

Measurement of Respiratory and Cardiac Motion Using a Multi Antenna Continuous Wave Radar Operating in the Near Field

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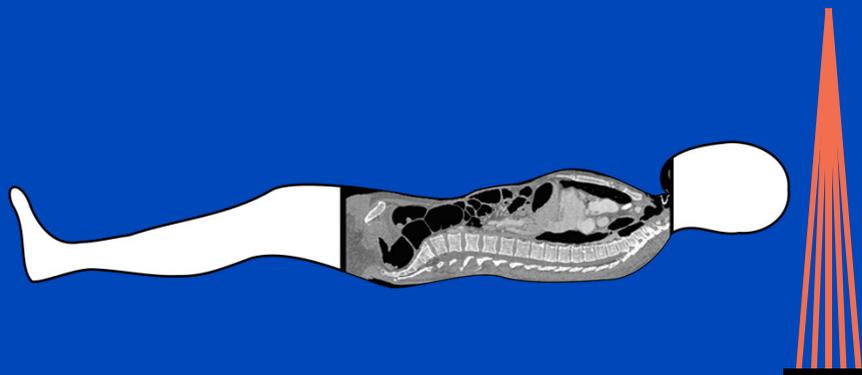
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Medical Imaging

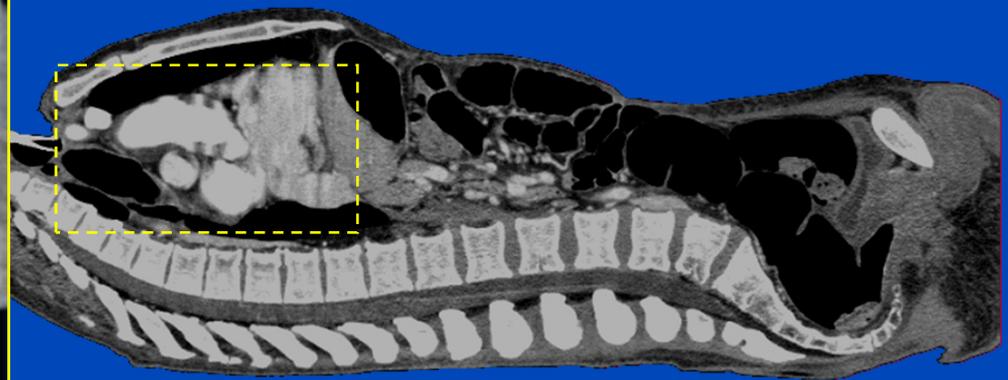
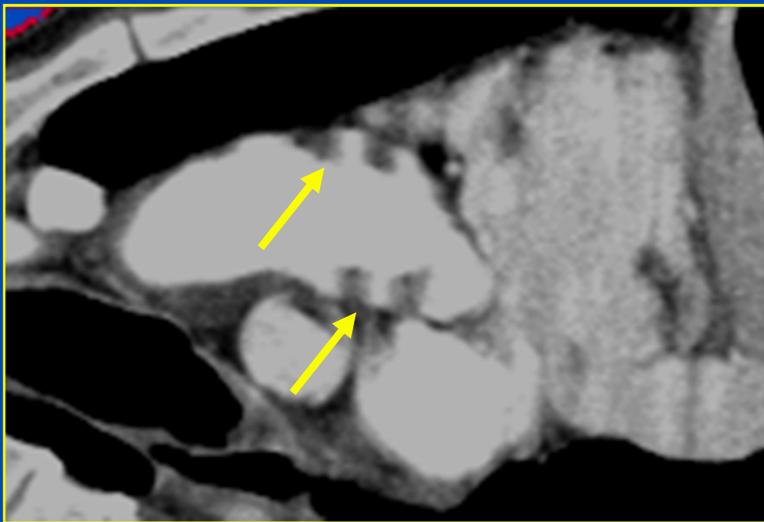
- Medical imaging devices like computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) or single-photon emission computed tomography (SPECT) record images slice by slice.
- A 3D volume is reconstructed using tomographic reconstruction algorithm.



C=0 HU / W=1000 HU

Motion Artifacts

- If the patient moves during data acquisition, the reconstructed volume may contain motion artifacts.
- Patients are advised not to move. Unfortunately this is not always possible due to breathing or cardiac motion.
- Alternatively, one may explicitly account for the patient motion by triggering the device.



