma_S(\omega)}$$

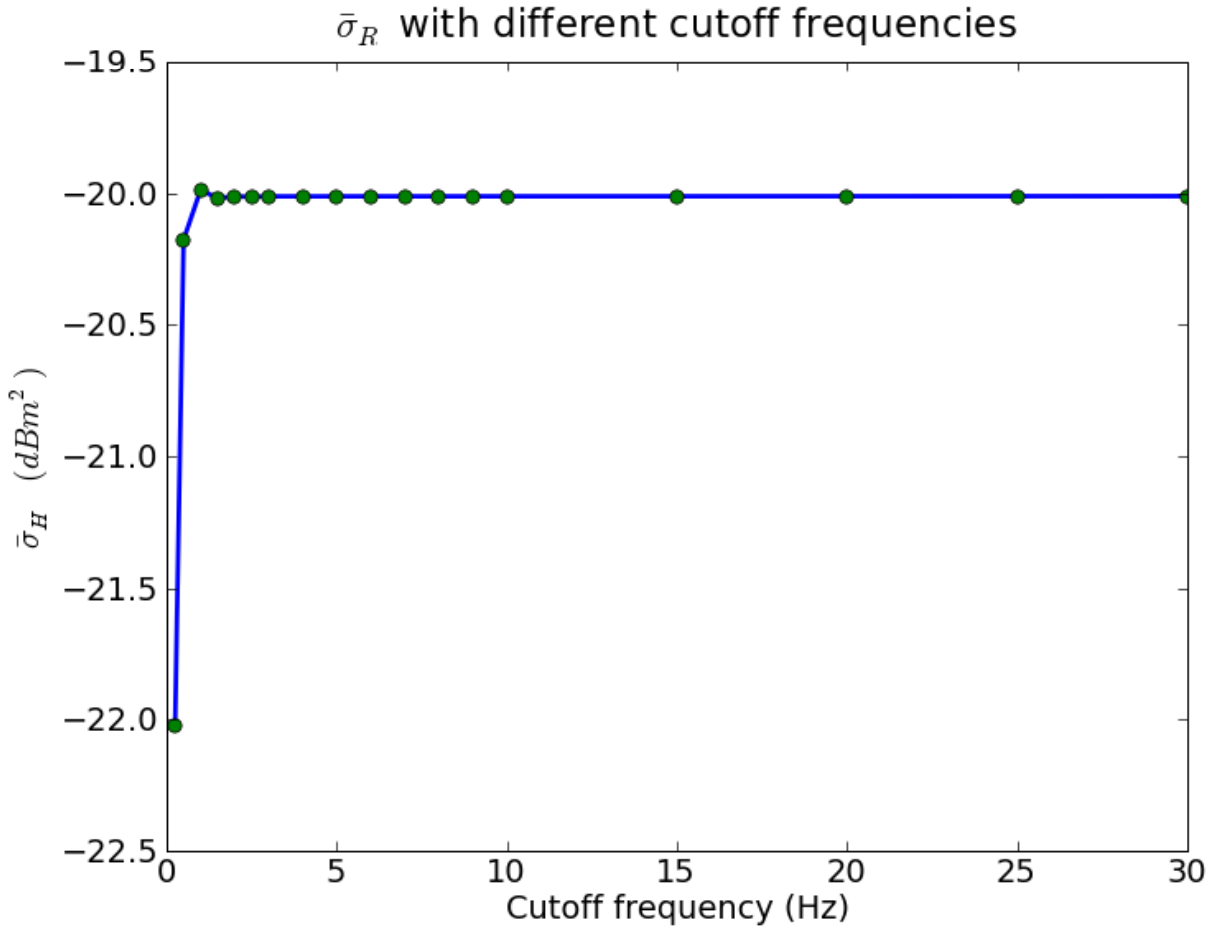
Radar Cross Section (RCS) of human heartbeats, processed with various passbands