Respiratory Gating Devices



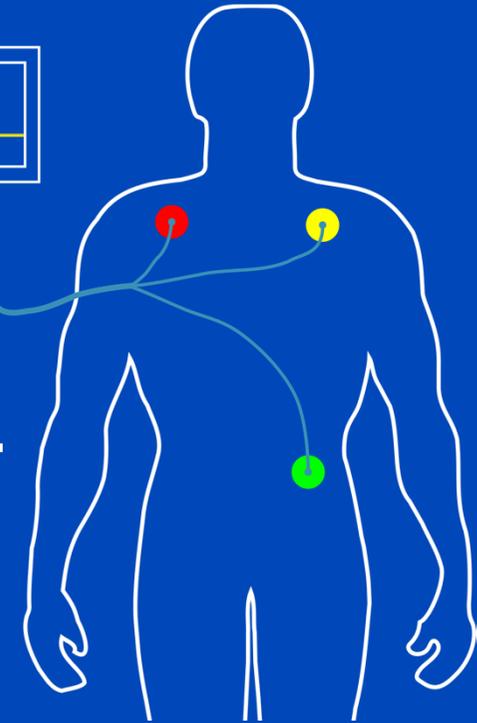
Pressure sensor with elastic belt (Anzai)



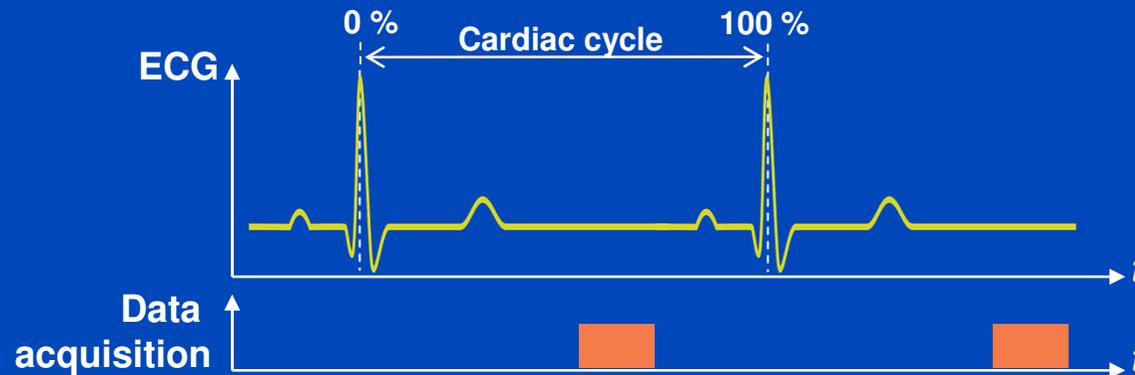
External marker block and infrared camera (Varian RPM)

Sadek A. Nehmeh and Yusuf E. Erdi. Respiratory motion in positron emission tomography/computed tomography: A review. *Seminars in Nuclear Medicine*, 38(3):167–176, 2008.

Cardiac CT



- Heart rate and heart periodicity is measured using an electrocardiogram (ECG).
- In dependency of the heart rate, a scan window is defined at which the data acquisition should be performed.

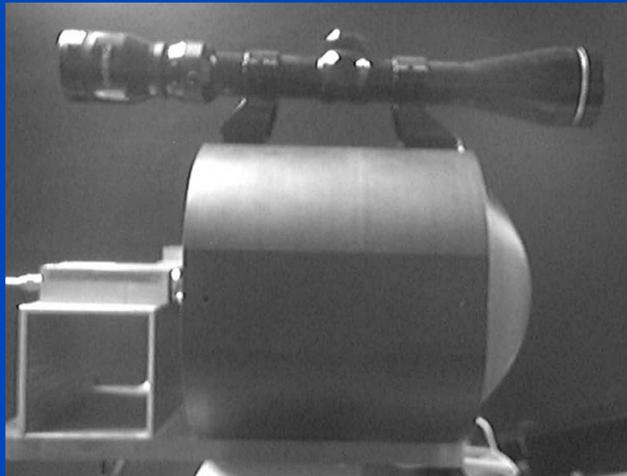


Marc Kachelrieß and Willi A. Kalender. Electrocardiogram–correlated image reconstruction from subsecond spiral computed tomography scans of the heart. *Med. Phys.*, 25(12):2417–2431, December 1998.

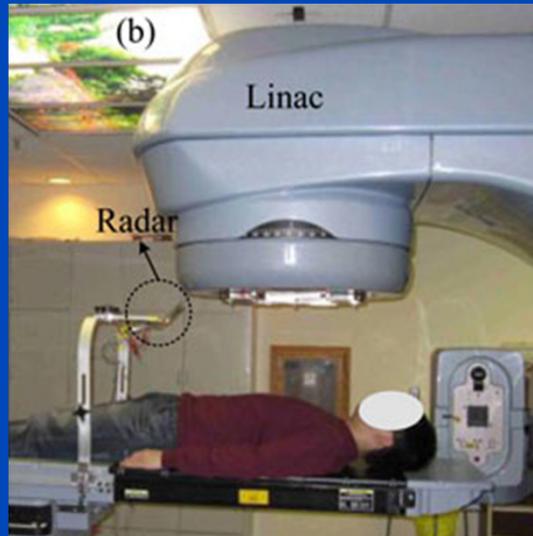
Motivation

- In many medical applications, motion caused by breathing or due to heartbeat needs to know:
 - CT, MRI
 - PET, SPECT
 - Radiation therapy
 - ...
- Approaches used today require additional effort in preparing the patient and they are not able to measure motion inside of the body without implanting markers.
- Use radar to measure respiratory and cardiac motion inside of the body.

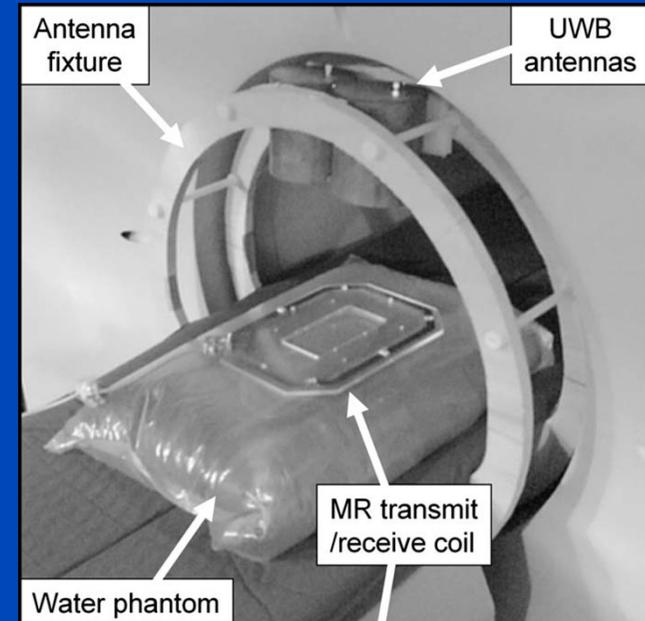
Prior Art



Remote Sensing of Heart Rate and Patterns of Respiration on a Stationary Subject Using 94 GHz Millimeter Wave Interferometry, I. Mikhelson et al., IEEE Transactions on Biomedical Engineering, 2011



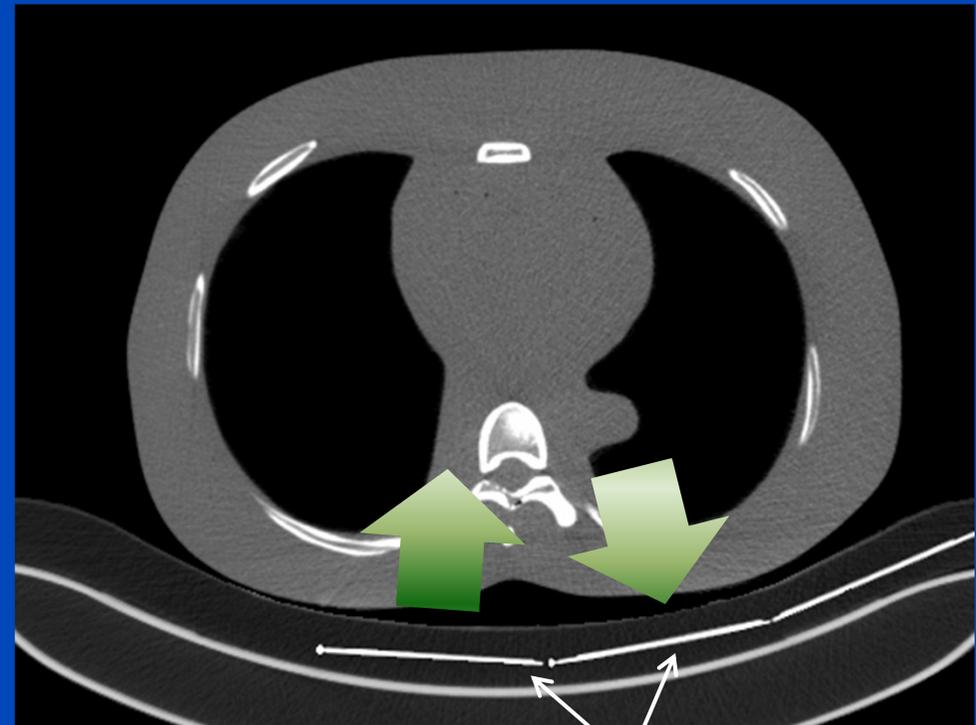
Accurate Respiration Measurement Using DC-Coupled Continuous-Wave Radar Sensor for Motion-Adaptive Cancer Radiotherapy, Changzhan Gu et al., IEEE Transactions of Biomedical Engineering, vol. 59, 2012