$$\sigma = |\hat{v}_{cal}(\tau)|^2 \sigma_S$$

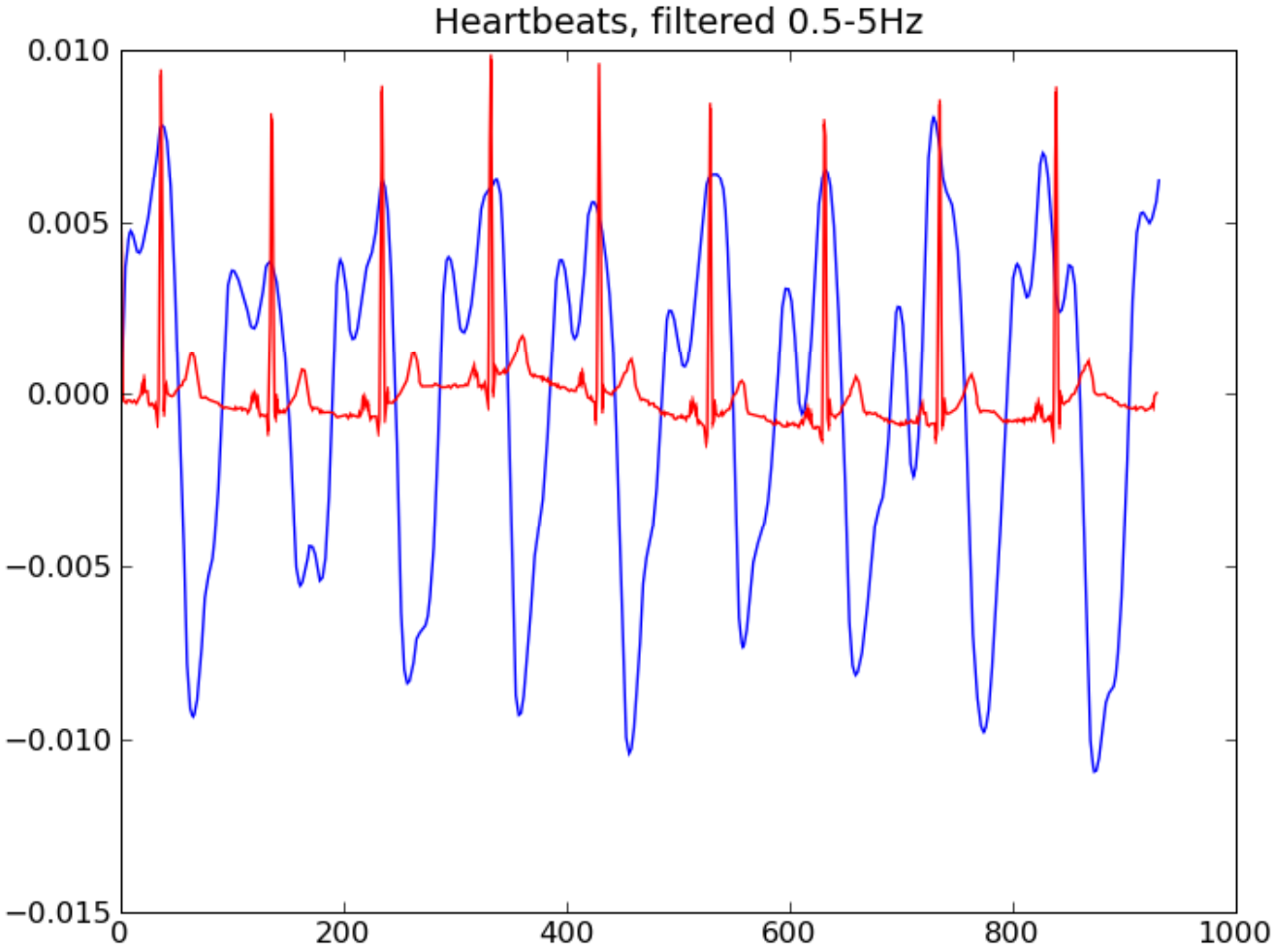


Radar Cross Section (RCS) of human respiration, processed with various passbands

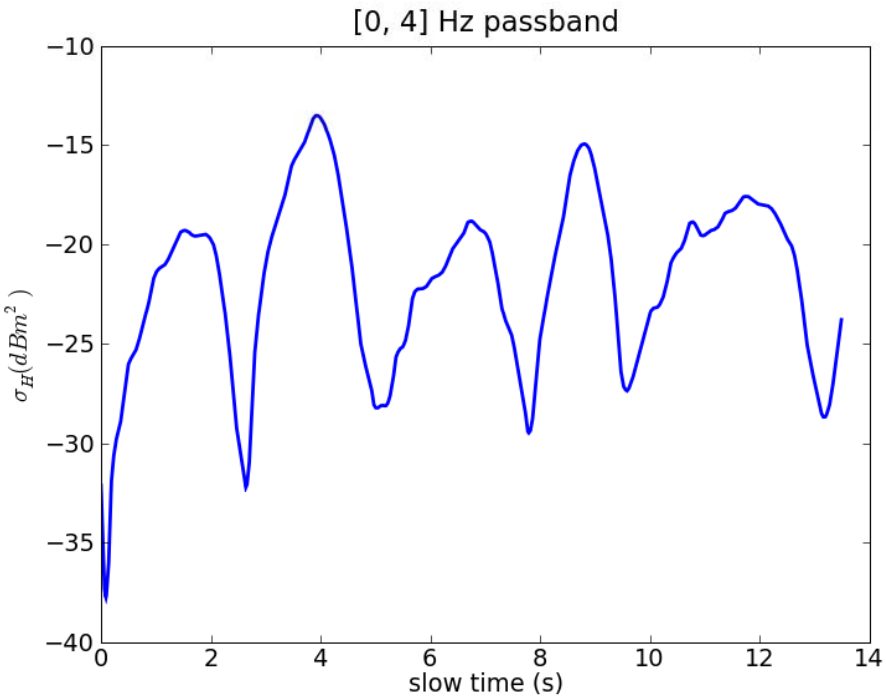