Combining magnetic resonance imaging and ultrawideband radar: A new concept for multimodal biomedical imaging, F. Thiel et al., Review of Scientific Instruments 80, 2009

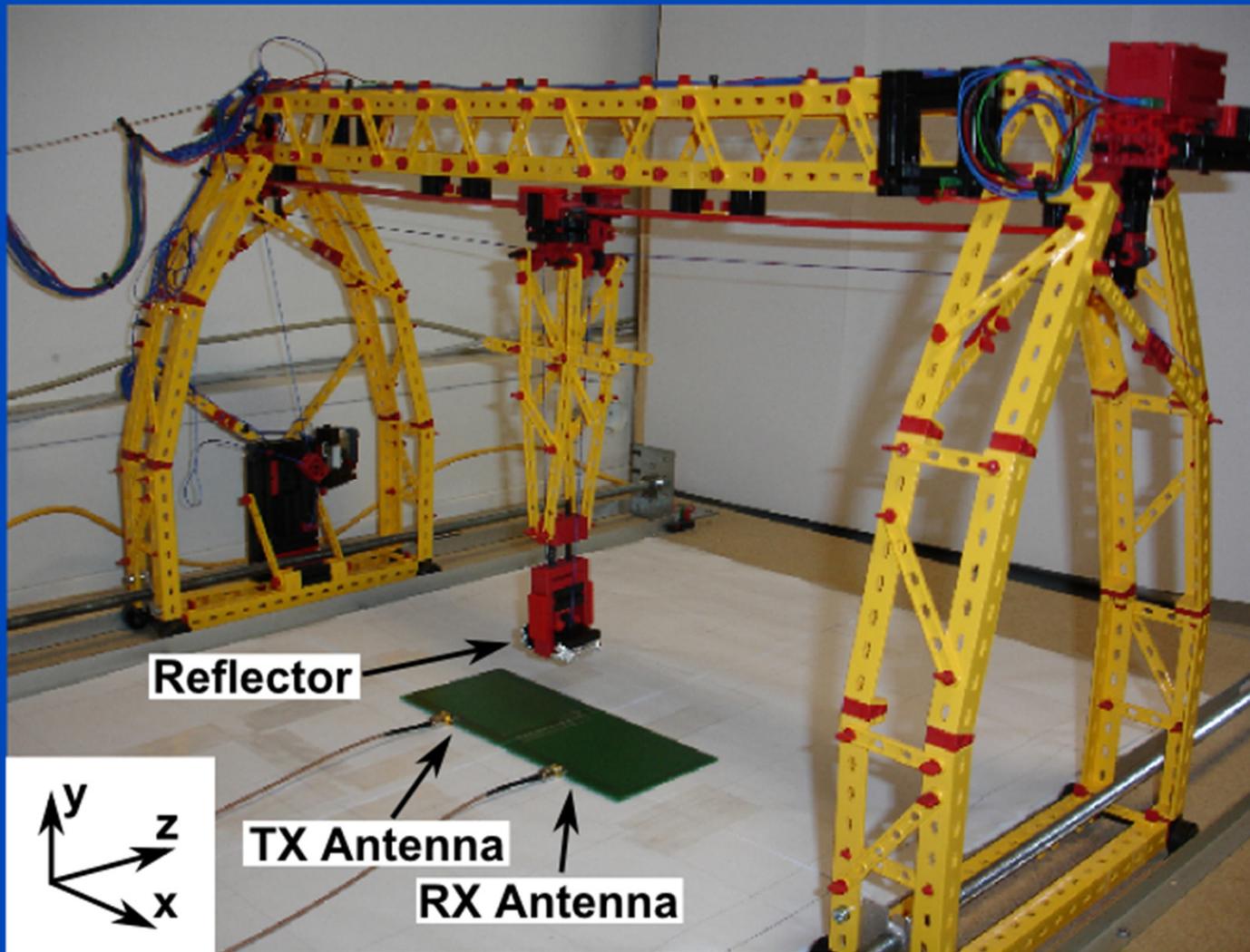
Basic Concept

- Use of radar waves that propagate into the body.
- Radar waves are reflected at organ boundaries.
- Evaluation of the distance between radar antennas and reflection point.
- Calculate motion of the reflection point.



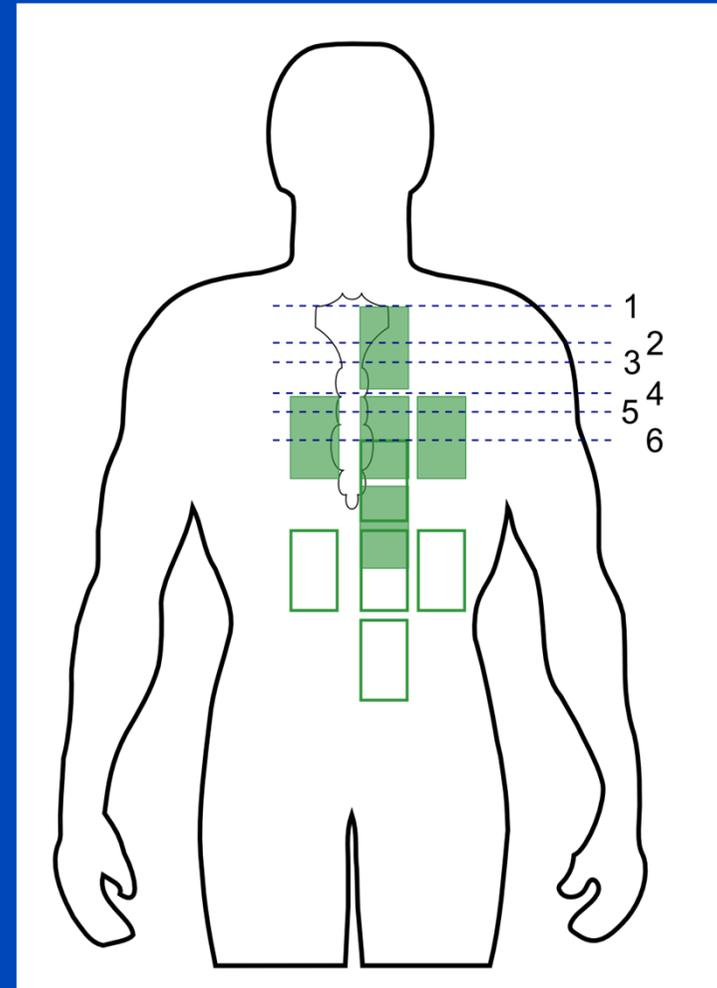
Radar antennas

Test Site Buildup



Test Person Measurement

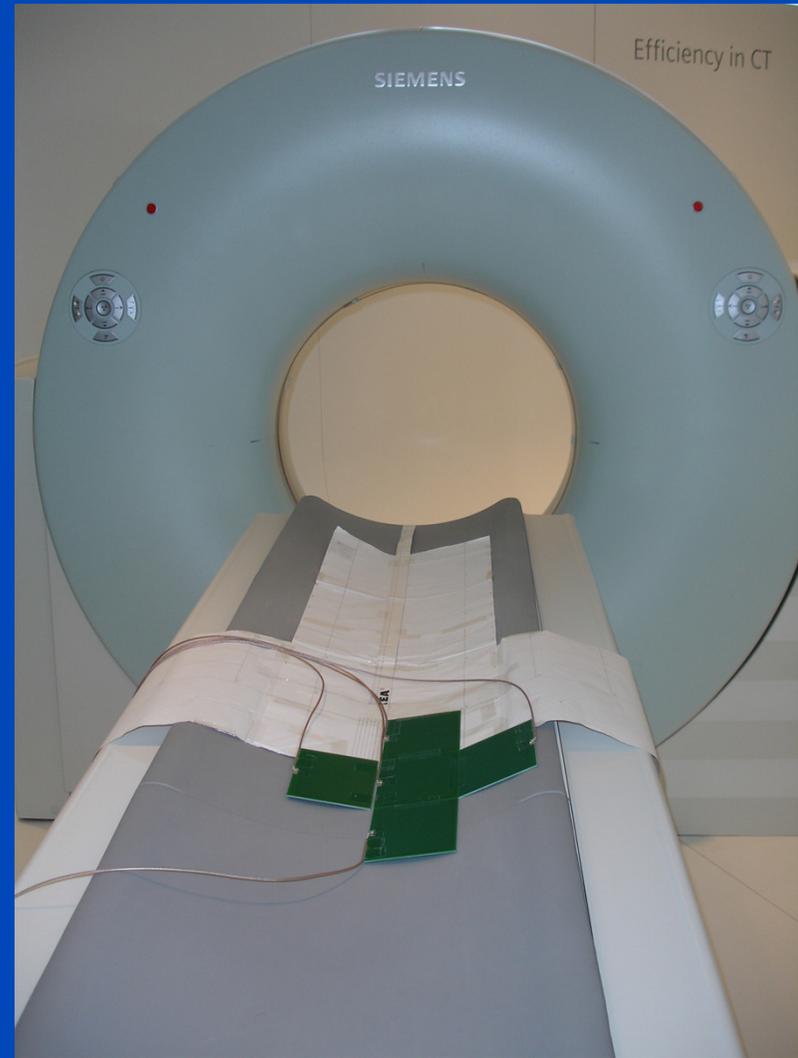
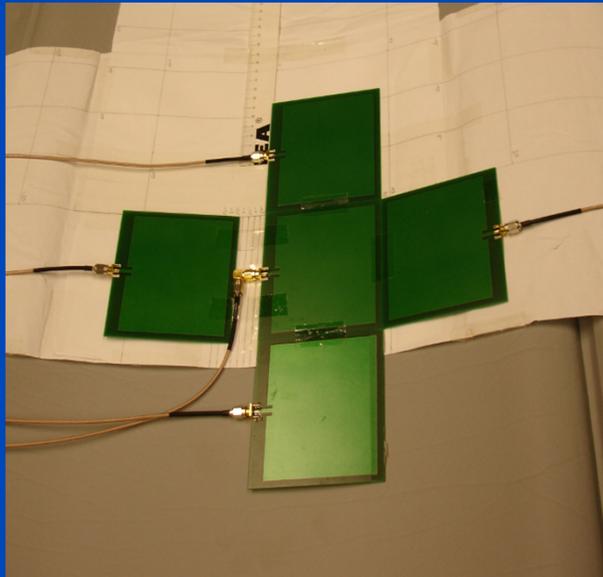
- 10 persons (6 male, 4 female)
- 6 different locations of the antennas.
- On each position of the test person above the antennas, two datasets are recorded:
 - Normal breathing
 - Normal breathing interrupted by breath-holds
- As a reference, the respiratory motion was recorded.
- Also the ECG was recorded simultaneously.