$$\sigma = | \hat{v}_{cal}(\tau) |^2 \, \sigma_S$$

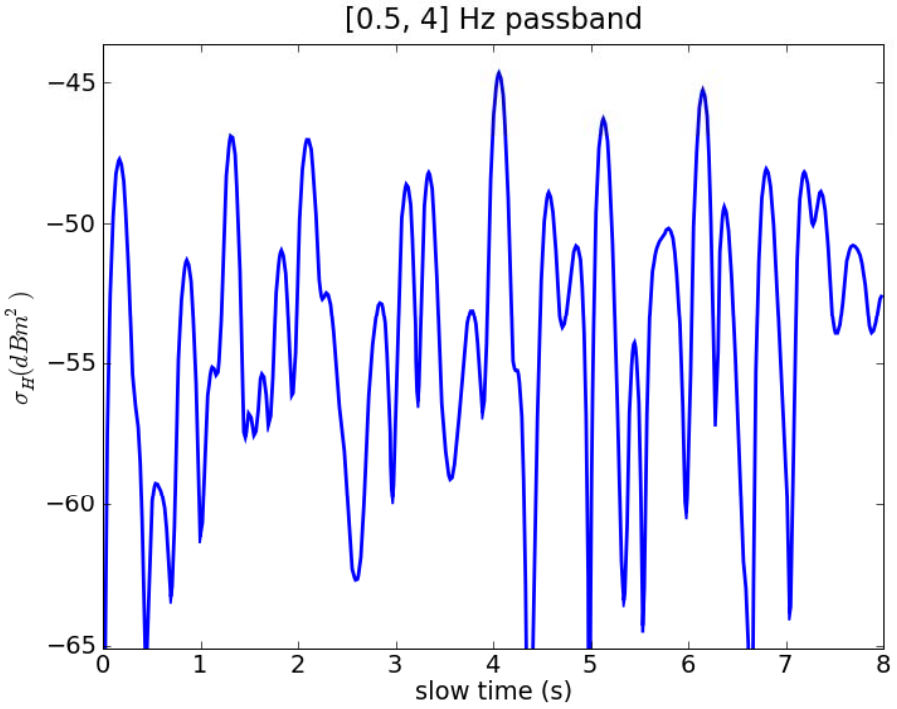


Radar heartbeat recordings agrees with ECG recordings



In conclusion: The human heartbeat and respiration RCS have been found for 2-3GHz





Questions?