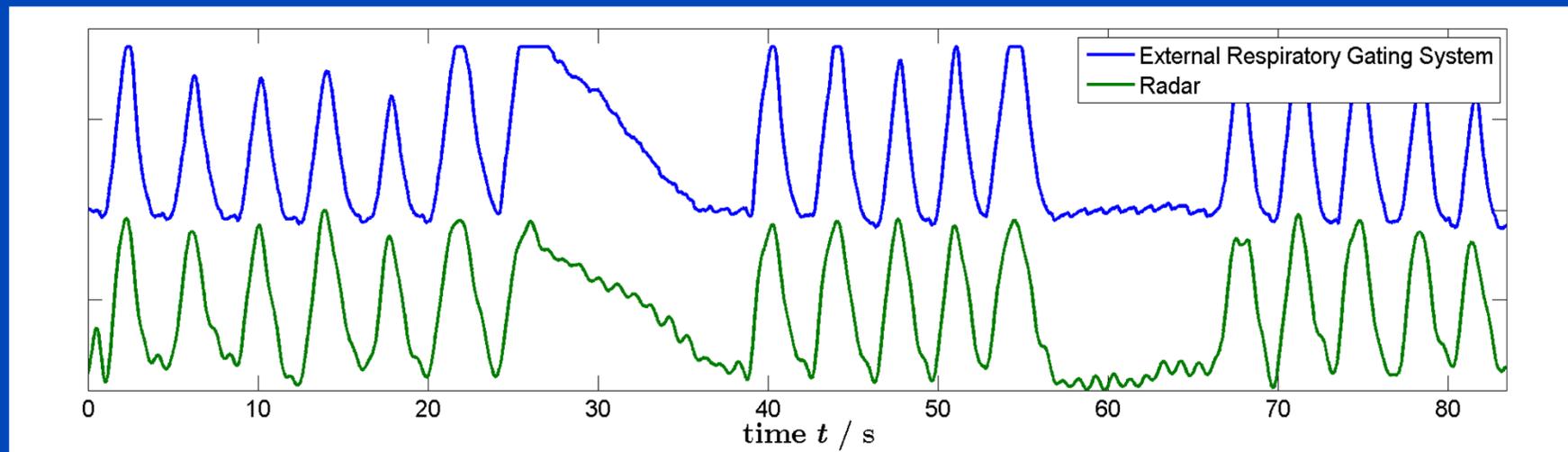
Location of the antennas for the six measurement positions.

Test Person Positioning

- The antennas were placed on top of a standard CT table.
- The patient lies in the supine position on the table, directly above the antennas.



Respiratory Motion

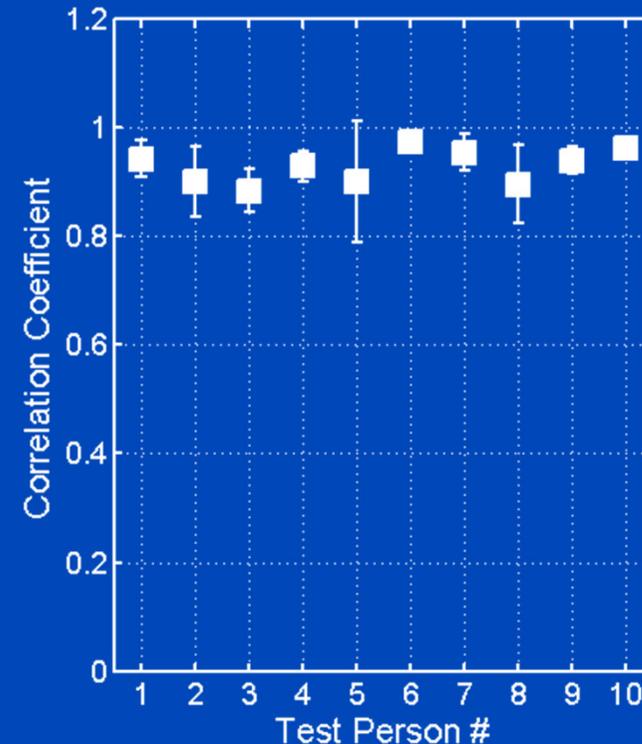


Normal breathing Inhale breath-hold, slow expiration Normal breathing Exhale breath-hold Normal breathing

Florian Pfanner, Joscha Maier, Thomas Allmendinger, Thomas Flohr, and Marc Kachelrieß. Monitoring internal organ motion with continuous wave radar in CT. *Med. Phys.*, 40(9):091915, 2013.

Test Person Measurements Respiratory Motion

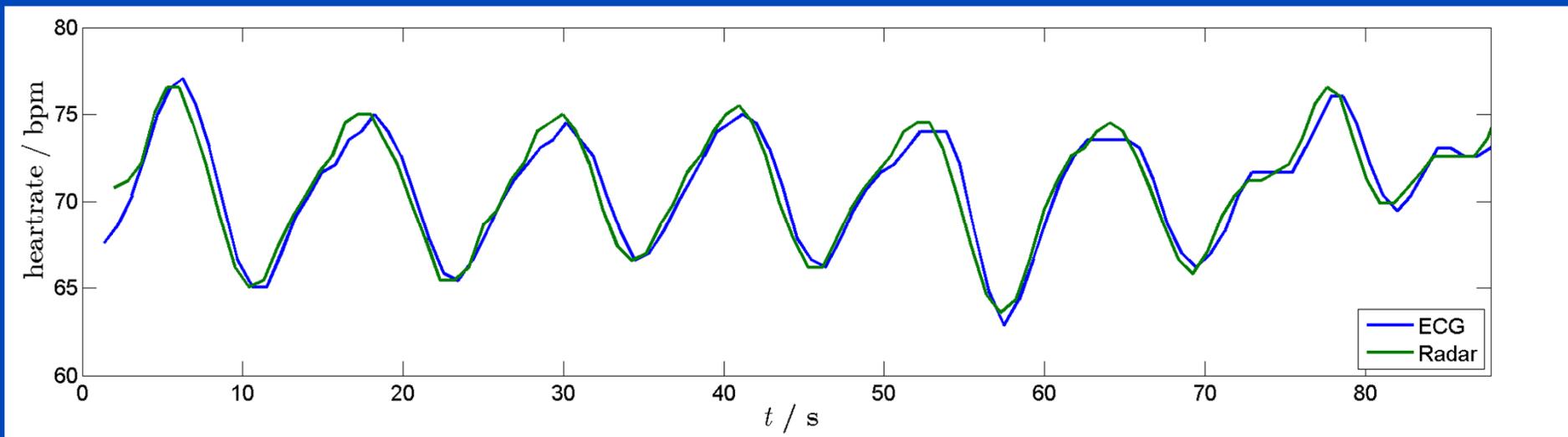
- Comparison between respiratory motion curve between radar and external gating system is done by calculating the Pearson correlation coefficient.
- The motion curves measured with the radar system are very similar to the motion curves measured with the external gating system.



Correlation coefficients between respiratory motion calculated from radar data and respiratory motion measured with the external respiratory gating system.

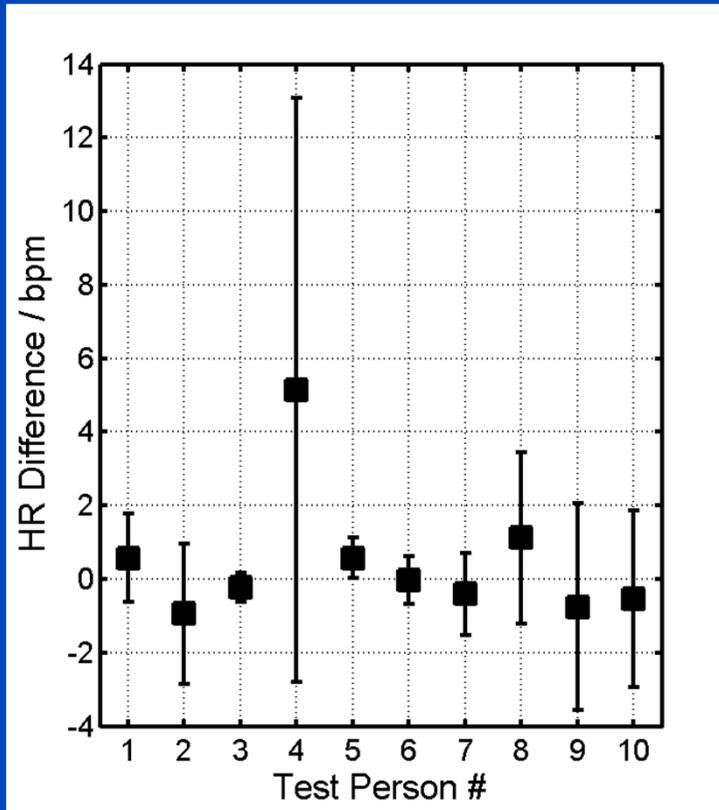
Test Person Measurements Heart Rate

- From the measured radar signals the cardiac motion is extracted using frequency filters.
- A correlation analysis is used to determine the periodicity of the cardiac motion from the filtered radar signals.

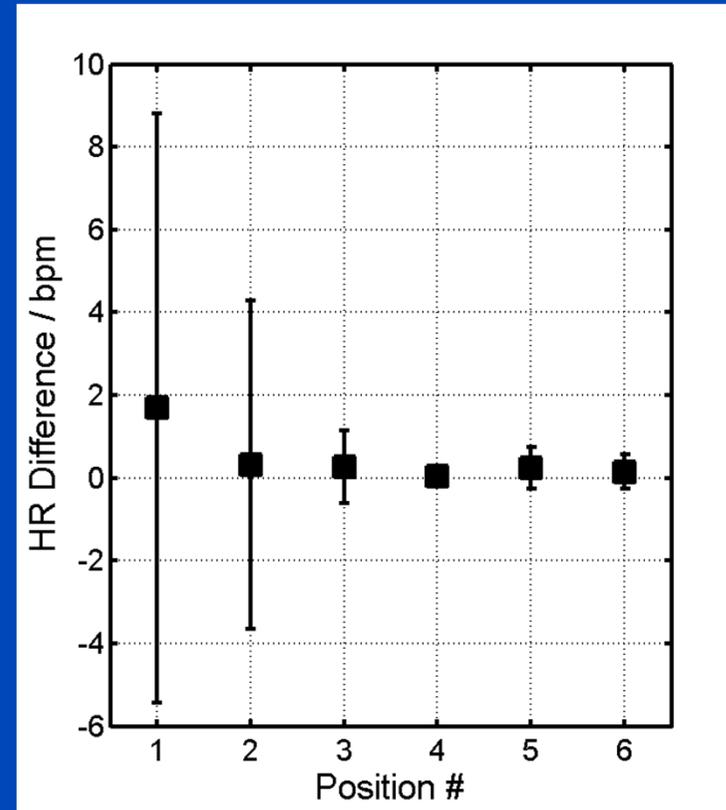


Example dataset showing the heart rate determined with our radar system compared to the heart rate determined using ECG signals.

Test Person Measurements Heart Rate



Mean and standard deviation of the heart rate difference between the radar and ECG for each test person.



Same results as on the left plot except that the datasets are sorted according to the antenna positions.

Conclusion

- Respiratory motion measured with the radar system show results comparable to a state-of-the-art respiratory motion tracking system.
- The respiratory motion is determined on a large area which avoids the need for exact patient location whereas systems used today only cover a small region.
- The test person measurements show good coverage between the detected cardiac motion and the ECG.
- Future research is needed to allow measurement of cardiac motion independent of the antenna position.

Thank You!